German Advisory Council on Global Change

Flagship Report

World in Transition
Governing the Marine Heritage

WBGU

German Advisory Council on Global Change

World in Transition

Governing the Marine Heritage

In memoriam Professor Jürgen Schmid

The Council Members

Prof Hans Joachim Schellnhuber CBE (chair)
Director of the Potsdam Institute for Climate Impact Research, external professor at the Santa Fe Institute and chair of the Governing Board of the Climate-KIC of the European Institute of Innovation and Technology

Prof Dirk Messner (vice chair)
Director of the German Development Institute, Bonn and Co-Director of the Center for Advanced Studies on Global Cooperation Research, University Duisburg-Essen

Prof Claus Leggewie
Director of the Institute for Advanced Study in the Humanities, Essen, Institute for Advanced Study of the University Alliance Metropolis Ruhr and Co-Director of the Center for Advanced Studies on Global Cooperation Research, University Duisburg-Essen

Prof Reinhold Leinfelder
Professor at the Institute of Geological Sciences, Free University Berlin, focus on geobiology, biodiversity, anthropocene science and science communication

Prof Nebojsa Nakicenovic
Professor of Energy Economics, Vienna University of Technology and Deputy Director, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

Prof Stefan Rahmstorf
Professor of Physics of the Oceans, Potsdam University and head of the Climate System department at the Potsdam Institute for Climate Impact Research

Prof Sabine Schlacke
Professor of Public Law, specializing German, European and International Environmental and Administrative Law, Bremen University

Prof Jürgen Schmid †
Director of the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), Kassel

Prof Renate Schubert
Professor for Economics at the Swiss Federal Institute for Technology and director of the Institute for Environmental Decisions, ETH Zurich (Switzerland)

WBGU is an independent, scientific advisory body to the German Federal Government set up in 1992 in the run-up to the Rio Earth Summit. The Council has nine members, appointed for a term of four years by the federal cabinet. The Council is supported by an interministerial committee of the federal government comprising representatives of all ministries and of the federal chancellery. The Council's principal task is to provide scientifically-based policy advice on global change issues to the German Federal Government.
The Council
- analyses global environment and development problems and reports on these,
- reviews and evaluates national and international research in the field of global change,
- provides early warning of new issue areas,
- identifies gaps in research and initiates new research,
- monitors and assesses national and international policies for sustainable development,
- elaborates recommendations for action,
- raises public awareness and heightens the media profile of global change issues.

WBGU publishes flagship reports every two years, making its own choice of focal themes. In addition, the German government can commission the Council to prepare special reports and policy papers. For more information please visit www.wbgu.de.

WBGU

German Advisory Council on Global Change

World in Transition

Governing the Marine Heritage

German Advisory Council on Global Change (WBGU)

WBGU Secretariat
Luisenstraße 46
D-10117 Berlin
Germany

Phone.: +49 30 263948 0
Email: wbgu@wbgu.de
Web: www.wbgu.de

Copy deadline: 28.02.2013

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

ISBN 978-3-936191-40-0

Translation: Bob Culverhouse, Berlin

The R&D project that generated this report was conducted on behalf of the German Federal Ministry of Education and Research and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety under grant number 01RIO708A2. Responsibility for the content of this publication rests with the author.

Design: WERNERWERKE GbR, Berlin
Cover photo: © Doreen Wild (www.mobilefotografie.net)

Production: WBGU
Typesetting: WBGU
Printing and binding: AZ Druck und Datentechnik GmbH

MIX
Paper from responsible sources
FSC® C008457
www.fsc.org

WBGU used certified eco-friendly paper for this publication.

Council Staff

This report would not have been possible without the excellent scientific and editorial work carried out by the WBGU office and the remarkable commitment of the scientific staff to the Council Members.

Scientific Staff at the Secretariat

Dr Inge Paulini
(Secretary-General)

Dr Carsten Loose
(Deputy Secretary-General)

Dr Karin Boschert
(until 30.4.2012)

Dr Rüdiger Haum

Dr Benno Pilardeaux
(Media and Public Relations)

Rasmus Relotius, MPP
(1.6.2012 until 31.5.2013)

Dr Astrid Schulz

Dr Birgit Soete

Administration, Editorial Work and Secretariat

Vesna Karic-Fazlic (Accountant)

Mario Rinn, BSc (System Administration and Graphics)

Martina Schneider-Kremer, M A (Editorial Work and Typesetting)

Margot Weiß (Secretariat)

Scientific Staff to the Council Members

Dipl-Volksw Julia E. Blasch (Institute for Environmental Decisions, ETH Zurich, Switzerland)

Dipl-Kfm Sebastian Busch (Vienna University of Technology, Energy Economics Group)

Hannes Hotz, MSc (German Development Institute, DIE, Bonn; until 31.10.2012)

Dipl-Pol Jan-Hendrik Kamlage (Institute for Advanced Study in the Humanities, KWI, Essen; since 1.9.2012)

Dr Daniel Klingenfeld (Potsdam Institute for Climate Impact Research, PIK; until 31.5.2012)

Dipl-Soz Silvia Kodeih (Potsdam Institute for Climate Impact Research, PIK)

Dr Susanna Much (Bremen University, Research Centre for European Environmental Law; until 31.5.2011)

Dr Carsten Pape (Fraunhofer Institute for Wind Energy and Energy System Technology, IWES, Kassel)

Alexander Schülke, MSc, MPP
(Museum für Naturkunde, Berlin; Institute for Biology at the Humboldt University Berlin; until 29.2.2012)

Verena Seemann, LLM (Bremen University, Research Centre for European Environmental Law; 1.6.2011 until 31.5.2012)

Olivia Serdeczny, M A
(Potsdam Institute for Climate Impact Research, PIK)

Ass iur Michael Stadermann (Bremen University, Research Centre for European Environmental Law; since 1.6.2012)

Dr Bernd Sommer (Institute for Advanced Study in the Humanities, KWI, Essen; until 31.8.2012)

Acknowledgments

The WBGU would like to thank the external contributors for their valuable input and assistance. Specifically, the following commissioned expert studies, which are available on the WBGU website, were integrated into this report:

- Prof Bela H. Buck and Dr Gesche Krause (SeaKult, Bremerhaven): Short Expertise on the Potential Combination of Aquaculture with Marine-Based Renewable Energy Systems, 2012.
- Dr Till Markus (University Bremen, Research Centre for European Environmental Law): Die EU-Fischereihandelspolitik: Analyse und Handlungsbedarf, 2012.
- Prof Rüdiger Wolfrum and Johannes Fuchs (Max Planck Institute for Comparative Public Law and International Law, Heidelberg and University Kiel): Ocean Governance und das Seerechtsübereinkommen der Vereinten Nationen, 2011.

The WBGU received valuable suggestions at hearings of experts conducted during its regular meetings:

Prof Boris Worm (Dalhousie University, Canada); Prof Bela H. Buck (Alfred Wegener-Institute Helmholtz Centre for Polar and Marine Research – AWI, Bremerhaven); Poul Degnbol (The International Council for the Exploration of the Sea – ICES, Copenhagen).

Furthermore, the WBGU wishes to thank all those who provided valuable support through discussions, comments, contributions, advice, research, and peer reviews for this report:

Dipl-Phys Jochen Bard (Fraunhofer IWES, Kassel); Prof Antje Boetius (Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research – AWI, Bremerhaven); Prof Bela H. Buck (Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research – AWI, Bremerhaven); Ass jur LLM Miriam Dross (The German Advisory Council on the Environment – SRU, Berlin); Dr Rainer Froese (Helmholtz Centre for Ocean Research – GEOMAR; Kiel); Prof Rüdiger Gerdes (Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research – AWI – Sea Ice Physics, Bremerhaven); Dr Kristin Gunnarsdóttir von Kistowski (The Pew Charitable Trusts, USA); Dorothée Herr (IUCN, Marine Programme Officer, Global Marine and Polar Programme, Berlin); Dr Christoph Humrich (Assistant Professor for International Relations, University Groningen; Research Assistant at the Hessische Stiftung Friedens- und Konfliktforschung – Internationale Organisationen und Völkerrecht, Frankfurt/M.); Dr Inge Kaul (Global Policy Studies, Berlin); Markus Knigge (The Pew Charitable Trusts, European Marine Programme, USA); PhD John Roald Isaksen (Norwegian Institute of Food, Fishery and Aquaculture – Nofima, Tromsø); Dr Gesche Krause (Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research – AWI – Earth System Knowledge Platform, Bremerhaven); Dr Birgit Lode (German Institute for International and Security Affairs – SWP, Berlin); Francisco J. Marí ('Brot für die Welt' – Protestant Centre for Development and Social Service, Berlin); Dr Till Markus (University Bremen, Research Centre for European Environmental Law); Prof Nele Matz-Lück (University Kiel, Faculty of Law); Dr Juliane Müller (Alfred Wegener-Institute Helmholtz Centre for Polar and Marine Research – AWI, Bremerhaven); Dr Markus Salomon (The German Advisory Council on the Environment – SRU, Berlin); Judith Schett, BSc (Vienna University of Technology); Prof Boris Worm (Dalhousie University, Canada).

We thank the staff of the Federal Environment Agency (UBA) for an internal consultation in Berlin: Director and Professor Ulrich Claussen, Hans-Peter Damian and Wulf Hülsmann.

Thanks are also due to the representatives of the German Marine Research Consortium (KDM), who held a lively discussion with the WBGU on key research issues on ocean management, resource exploitation, and ocean conservation:

Prof Gerhard Bohrmann (University Bremen); Dr Gerd Kraus (The Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries, Hamburg); Prof Karin Lochte (Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research – AWI, Bremerhaven); Prof Harry W. Palm (University Rostock); Prof Carsten Schulz (University Kiel, Büsum); Prof Klaus Wallmann (Helmholtz Centre for Ocean Research – GEOMAR, Kiel); Prof Gerold Wefer (MARUM, University Bremen); Prof Hildegard Westphal (Leibniz Center for Tropical Marine Ecology – ZMT, Bremen).

The WBGU would moreover like to thank MinDir Dr Karl Eugen Huthmacher (head of department) and MinR Karl Wollin (head of section) of the Federal Ministry of Education and Research (BMBF), Bonn, for their participation in the above discussion with the KDM.

Contents

Boxes

Tables

Figures

Acronyms and Abbreviations

ABNJ	Areas Beyond National Jurisdiction
ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
AEPS	Arctic Environmental Protection Strategy
ALLFISH	The Alliance for Responsible Fisheries
AMAP	Arctic Monitoring and Assessment Programme (UNEP)
AOSIS	Alliance of Small Island States
ASC	Aquaculture Stewardship Council (WWF, IDH)
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (CMS)
AWTS	Advanced Wastewater Treatment Systems
BBNJ	Biological Diversity Beyond Areas of National Jurisdiction (UNGA)
BMBF	Bundesministerium für Bildung und Forschung *Federal Ministry of Education and Research, Germany*
BMELV	Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz *Federal Ministry of Food, Agriculture and Consumer Protection, Germany*
BMP	Best Management Practices
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit *Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany*
BMVBS	Bundesministerium für Verkehr, Bau und Stadtentwicklung *Federal Ministry of Transport, Building and Urban Development, Germany*
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung *Federal Ministry for Economic Cooperation and Development, Germany*
BSAP	Baltic Sea Action Plan (HELCOM, EU)
BSH	Bundesamt für Seeschifffahrt und Hydrographie *Federal Maritime and Hydrographic Agency, Germany*
C	Carbon
CBD	Convention on Biological Diversity
CBM	Community-Based Management
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CCS	Carbon Dioxide Capture and Storage
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CDM	Clean Development Mechanism (Kyoto Protocol, UNFCCC)
CFP	Common Fisheries Policy (EU)
CGIAR	Consultative Group on International Agricultural Research
CH_4	Methane (main component of natural gas)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora (UN)
CMS	The Convention on the Conservation of Migratory Species of Wild Animals, also: Bonn Convention (UNEP)
CNG	Compressed Natural Gas
CoC	FAO Code of Conduct for Responsible Fisheries
COFI	Committee on Fisheries (FAO)
COP	Conference of the Parties

CO_2	Carbon dioxide
CtL	Coal-to-Liquid
DDT	Dichlordiphenyltrichlorethan (insecticide)
DG Devco	Directorate-General Development and Cooperation (EU)
DG Mare	Directorate-General for Maritime Affairs and Fisheries (EU)
DOALOS	Division for Ocean Affairs and the Law of the Sea (UN)
EASAC	European Academies Science Advisory Council
EBSAs	Ecologically or Biologically Significant Marine Areas (CBD)
ECSC	European Coal and Steel Community (Coal and Steel Union)
EEZ	Exclusive Economic Zone
EFF	European Fisheries Fund (EU)
EIA	Energy Information Administration (USA)
EIA	Environmental Impact Assessment
EJ	Exajoule (10^{18} Joule)
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency (USA)
ERICA	Environmental Risk from Ionising Contaminants: Assessment and Management
EU	European Union
EWEA	The European Wind Energy Association
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization of the United Nations Statistics Division
FCR	Feed Convertion Ratio
FFH	Fauna-Flora-Habitat-Richtlinie *Habitats Directive, EU*
FONA	Rahmenprogramm Forschung für nachhaltige Entwicklung *Framework Programme Research for Sustainability, BMBF*
FOS	Friend of the Sea
FPAs	Fisheries Partnership Agreements (EU)
FSA	Fish Stocks Agreement (UN)
GAA	Global Aquaculture Alliance
GAPI	Global Aquaculture Performance Index
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GEA	Global Energy Assessment
GEF	Global Environment Facility (UNDP, UNEP, World Bank)
GFCM	General Fisheries Commission for the Mediterranean
GAA	Global Aquaculture Alliance
GIZ	Gesellschaft für Internationale Zusammenarbeit *German Society for International Cooperation*
GLOMAR	Global Change in the Marine Realm (Bremen International Graduate School for Marine Sciences)
GOOS	Global Ocean Observing System
GPS	Global Positioning System
Gt	Gigatonnes (10^9 t, Mrd. t)
GtL	Gas to Liquids
GW	Gigawatts (10^9 W, Mrd. W)
HELCOM	Baltic Marine Environment Protection Commission, also: Helsinki Commission
HEPCA	Hurghada Environmental Protection and Conservation Association
HFO	Heavy Fuel Oil
HVDC	High-Voltage Direct Current Electric Power Transmission System
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas

ICSEAF	International Commission for the South East Atlantic Fisheries
ICSID	International Centre for Settlement of Investment Disputes (FAO)
ICZM	Integrated Coastal Zone Management
IDH	Dutch Sustainable Trade Initiative
IEA	International Energy Agency (OECD)
IMTA	Integrated Multi-Trophic Aquaculture
IMO	International Maritime Organization (UN)
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IODE	International Oceanographic Data and Information Exchange (IOC)
IOTC	Indian Ocean Tuna Commission
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (UN)
IPCC	Intergovernmental Panel on Climate Change (WMO, UNEP)
IRENA	International Renewable Energy Agency
ISA-Virus	Infectious Salmon Anaemia Virus
ISA	International Seabed Authority (UNCLOS)
ISSC	International Social Science Council
ITLOS	International Tribunal for the Law of the Sea (UNCLOS)
ITQs	Individual Transferable Quotas
IUCN	International Union for Conservation of Nature, also: World Conservation Union
IUU	Illegal, Unreported and Unregulated Fishing
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology (IOC)
KfW	KfW Bank Group (Germany)
KRAV	Kontrollföreningen för Alternativ Odling (Ecolabel, Sweden)
LCA	Life-Cycle Assessment
LIFDC	Low-Income Food-Deficit Countries (FAO, WFP)
LIFE	Low-Impact, Fuel-Efficient Fishing (FAO)
LNG	Liquid Natural Gas
MARPOL	International Convention for the Prevention of Pollution from Ships (IMO)
MCEB	Marine and Coastal Ecosystems Branch (UNEP)
MCS	Monitoring, Control and Surveillance
MDG	Millennium Development Goals (UN)
MFMR	Ministry of Fisheries and Marine Resources (Namibia)
MMSY	Maximum Multispecies Sustainable Yield
MPAs	Marine Protected Areas
MSC	Marine Stewardship Council
MSD	Marine Sanitation Devices
MSFD	European Marine Strategy Framework Directive
MSY	Maximum Sustainable Yield
MW	Megawatts (10^6 W, Mio. W)
N	Nitrogen
NAFO	Northwest Atlantic Fisheries Organization
NASA	National Aeronautics and Space Administration
NatMIRC	Ministry's National Marine Information and Research Centre (Namibia)
NATO	North Atlantic Treaty Organization
NEAFC	North East Atlantic Fisheries Commission
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPFC	North Pacific Fisheries Commission
NRC	National Research Council (USA)
NTC	Nutrient Trading Credits
NTZ	No-Take Zone
N_2O	Nitrous Oxide, laughing gas
OECD	Organisation for Economic Co-operation and Development
OPRC	International Convention on Oil Pollution Preparedness, Response and Co-operation (IMO)

ORECCA	Offshore Renewable Energy Conversion Platform Coordination Action (EU)
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
OSS	Offshore Site Selection for a Sustainable and Multi-Functional Use of Marine Areas in Heavily Utilized Seas with the North Sea as an Example (BMELV)
OTEC	Ocean Thermal Energy Conversion
OWC	Oscillating Water Column
P	Phosphorus
PCBs	Polychlorinated biphenyls
PES	Payments for Ecosystem Services
PFCs	Polyfluorinated Compounds
Pg	Petagramms (10^{15} g, Gt)
POPs	Persistent Organic Pollutants
PRO	Pressure Retarded Osmosis
PROFISH	The Global Program for Fisheries (World Bank)
PSMA	Port State Measures Agreement (FAO)
PSSA	Particularly Sensitive Sea Area (IMO)
RAS	Recirculating Aquaculture Systems
R&D	Research and Development
REDD	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UNFCCC)
RFMO	Regional Fisheries Management Organizations (UN)
RMMO	Regional Marine Management Organizations (WBGU proposal)
RSP	Regional Seas Programme (UNEP)
SCO	Single Cell Oils
SEAFO	South East Atlantic Fisheries Organisation
SIDS	Small Island Developing States
SIOFA	South Indian Ocean Fisheries Agreement
SOLAS	International Convention for the Safety of Life at Sea (UN)
SPRFMO	South Pacific Regional Fisheries Management Organisation
SRU	Sachverständigenrat für Umweltfragen *German Advisory Council on the Environment*
SUP	Strategische Umweltprüfung
TAC	Total Allowable Catch
TEU	Twenty feet Equivalent Unit
TFEU	Treaty on the Functioning of the European Union
TTS	Temporary Threshold Shift
TURFs	Territorial Use Rights in Fisheries
TWh	Terawatt hour
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNCSD	United Nations Conference on Sustainable Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
UNICPOLOS	United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea
VCLT	Vienna Convention on the Law of Treaties
VECTORS	Vectors of Change in Ocean and Seas Marine Life (EU Project)
VME	Vulnerable Marine Ecosystems (FAO)
VMS	Vessel Monitoring System
WAVES	Wealth Accounting and Valuation of Ecosystem Services (World Bank)

WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen *German Advisory Council on Global Change*
WCD	World Commission on Dams
WCMC	World Conservation Monitoring Centre (UNEP)
WCPFC	Western and Central Pacific Fisheries Commission
WFD	Water Framework Directive of the European Parliament and of the Council
WMO	World Meteorological Organization (UN)
WOO	World Oceans Organization (WBGU recommendation)
WSSD	World Summit on Sustainable Development
WTO	World Trade Organization
WWF	World Wide Fund for Nature

Summary

Rethinking the oceans

For a long time humanity thought of the sea as something inexhaustible. Given the sheer size of the oceans, it seemed inconceivable that humans might be able to exert any appreciable influence on the 'blue continent'.

Changes caused by humans take place gradually, and even today they are very difficult to detect or measure. It therefore took a long time before it was discovered that the impact of humankind on the sea grew ever stronger as our society became more industrialized, finally reaching disturbing dimensions: marine fish stocks are in a poor state due to overfishing, so that almost two-thirds of stocks need time to recover; a fifth of the species-rich coral reefs have already disappeared and three-quarters are at risk; and not least, our societies use the oceans as a rubbish dump, threatening species and ecosystems with nutrients, toxins and plastic. Man-made hazards also include CO_2 emissions from fossil fuels, which are increasingly acidifying the oceans and thus endangering marine ecosystems. The acid concentration has already risen by almost a third since industrialization began, and this can have considerable effects on marine ecosystems and fishery.

Further examples of humanity's huge impact include cases of large-scale pollution (like after the disastrous accident involving the Deepwater Horizon oil rig in April 2010), the sudden collapse in the early 1990s of the once seemingly inexhaustible stocks of cod off Newfoundland, and the rising temperature of the world's oceans, which has already led to a dramatic reduction in the size of the Arctic sea ice. Overall, the oceans are in an unsatisfactory state. This largely still undiscovered 'blue continent' is proving to be fragile, and in parts it is already irreversibly damaged. For these reasons, the oceans – their treasures and the threats they face – repeatedly find themselves at the focus of public attention.

Human influence grows with technological development. Today, new ways of using the seas promise great opportunities, but they can also put new pressure on the oceans and their ecosystems. Using the huge potential of offshore wind power can contribute to a climate-friendly energy supply. On the other hand, unprecedented and unquantifiable risks are involved in the extraction of fossil oil and gas resources from the deep sea and the Arctic, and in mining methane hydrates – all of which are now becoming technically feasible. Similarly, the increasingly effective methods being used to detect and catch fish in remote areas of the high seas and at ever-greater depths are increasing pressure on fish stocks and marine ecosystems.

Humankind is dependent on the seas, their ecosystem services and their biological diversity – for food, energy generation, medical products, tourism, climate-regulating functions and the oceans' absorption of CO_2. Against the background of humanity's influence on the seas – which is already big today and could potentially become much larger in the future – and in view of the seas' key importance for our societies, the WBGU asks how humanity might best go about the task of developing a sustainable stewardship of the oceans.

What condition will the oceans be in when we hand them over to coming generations in the middle of this century? Are we now going to take on responsibility and embark on the path of sustainability in the real world and not merely on paper? Much will depend on how marine conservation and ocean uses are organized, in other words on ocean governance. This report therefore focuses on the global, regional and national rules governing the conservation and sustainable use of the oceans, and above all on how we can ensure that these rules are implemented, which has been a huge problem in the past.

The WBGU puts the debate on the seas into the context of the 'Great Transformation' towards a low-carbon, sustainable society – the subject of its 2011 flagship report 'A Social Contract for Sustainability'. Here, the WBGU argued that if greenhouse-gas emissions continued growing unabated, the Earth system would breach planetary guard rails within a few decades and enter domains that would be incompatible with sustainable development. The WBGU is convinced that nothing short of a new industrial revolution can prevent this.

For that to happen, the world will have to phase out not only fossil power generation, but also energy-intensive urbanization and emissions-intensive land use within the next few decades. The WBGU believes the seas should be fully incorporated into this transformation towards a low-carbon, sustainable society, in particular because of the irreversibility of some of the processes involved. The oceans have the potential to give the transformation massive support; in turn, the transformation is necessary for the long-term conservation of the marine ecosystems.

The WBGU already focused on the seas in its 2006 special report 'The Future Oceans – Warming Up, Rising High, Turning Sour'. In particular it took a closer look at the interface between greenhouse-gas emissions and the oceans (e.g. warming, sea-level rise, ocean acidification). In the present report the WBGU examines the examples of food and energy, which were already at the centre of its 2011 flagship report on transformation. It studies the sustainable management of fish stocks, sustainable aquaculture and the development of marine renewable-energy systems. It also shows how the oceans can make a substantial contribution to the transformation. At the same time, the seas and their ecosystems are threatened by the effects of climate change and ocean acidification.

The WBGU shows that the conservation and sustainable use of the oceans are urgently necessary, that a transformation towards low-carbon, sustainable development is possible including the oceans, and that it can yield substantial advantages worldwide for sustainable energy supplies and food security.

Guiding principles for future ocean governance

Future ocean governance – i. e. how to develop a sustainable stewardship of the oceans – will play a crucial role if mankind is to reverse the present trend and manage the seas in a sustainable way. The current situation is quite favourable as a starting point: the world already has a comprehensive international treaty – the United Nations Convention on the Law of the Sea, or UNCLOS – which, together with accompanying agreements, functions as a kind of 'constitution of the seas'. However, UNCLOS was adopted in 1982, so that more recent insights are either absent altogether or given inadequate attention. In particular, it has meanwhile become increasingly accepted that humanity is a dominant factor in the entire Earth system. Humankind's new shaping impact is expressed by the term 'Anthropocene' to describe our present era. In the Anthropocene, humanity should take on responsibility for the stewardship of the natural environment. This also applies to the seas.

The existing system of ocean governance has failed in several areas, not only because the intergovernmental regulations that have been agreed are insufficient, but primarily because these regulations are not resolutely implemented and misconduct is hardly ever prevented by sanctions.

Given these challenges, the WBGU recommends basing our interaction with the oceans on three guiding principles. They are crucial for designing a regime for protecting and sustainably using the oceans which, in combination with ten criteria for sustainable ocean governance (Box 1), can ensure the long-term conservation of ecosystem services, biodiversity, and yields from the sustainable use of the sea. The starting point is a fundamental change of position and perspective applying the following three principles:

1. *The oceans as a common heritage of mankind:* The oceans are a global public good for which no clearly defined, sustainability-based conservation obligations or rights of use exist. The idea that the oceans are a 'common heritage of mankind' was put forward as early as the 1960s by Arvid Pardo and Elisabeth Mann Borgese in the negotiations on UNCLOS. Although it was not enforced as a principle of international law for the oceans as a whole, it was codified for the mineral resources of the seabed beyond national jurisdiction ('the Area'). In the WBGU's view, it follows from the common heritage of mankind principle that global public goods must be accessible to all people and not be fully at the disposal of any state, individual or company. The conservation and sustainable use of the common heritage of mankind requires stewards, a management regime for conservation and sustainable use, and rules on sharing to ensure that the costs and benefits of the regime are distributed fairly. From a political perspective this results in a system of shared sovereignty between states which is based on a global regulatory framework geared towards sustainability goals. The marine public goods are to be conserved and their short-term exploitation and overexploitation avoided, thus also enabling future generations to use them.
2. *The systemic approach:* The sectoral approach, which is widely prevalent in ocean governance at present, is characterized by a narrow view of the different forms of use (e.g. fishing, oil extraction, conservation) and does not do justice to the systemic requirements of sustainability. The WBGU proposes the introduction of a systemic approach in order to integrate both the different levels of the system and the interactions between the natural and social systems that should be taken into account when dealing with the oceans. The approach com-

prises the following levels: *First*, marine ecosystems are themselves complex systems which should be protected and used according to the 'ecosystem approach'. The ecosystem approach was developed in the context of the Convention on Biological Diversity and is now widely recognized by governments. *Second,* the systemic approach should go far beyond the uses of the marine ecosystems and also take land/sea interactions into account – after all, many of the risks to the oceans are caused by economic activities on land. For example, industrial production can damage the oceans when plastic products or long-lived pollutants find their way into the sea via the atmosphere or rivers. Regulating industrial production can therefore also contribute to marine conservation. Last, but not least, agriculture too is responsible for considerable input of nutrients and sediments into the oceans. *Third*, in the era of the Anthropocene, linkages in the Earth system should also be taken into account – e.g. CO_2 emissions from fossil fuels, which damage marine ecosystems both indirectly – via climate change by raising temperatures – and directly by acidifying the seawater. *Fourth*, on all these levels it must be taken into account that there are complex and dynamic interactions between society and nature. The WBGU therefore regards the integrated observation of these interactions between marine ecosystems and societies as indispensable to a comprehensive systemic approach.

3. *The precautionary principle:* According to the precautionary principle, steps based on the state of the art in science and technology are taken to prevent possible environmental damage, even when there is no full scientific certainty on how likely it is that there actually will be any damage or how much it might cost. The application of the precautionary principle is particularly important in complex systems – to which marine ecosystems and their land/sea interactions definitely belong – because their reactions to influences or disturbances are difficult to predict. It is therefore important to allow enough scope for decisions to be flexible and reversible. Although the precautionary principle is reflected in many regulations and decisions on ocean governance, it is rarely strictly applied in practice.

Ways toward a future form of ocean governance

The need for a radical turnaround in the use of the oceans is well known, as is what needs to change. And although this is already enshrined to some extent in the existing system of ocean governance, in practice governments do not implement or follow the corresponding regulations strictly enough. Not least, there are loopholes in the existing international law of the sea. In this report, therefore, the WBGU has scrutinized UNCLOS from the perspective of the three guiding principles and ten criteria. The future system of ocean governance should not only correspond to these principles and criteria, it should also establish suitable mechanisms for ensuring compliance with, and the enforcement of, the rules and for sanctioning misconduct.

The regulatory framework that needs to be observed is defined by shared responsibility for conserving the oceans according to the common heritage of mankind principle. The players should be able to move as freely and autonomously as possible within this framework. Ultimately, however, all users need to fundamentally rethink the way they interact with the oceans at all levels of governance. Humanity must stop the way in which the seas are predominantly managed today, which is often geared to short-term profits. The focus should be on marine conservation for the benefit of present and future generations, including the conservation of biodiversity and marine ecosystem services.

The WBGU is convinced that profound changes in the governance of the oceans are necessary and appropriate in order to create a suitable institutional and political framework for a sustainable stewardship of the oceans. However, resolute implementation of the proposed guiding principles would require major changes to UNCLOS. In the WBGU's view, such an initiative currently has little chance of implementation, because the gap between the changes in ocean governance that are necessary from the sustainability perspective and political feasibility seems too deep at present.

Against this background, the WBGU has decided to focus attention on two paths, each with a different ambition and speed. *First*, the WBGU outlines the vision of a fundamental reform of the existing law of the sea – irrespective of the current chances of implementing it – offering orientation on how best to address the challenges of marine conservation and the sustainable use of the oceans. *Second*, the WBGU develops recommendations for action which link up with ongoing political processes, are easier to implement, and are therefore suitable as steps towards the vision without requiring a reform of UNCLOS.

As a basis for its vision of a reformed law of the sea, the WBGU recommends extending the common heritage of mankind principle as a binding guiding principle to cover all uses of all marine biological and mineral resources – but varying in specificity across the maritime zones seaward of the territorial sea (exclusive economic zone (EEZ), continental shelf, high seas and the Area). The vision also outlines the institutional design

Box 1

Ten criteria for a future system of ocean governance

In this report the WBGU has developed ten criteria for analysing the existing system of ocean governance at various levels, from local to global, which should simultaneously guide measures aimed at redesigning the ocean governance of the future.

1. *Adaptive management* aims to continuously improve the knowledge base for governance and to promptly use it for improving the conservation and sustainable use of the oceans. Adaptive management increases our knowledge of the structure and dynamics of ecosystems via a learning process and thus iteratively improves the protection and management of the seas.
2. *Incentives for innovation* encouraging a sustainable, low-risk use of the oceans reward players who develop long-term, sustainable business models on the use and conservation of the seas instead of seeking short-term profit maximization.
3. A *clear assignment of rights of use* is necessary to prevent the overexploitation of the sea, which is a common good. This makes it possible to exclude certain users and thus to coordinate use – either via markets or by negotiation. Furthermore, the societal costs of use can be charged to the users according to the *polluter pays* principle, so that the external costs are internalized.
4. Neither the conservation nor the sustainable use of the oceans as a global public good is possible without an unprecedented level of global cooperation and *global cooperation mechanisms*. Global cooperation forms the foundation for the development of international treaties on marine conservation and use, and for the joint implementation of these treaties.
5. *Subsidiary decision-making structures* – i.e. assigning decision-making powers primarily to decentralized decision-makers at the regional or local level, and secondarily to central international agencies – are crucial for the acceptance of global and national regulations. Moreover, such an interpretation of subsidiarity makes regulations easier to enforce efficiently.
6. *Transparent information* ensures that all players have access to the relevant data.
7. *Participatory decision-making structures* make it possible to reveal interests; they lead to decisions that all stakeholders can understand.
8. *Fair distribution mechanisms* aim to ensure an equitable distribution both of the benefits of marine resource use and of the costs – e.g. of conservation, monitoring, surveillance and sanctions. This applies to the sharing of costs and benefits between countries and between different levels of a country's government.
9. *Conflict-resolution mechanisms* are necessary in order to coordinate the many and complex use interests of different stakeholders (e.g. governments and individuals).
10. *Sanction mechanisms* at the different governance levels are key instruments for enforcing compliance with regulations on use.

of a corresponding regime of conservation and use. A World Oceans Organization (WOO) would be set up as a global steward of the common heritage of mankind. According to the subsidiarity principle, the sustainable management of the sea as a common good should as far as possible be decentralized and left to regional and national institutions according to the principles of a reformed UNCLOS. On the high seas, newly established Regional Marine Management Organizations (RMMOs) would shape ocean conservation and use. The coastal states, as stewards, should be accountable to the international community as regards the sustainability of the management of the marine zones entrusted to them, by meeting strict reporting obligations.

This vision, which the WBGU considers necessary and appropriate, is evidently very ambitious in view of the lengthy negotiations required, the complexity of global marine conservation, and conflicts over the use of marine resources. It is therefore highly unlikely to be politically implemented any time soon. Nevertheless, the WBGU is outlining this ambitious vision of ocean governance, as recent experience has shown that political feasibility is difficult to predict. Numerous political events and crises of recent contemporary history – such as Germany's phasing out of nuclear power after Fukushima or the euro crisis – show that, given urgent challenges or events, reforms can become possible which are so radical that they were previously considered totally unrealistic. In the same way, far-reaching opportunities for marine policy that are unforeseeable today might open up one day. Such reforms should be well thought through and discussed beforehand. The WBGU's aim with this vision is to contribute to this discussion.

In order to get closer to the vision's long-term objective, the WBGU also makes policy recommendations that link up with ongoing or envisaged political processes that do not require any changes to UNCLOS and are therefore suitable as steps along the road towards the more ambitious vision. Overall, the report aims to serve as a compass to give long-term orientation for reforms on conservation and the use of the oceans.

The focal themes

In this report on the oceans, the WBGU focuses on the examples of food and energy, as in its previous report entitled 'A Social Contract for Sustainability'. These are key issues in the Great Transformation towards a low-carbon, sustainable society, to which the oceans can make a significant contribution. In this context the

WBGU analyses the sustainable use of fish stocks and aquacultures as well as marine renewable energy technologies, and outlines a reform of ocean governance based on these examples.

- *Fishing: stopping overexploitation and raising long-term revenue.* Food from the sea can help ensure food security for a growing world population and thus to some extent ease the rising pressure on land use. In this way fishing and aquaculture based on sustainability can make an important contribution to the transformation towards a climate-friendly society. It is becoming increasingly clear that overfishing is not only inflicting environmental damage worldwide, but that it is also economically inefficient. The depletion of fish stocks must therefore be stopped so that the seas can be used sustainably. A good foundation under international and 'soft law' for the modern, sustainable management of fish stocks has already been laid by the UN Fish Stocks Agreement, the FAO Code of Conduct for Responsible Fisheries, the goals of the Rio follow-up process and the decisions of the Biodiversity Convention. Yet these regulations and decisions are poorly implemented in practice. So a transformation towards sustainability and an end to overfishing would be doubly worthwhile: marine ecosystems and their biodiversity would be spared, and incomes would actually rise as the fishing pressure declined and stocks recovered.
- *Marine energy: momentum for the energy-system transformation.* In order to succeed with the transformation towards a climate-friendly society, the energy systems, which are currently dominated by fossil energy carriers, should be converted to renewable energy generation. The huge potential of offshore wind power and the use of other marine renewable energy technologies could make a significant contribution to an emission-free future in a decarbonized energy system. The important thing now is to accelerate the already developing momentum by providing targeted government support for innovations. To ensure sustainability, the environmental compatibility of marine renewable-energy technologies must already be a key development criterion at very early phases of technological development. The expansion of renewable energy also brings the phasing out of fossil offshore oil and gas exploitation closer and makes it easier to avoid even starting the extraction of climate-damaging methane hydrates.
- *Arctic: the race for resources.* The WBGU complements the two above-mentioned thematic perspectives by adding a regional focus on the Arctic (Box 2). Here, in addition to other valuable resources, access to both energy and fish stocks plays an essential role and currently involves considerable potential for conflict. In the Arctic, the race to exploit marine resources in general, and oil and gas reserves in particular, is becoming increasingly noticeable. Responsibility for protecting the common heritage of mankind around the North Pole, with its valuable but extremely fragile polar ecosystems, is being increasingly eclipsed by the expected short-term profits. This highly risky expansion will lengthen the climate-damaging fossil energy path; national interests are threatening to gain the upper hand over the common heritage of mankind and the interests of future generations. This could be counteracted by a comprehensive, cross-border marine protected area for the Arctic (Box 2).

Research in the context of transformation

Research has a key role to play in the transformation towards a sustainable stewardship of the oceans. It must examine the role of the oceans in the Earth system, the impact of human activity and the repercussions of changes on human societies. At the same time it should think ahead and develop visions of a sustainable stewardship of the seas, study specific possibilities of sustainable use and draft political strategies for achieving them. Such research, which the WBGU terms 'transformative', promotes transformation by generating sustainable innovations in relevant sectors and supporting their dissemination. In addition, 'transformation research' is needed for the analysis of societal transformation. It should investigate the overall conditions and key factors affecting overarching societal transformation processes in the fields of ocean conservation and use – as well as their interactions with technical systems and ecosystems – in order to develop alternative transformation paths and make recommendations on how to shape them politically. However, transformation research is hardly established to date in German marine research. It seems essential for the use of the oceans as the common heritage of mankind.

A social contract for the seas

Agreement on a virtual, global 'social contract for the seas' is the prerequisite for sustainable stewardship of the oceans. It would also make a reformed system of ocean governance more effective and legitimate. Such a social contract for the seas would effectively be part of the social contract for a great transformation towards a low-carbon, sustainable society. In this way humanity should above all take responsibility for the perma-

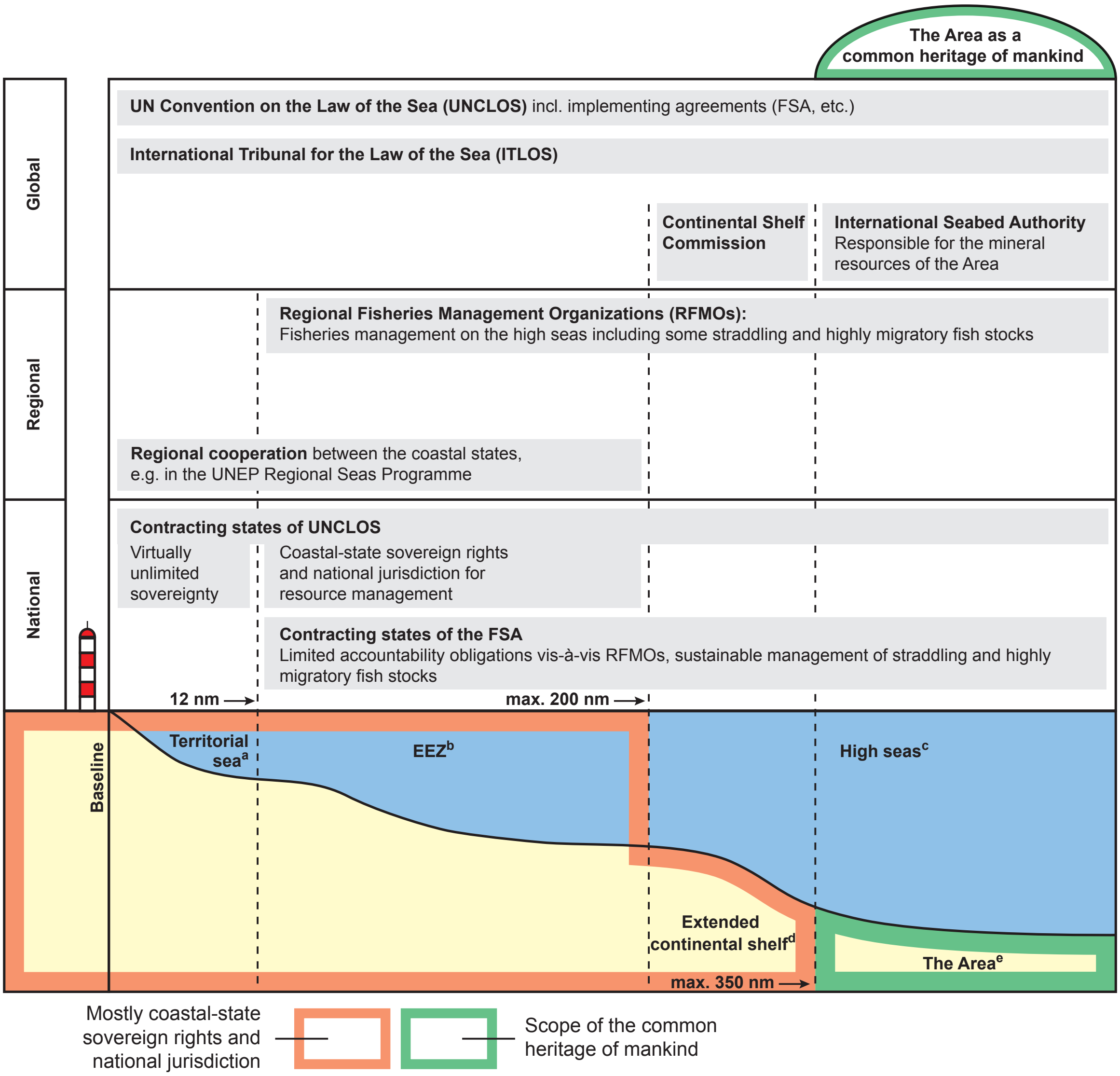


Figure 1: Status quo of ocean governance, simplified diagram.
The common heritage of mankind is today limited to the mineral resources of the seabed seaward of national jurisdiction ('the Area'). These resources are administered by the International Seabed Authority. The UN Convention on the Law of the Sea (UNCLOS), together with its implementing agreements (primarily the UN Fish Stocks Agreement, FSA), defines the framework of ocean governance. The Regional Fisheries Management Organizations (RFMOs) organize the management of fish stocks on the high seas and of the straddling and highly migratory fish stocks in the exclusive economic zones (EEZs). The coastal states have far-reaching sovereign rights to use all resources in their EEZ and the mineral resources of the continental shelf. Regional cooperation between coastal states is organized through programmes and agreements (especially UNEP Regional Seas Programmes).

a The territorial sea extends up to 12 nautical miles (nm) from the baseline. It comprises, inter alia, the seabed and its subsoil. The coastal state has territorial sovereignty in the territorial sea.
b The EEZ covers the marine area seaward of the territorial sea, extending for a maximum of 200 nm measured from the baseline. The EEZ comprises the water column as well as the seabed and its subsoil.
c The high seas begin seaward of the EEZ and are limited to the water column. They are not subject to any national sovereignty; freedom of navigation, fishery, research, etc. applies here.
d The continental shelf comprises the seabed and its subsoil seaward of the territorial sea. The continental shelf regularly overlaps with the EEZ and has no separate importance. The continental shelf can, however, extend further than the seaward boundary of the EEZ ('extended continental shelf'). The outer limit of the continental shelf may not be more than 350 nm from the baseline (or 100 nm from the 2,500 m isobath).
e The Area comprises the seabed and its subsoil seaward of national jurisdiction.

Source: WBGU

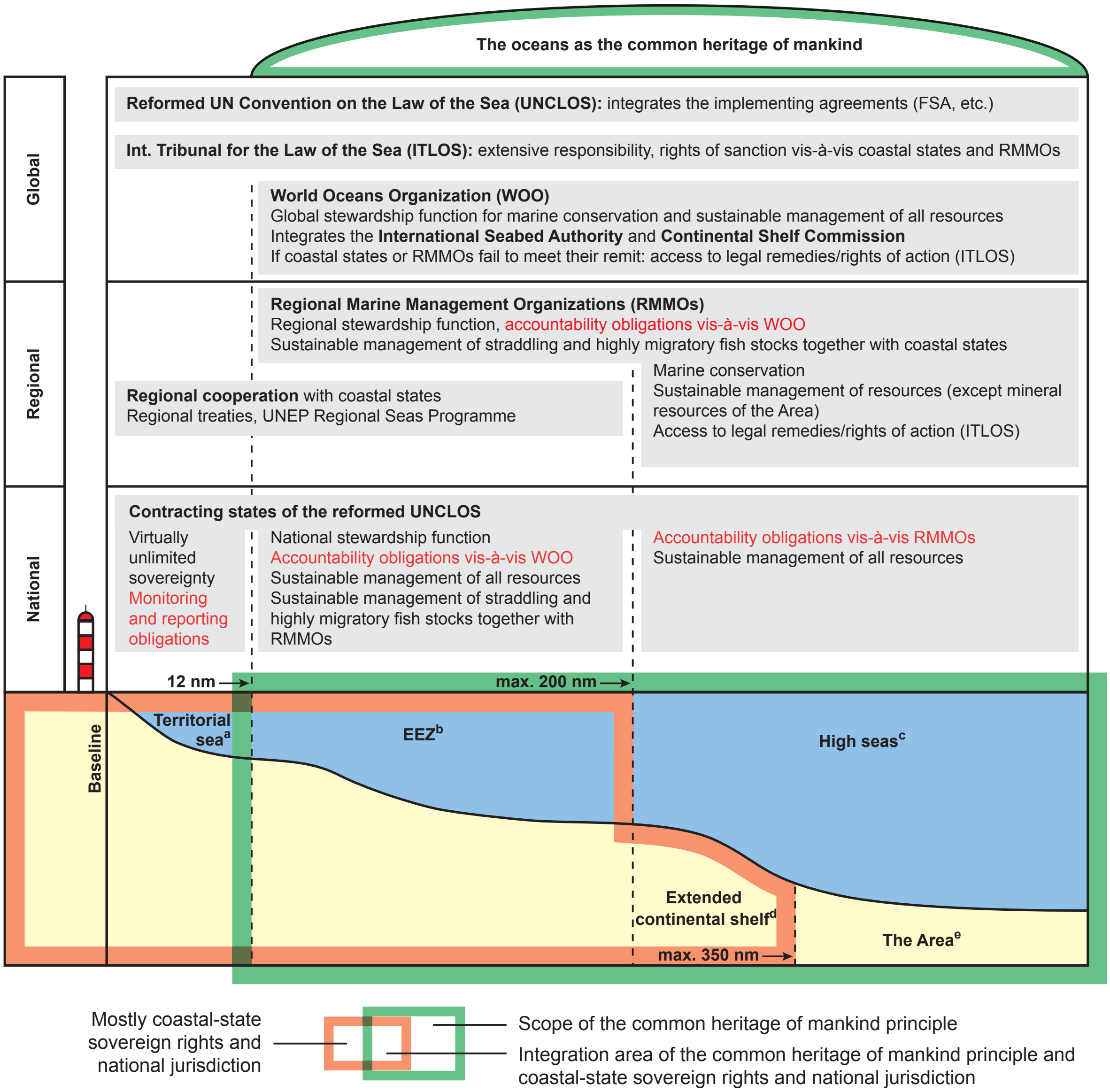


Figure 2: Vision for a future system of ocean governance, simplified diagram.
All marine areas, with the exception of the coastal waters, are given 'common heritage of mankind' status. This includes all resources seaward of the territorial sea, including mineral and biological resources. The coastal states retain their rights of use over the resources in the exclusive economic zone (EEZ) and the mineral resources of the continental shelf. As stewards of the marine environment within the EEZ, the coastal states have an obligation to use these resources sustainably. The rights of use therefore also involve accountability obligations vis-à-vis the new World Oceans Organization (WOO). The International Seabed Authority and Continental Shelf Commission are integrated into the WOO. The Regional Fisheries Management Organizations (RFMOs) are integrated into the Regional Marine Management Organizations (RMMOs) which organize the sustainable management of all resources on the high seas. They also organize the management of straddling and highly migratory fish stocks in cooperation with the coastal states. The WOO takes on the role of the oceans' global steward and monitors compliance with rules on their conservation and sustainable use. It has access to legal remedies, especially rights of action, at the International Tribunal for the Law of the Sea (ITLOS). Regional cooperation between the coastal states under programmes and agreements continues.
Red text: Accountability obligations vis-à-vis higher levels of governance.
a-e: See Figure 1 for explanations
Source: WBGU

nent conservation of healthy, productive and resilient marine ecosystems for present and future generations and translate this responsibility into political action. In addition, accepting responsibility for the common heritage of mankind involves sharing marine resources in a responsible and fair manner, as is already laid down in the law of the sea. This requires 'proactive states', particularly coastal states that commit themselves to the sustainable management of the oceans and enforce internationally agreed regulations. Designing the social contract for the sea is an open process in which the participation of civil societies should be a key element. This participation is based on involvement, transparency and monitoring decisions made by the proactive states on the oceans. Change agents have a key role to play in the sustainable stewardship of the oceans: supported by proactive states, they drive the transformation process forward by developing and testing new technologies and modes of behaviour – starting in niches. They then disseminate them using opportunities which they create themselves or which become available in other ways.

The WBGU's vision of a comprehensive reform of the international law of the sea

The following sections present in detail the vision, the recommended steps for a comprehensive reform of the law of the sea, and the WBGU's research recommendations.

The WBGU recommends placing the use of the oceans on a new foundation which not only takes account of the realities of ocean use and the needs of ocean protection, but also ensures the long-term conservation of ecosystem services and yields from sustainable use of the sea for both present and future generations. For this purpose, the WBGU is formulating a new, overarching vision of future ocean governance based on the conviction that the sea should be understood as a common heritage of mankind. This vision is outlined below.

- *Establish the 'common heritage of mankind' principle, the systemic approach and the precautionary principle:* The WBGU recommends enshrining in international law these three guiding principles – the common heritage of mankind, the systemic approach and the precautionary principle – for all uses of the sea as a global public good by reforming UNCLOS. The regime for marine conservation and use based on the common heritage of mankind principle should apply in differentiated forms to the maritime zones seaward of the territorial sea (EEZ, continental shelf, high seas, Area) and include all their resources.
- *Form a World Oceans Organization:* An international organization should be formed to function as a global steward of the marine environment and its resources in accordance with the extended scope and powers of UNCLOS. The aim of this World Oceans Organization (WOO) is not to be a 'super-authority for marine matters'; rather, it should only intervene if the management and monitoring tasks assigned to the parties to the convention (EEZ and continental shelf) or RMMOs (high seas) are not being properly carried out. Accordingly, the WOO would be equipped with the right to sue countries or agencies before the International Tribunal for the Law of the Sea (ITLOS). Furthermore, the WOO would also be given the authority to set standards. The International Seabed Authority and the Commission on the Limits of the Continental Shelf set up under the existing UNCLOS would be integrated as independent entities into the WOO's new organizational structure and retain their areas of jurisdiction.
- *Set up Regional Marine Management Organizations:* Regional Marine Management Organizations (RMMOs) should be set up under regional intergovernmental agreements to organize the conservation and sustainable use of the regional resources of the high seas (e.g. fish stocks, marine energy, genetic resources). They would also be responsible for marine protected areas and for implementing a system of marine spatial planning on the high seas. Their remit would furthermore include equitably distributing the yield from the use of the sea, by either selling or auctioning rights of use to the member states. Some of the proceeds could be used to finance marine conservation, monitoring and capacity building in developing countries. As regional stewards the RMMOs would be accountable to the WOO, particularly in matters relating to the sustainability of use. Each should cover a marine region, so that the entire area covered by the high seas could be administered without overlap.
- *Extend the jurisdiction of ITLOS:* The International Tribunal for the Law of the Sea (ITLOS) should be strengthened to create a judicial reference in the field of the law of the sea and international environmental law. In future, disputes over the interpretation of the law of the sea and international environmental law, and actions to prosecute cases of marine pollution, should be assigned first to ITLOS. The interpretation of UNCLOS would also remain the responsibility of ITLOS as the 'guardian of the treaties'. The new WOO should be equipped with the right to bring actions before ITLOS. Furthermore, selected and recognized non-governmental organizations should be granted class action rights.
- *Conservation and sustainable use of the high seas:* The

WBGU recommends declaring the high seas as part of the common heritage of mankind. In future, marine biological resources (e.g. fish stocks, genetic resources) should also be sustainably managed in line with the common heritage of mankind principle, and the benefits generated by this management should be fairly distributed – as under the regulations on seabed mineral resources. The UN Fish Stocks Agreement (FSA) would become part of the reformed UNCLOS. In line with the subsidiarity principle, the management of high-seas marine resources should be decentralized and transferred to the RMMOs. Financial advantages resulting from the use of marine resources on the high seas should benefit all humankind, focusing in particular on the interests of developing countries.

- *Conservation and sustainable use of the EEZ:* The common heritage of mankind principle should be extended to the exclusive economic zone (EEZ). The trusteeship for the management of the common heritage of mankind in the EEZs and on the continental shelf would be transferred to the respective coastal states. Violations of the common heritage of mankind principle would have to be sanctionable in order to achieve a sustainable use of the sea. The coastal states would maintain their customary, far-reaching rights of use within the EEZ which have already been assigned to them under the existing UNCLOS. They would, however, be under an obligation to the international community to protect the common heritage of mankind and to use it in a sustainable way; they would be accountable to the WOO in this respect.
- *Introduce rights of action and sanctions:* It should be possible for the WOO and parties to the reformed UNCLOS to sue those parties that fail to meet their reporting or conservation obligations at ITLOS, and for ITLOS to subsequently impose sanctions. These sanctions might include export or import restrictions on illegally sourced resources. Furthermore, a country that is in breach of the treaty could be excluded from participating in licence auctions for the resources of the high seas. As a last resort ITLOS should have the power to restrict a state's sovereign rights in the EEZ if it has abused its powers.
- *Set up a stricter liability regime:* A much more effective international liability regime should be created covering all activities across all sectors involving a potential risk to the seas (absolute liability with residual state liability).
- *Strengthen civil-society engagement:* Civil society, especially non-governmental organizations committed to marine conservation, should be given access to ocean-specific information, be informed about planning and approval processes relating to law of the sea and international environmental law, and be given corresponding rights of participation and legal action.
- *Expand marine protected areas and establish spatial planning:* An ecologically representative and effectively managed system of marine protected areas should cover at least 20-30% of the area of marine ecosystems. Furthermore, using graded zones allowing different intensity of use, this system of marine protected areas should be a core component of a marine spatial planning system to be set up and established as an instrument at the national, regional and global levels of ocean governance. On the high seas the WOO would take on the coordination and supervision of protected areas and spatial planning, while the RMMOs would carry out planning and management.
- *Provide for environmental impact assessment:* Interventions by planned activities in the oceans should only be allowed if the dangers they present for existing ecosystems are evaluated in advance and weighed up against the benefits of the intervention; this process should be obligatory. Accordingly, a strategic environmental assessment is recommended for plans and programmes relating to the oceans. A 'marine impact assessment' should be established for land-based activities. In this way the authorization process for land-based industrial production plants could already ensure that the only substances and products that can reach the oceans are those that have no harmful effects.

The road to a comprehensive reform of the law of the sea: recommendations for action

Bearing in mind the likely need for lengthy negotiations, the complexity of marine conservation, and the conflicts of interest about marine resources and their use, it is evident that the WBGU's vision is very ambitious and unlikely to be politically implemented in the near future. In order to get closer to the vision's long-term objective, the WBGU has drawn up recommendations for action that can link up with ongoing or envisaged political processes, do not require any changes to UNCLOS, and therefore seem more politically feasible.

Ocean governance

The following recommendations are designed in such a way that they could open the door for further reforms. They are thus the first steps recommended by the

WBGU for realizing a sustainable form of ocean governance as outlined in its vision of an ambitious reform of the law of the sea.

- *Strengthen the knowledge and action base of ocean governance:* In order to improve the scientific basis, the WBGU recommends the rapid enhancement of a global monitoring system for the oceans. The existing activities (e.g. IOC, FAO, WMO, WCMC) should be extended, better coordinated and combined. Monitoring activities should go hand in hand with the further development and supervision of policy objectives for the oceans. Moreover, scientific knowledge should be processed in an integrated way for policy-makers to give them a reliable overview of the current state of knowledge and the possibilities for action on the oceans. To this purpose the UN General Assembly decided in 2005 to have a regular global report drawn up on the state of the marine environment ('Regular Process'), which takes into account both scientific and socio-economic aspects and is comparable to the IPCC's reports. The Regular Process is relatively unknown among German marine scientists. The WBGU recommends giving the project much stronger support and integrating it into the existing scientific infrastructure. In addition, an international, consensus-oriented, multi-stakeholder process should be initiated to build a knowledge-based foundation for action and develop guidelines for humanity's future stewardship of the oceans (perhaps along the lines of the World Commission on Dams or the International Assessment of Agricultural Knowledge, Science and Technology for Development, IAASTD). The 'Ocean Advisory Group' announced in the Oceans Compact could become the starting point for this process.
- *Create the necessary conditions for sustainable, long-term management:* At present, ocean management is often largely focused on short-term profit. A suitable institutional and political framework is urgently needed to put an end to this state of affairs and move towards long-term and sustainable business models. Ecosystem services should be evaluated and priced; these prices should be taken into consideration in decisions on state investment and development projects and incorporated into marine users' economic decision-making processes. Harmful subsidies in the fishing sector should be cut back and funding provided for sustainable-use infrastructures and research and development work on sustainable management (capacity building).
- *Develop strategies for sustainable ocean governance:* The Oceans Compact initiated in 2012 by UN Secretary General Ban Ki-moon should be promoted and used to establish a strategic vision of the United Nations on the conservation and sustainable use of the oceans. The Oceans Compact should be further developed into an 'Integrated World Oceans Strategy' incorporating a new sustainable and systemic form of ocean governance, as outlined in this report. In line with the Millennium Development Goals (MDGs) or the yet-to-be-developed Sustainable Development Goals (SDG), it should be equipped with a list of objectives for the seas ('Oceans MDGs' and 'Oceans SDGs') and passed by the UN General Assembly. Such a global strategy for the oceans recalls the Rio Declaration of 1992 and should bring together the principles, guidelines, development paths and goals that are fundamental to the conservation and sustainable use of the oceans. They should be taken up and implemented at the regional, national and local levels. To promote a coherent transformation policy, the proposed guiding principles and goals should also be enshrined in regional and national marine strategies. Germany and the EU should also forge alliances with like-minded states and become pioneers of subglobal ocean governance. Such alliances should support efforts to implement the Oceans Compact.
- *Improve accession to and implementation of UNCLOS:* The WBGU regards UNCLOS as the basis for a social contract for the seas and recommends developing the convention further. The parties to UNCLOS should intensify their diplomatic efforts to persuade the remaining non-member states to join, and improve the implementation of the agreed political objectives.
- *Support an implementing agreement on biological diversity on the high seas:* There are above all three specific regulatory gaps on the high seas which are supposed to be closed by the planned implementing agreement to UNCLOS: the use of marine genetic resources, marine protected areas and environmental impact assessments. The WBGU recommends holding detailed negotiations on this new implementing agreement as soon as possible. In addition, the agreement should be equipped with a funding mechanism.
- *Advance the UN Fish Stocks Agreement and RFMOs:* The ratification of the UN Fish Stocks Agreement (FSA) with its precaution-oriented and knowledge-based approach should be promoted via diplomatic channels. In the longer term, the FSA should be extended by adding the common heritage of mankind principle. Its jurisdiction should be expanded to cover all species fished on the high seas. Urgent action is required to encourage the Regional Fisheries Management Organizations (RFMOs) to manage their fish stocks in a sustainable manner. Positive case examples should be taken up here. The provisions of the FSA and the FAO Code of Conduct for Responsible Fisheries should be incorporated into the RFMOs' regional agreements, and regular and

transparent performance reviews should be conducted. There should be a globally accessible register for all fishing vessels that want to operate on the high seas in RFMO areas, and compulsory licensing to make illegal, unreported and unregulated (IUU) fishing more difficult. The RFMOs should make full use of their rights under UNCLOS and the FSA to make it difficult or impossible for ships based in non-cooperating states to use RFMO stocks.

- *Strengthen and extend regional ocean governance:* In the context of the UNEP Regional Seas Programme, Germany's Federal Government and the EU should encourage the development of regional agreements for all marine regions covering as much of the global ocean as possible. The WBGU recommends upgrading the programme and integrating it into the Oceans Compact. Moreover, greater efforts should be made to implement the existing regional seas agreements, e.g. by agreeing ambitious protocols and action plans. The WBGU also recommends more institutionalization, for instance by delegating more tasks to commissions (e.g. HELCOM); these should regionally pool knowledge and skills, among other tasks
- *Improve dovetailing in regional ocean governance:* Cooperation should be deepened between adjacent marine conservation agreements and, in the case of fisheries, between adjacent RFMOs. The existing inter-regional collaborations should be based on the common heritage of mankind principle, the systemic approach and the precautionary principle. Significantly improved cooperation and coordination between stakeholders is also recommended within individual marine regions, e.g. between regional agreements, RFMOs and the UNEP Regional Seas Programme, to speed up the harmonization of objectives and measures.
- *Boost international financing for conservation and the sustainable use of the seas:* Following the equality principle, all states should take part in financing marine conservation; the size of payments by the individual states should be based on their economic strength. According to rough estimates, reorienting ocean management towards sustainability is likely to cause one-off costs of at least US$ 200-300 billion worldwide – plus annual costs of at least US$ 20-40 billion. In view of such sums, existing funding mechanisms are clearly totally inadequate. The WBGU recommends setting up two additional international funds: one (subsidiary) fund to support measures for the protection and sustainable use of the oceans within the EEZs, and one to finance the conservation of the high seas. The money should come from user charges, among other sources.
- *Create investment incentives for the conservation and sustainable use of the seas:* Targeted positive and negative economic incentives – such as user charges, payments for ecosystem services or temporary subsidies – should be used to support sustainable long-term uses. Via public financing mechanisms, potential users and investors should also be provided with low-interest loan capital and instruments for hedging the risks of investing in the sustainable use of the seas.
- *Strengthen and expand private governance:* In recent years private players have developed forms of governance relating to the conservation and sustainable use of the oceans that are not prescribed by state rules. The main ones are private certification initiatives aiming to encourage the sustainable use of the oceans (e.g. Marine Stewardship Council, Friend of the Sea, Aquaculture Stewardship Council). The number of fisheries certified by such programmes and the number of labelled fish and seafood products has increased considerably in recent years, involving the risk of standards weakening and the credibility of certifications dwindling. The WBGU recommends laying down minimum requirements within Europe on private sustainability standards for wild fishery products. Furthermore, the conformity of voluntary – both private and public – sustainability standards with applicable international commercial law should be clarified in the context of the WTO negotiations.
- *Considerably expand marine protected areas:* The Biodiversity Convention (CBD) aims to designate 10% of the oceans as marine protected areas by 2020; this does not seem ambitious enough. The WBGU recommends that at least 20-30% of the area of marine ecosystems be included in an ecologically representative and effectively managed system of protected areas. However, in view of the current global extent of marine protected areas (only 1.6%), it seems even more urgent to accelerate the knowledge-based implementation of existing objectives. The successes at the regional level (OSPAR Commission) should be continued and transferred to other regions wherever possible. Furthermore, the German Federal Government should continue giving a high priority to overcoming political blockades against an agreement on protected areas in the high seas.
- *Set up marine spatial planning:* The WBGU recommends a multilateral system of marine spatial planning that ensures cross-national coordination in order to realize large-scale environmentally friendly uses across zones. In the EU the instrument of marine spatial planning should be made a permanent and obligatory part of integrated marine policy. Germany should play a pioneering role in this and organize a European exchange of experience. A comprehen-

Box 2

Regional focus on the Arctic: Comprehensive conservation of a unique natural environment

Unlike the Antarctic, which is an ice-covered continent surrounded by the sea, the Arctic is a sea, much of which has hitherto been covered by ice all year round; it is surrounded by land. According to the WBGU's vision, the Arctic Ocean should be assigned to the common heritage of mankind. At the same time the Arctic, with its marine and terrestrial ecosystems, is a unique natural environment that is particularly worth protecting. Its use should be subject to very strict conservation requirements. The Arctic ecosystems are much more fragile and sensitive than those at lower latitudes. The Arctic also fulfils an important function in marine food production. The effects of the Anthropocene in general, and climate change in particular, are revealed especially clearly there.

Access to such Arctic resources as oil, gas, gold, zinc, rare earths and fish stocks, and the passage of shipping through Arctic waters have been made easier by continuous technological development and the retreat of the Arctic ice. Greater use would cause substantial risks to the fragile polar ecosystems from pollution and accidents, involving the danger of irreversible damage.

A comprehensive, cross-border marine protected area covering both the Arctic areas of the high seas and the adjacent EEZs and precluding resource extraction and fishing would be the most likely to meet conservation requirements. Until such a protected area has been established, the following recommendations represent steps in the desired direction:

- *Arctic protected area for the High Arctic:* The High Arctic should be declared a protected area. Protected-area status involves restrictions on rights of use.
- *Extend and promote the existing protected areas in the Arctic:* In 2004 a working group of the Arctic Council drafted a Marine Strategic Plan which aims to promote networking between existing protected areas. The German Federal Government should support the efforts of the working group. There are already a number of marine protected areas within the territories of various countries bordering the Arctic, e.g. in Canada, Norway and Greenland. These efforts should also be acknowledged and encouraged.
- *Institutionalize the sustainable use of the Arctic:* The WBGU recommends that the international community and the states bordering the Arctic should agree to maintain the ecological balance of the Arctic Ocean as part of the common heritage of mankind. Within the EEZs, too, the Arctic Ocean should only be used sustainably. Uses – especially the offshore production of oil and gas – should be allowed only according to strict safety and environmental-protection standards.
- *Implement a binding Polar Code:* Germany should support the efforts of the European Commission to develop a binding code of conduct (Polar Code) on shipping in the region to be administered by the IMO. The aim here is to counter the environmental risks from rising shipping traffic in the Arctic; corresponding safety measures should be agreed.
- *Establish a liability regime:* To date there is no liability regime that applies in the event of environmental damage in the Arctic Ocean. Such a liability regime should be agreed. It should centre on the principle that states are responsible for taking precautions and provide a clear framework for action with liability provisions for individual user groups and causers.

sive system of marine protected areas is an essential component of marine spatial planning systems.

- *Promote the harmonization of existing liability regimes:* The current law on liability has gaps and deficits. The WBGU therefore supports the European Commission's intention to standardize the law on liability for offshore activities.

Focus: food from the sea

In many developing countries fish plays an important role for food security, income generation and health care. However, most fish stocks are still poorly managed today worldwide, both ecologically and economically. Overexploitation of fish stocks poses one of the most serious threats to marine ecosystems. At the same time, the demand for fish and seafood is on the increase – and with it the pressure on fish stocks. Despite ever greater efforts by fisheries, global yields are now declining. The depletion of fish stocks must be stopped if sustainable ocean stewardship is to succeed. Such a transformation towards sustainability has already begun in some countries: stocks are recovering, they are being managed sustainably, and marine ecosystems are being protected. Thus future catch volumes could even be permanently higher than they are today in the long term. However, for this to happen the fishing pressure and the overcapacity of fishing fleets would have to be reduced. This would involve political, social and economic costs for a transitional period. The potentially larger yields once fish stocks have recovered won't materialize for years or even decades.

In view of the unsatisfactory state of many fish stocks and the growing demand for fish, many people's hopes are directed towards aquaculture. However, the currently prevalent form of marine aquaculture cannot meet the expectations of rising sustainable fish production. Breeding focuses primarily on carnivore fish species whose feed is largely produced from forage fish; the latter are in turn caught by conventional fishing. Depending on the species of fish, several kilograms of forage fish are required to produce every kilo of bred fish. These problems can for the most part be avoided by other forms of aquaculture, i.e. breeding herbivorous freshwater species or mussels. A form of sustainable aquaculture should therefore be promoted that operates in a socially acceptable and environmentally responsible way.

Important preconditions have already been met for the transformation of fisheries. For example, ambitious international regulations and political objectives are in place to stop overfishing by 2015; this was reaffirmed at the Rio+20 Conference in 2012. The overall legal framework and incentive systems are important starting points for implementation. At present they often still offer misguided incentives, such as subsidies for expanding fishing capacity or for fuel. Ecological damage is not internalized. There are also recommendations for responsible aquaculture that have been agreed at the international level. The technical instruments and management options for sustainable fisheries and aquaculture are already known or are being developed. What is primarily needed now is the effective implementation and enforcement of agreed rules and targets. Then overfishing can be stopped, yields could rise, and the contribution to food security for a growing world population would be guaranteed. In order to achieve this, the WBGU recommends the following:

- The ecosystem approach and the precautionary principle should be rigorously applied. Furthermore, scientifically based, sustainable yield limits should be fixed for fish stocks and applied as broadly as possible. The maximum sustainable yield (MSY) should not be regarded as a target, but as the absolute upper limit of catches: actual production should remain well below it for environmental reasons. This new role of the MSY should be enshrined in fishery governance at all levels. On this basis, ecosystem-based management plans covering several years should be drawn up and adhered to. It is crucial here to effectively monitor compliance with rights of use and access and to apply corresponding sanctions.
- The capacities of fishing fleets should be reduced worldwide as a matter of urgency. The decisive factor in this context is to phase out subsidies which up to now have encouraged overfishing and fleet overcapacity. The WBGU recommends pushing hard for the abolition of subsidies in the corresponding WTO negotiations.
- Urgent steps should be taken to reduce the ecological risks and side effects of marine capture fisheries. Destructive or wasteful fishing methods should be prohibited and environment-friendly methods that reduce bycatch made mandatory. The WBGU recommends compulsory landing for bycatch.
- Illegal, unreported and unregulated (IUU) fishing will only be stopped by better treaties with strict controls and sanctions. Widespread acceptance of the UN Fish Stocks Agreement and resolute reforms to the Regional Fisheries Management Organizations (RFMOs) would make IUU fishing on the high seas much more difficult. International cooperation should be greatly improved in order to generate a large enough pool of data about the high seas. The FAO International Plan of Action against IUU Fishing deserves stronger support. Monitoring the port states is regarded as particularly effective; it is therefore important that the FAO Port State Agreement comes into force and is implemented quickly. In the European Union, an IUU fishing regulation has already come into effect, although its effectiveness cannot yet be finally assessed.
- Fisheries in the EU are in a poor condition, although the situation is improving slowly. The reforms to the EU's Common Fisheries Policy proposed by the European Commission should be adopted and resolutely enforced, otherwise the internationally agreed objective of sustainable fisheries by 2015 cannot be reached. Similarly, the Fisheries Partnership Agreements with developing countries must be fundamentally reformed in order to meet environmental, economic and social sustainability criteria. Since the EU is the largest importer of fish in the world, it should take advantage of all available commercial-policy options to strengthen sustainable management in the exporting countries.
- The EU and Germany should do more to help developing countries build up a sustainable system of fisheries management and corresponding value chains. Greater emphasis in global and national policies should especially be placed on the concerns of small-scale fishermen and on securing their participation. Low-income groups who cover a large proportion of their animal protein intake from fish and seafood should be reimbursed for losses of yield in the course of the transition to sustainable fisheries.
- Fishing for forage fish for aquaculture operations focusing on carnivorous fish should be replaced as quickly as possible by alternatives; in this way aquaculture might be able to ease the pressure on wild fish stocks. Instead, the forage fish stocks should be used as far as possible for direct human consumption. Instead of breeding predators, sustainable aquaculture should rely more on omnivorous and herbivorous species of freshwater fish and crab, as well as clams, snails and algae, to reduce the need for input from wild fisheries (fish meal, fish oil or fry).
- The ecosystem and precautionary approaches should also be a basic principle of management in aquaculture. The regulations of the FAO Code of Conduct for Responsible Fisheries that are relevant for aquaculture should be stipulated by states as binding national law and implemented by means of suitable

political, institutional and economic conditions and control instruments – and enforced by inspections and sanctions.

- Development cooperation should focus on increasing support for small and medium-sized aquaculture operations in developing and newly industrializing countries and on promoting sustainable production there. In particular they should help stop the further destruction of mangrove forests by shrimp farms.
- In the EU and in the international arena, the German Federal Government should seek to improve, harmonize and expand certification schemes for sustainable aquaculture. Retailers should stock more aquaculture products that are certified according to sustainability criteria. Consumers should, for example, be provided with more information to encourage them to buy more products that are sustainably produced.
- The technological development of sustainable aquaculture systems should be supported. Above all, integrated, poly- and multitrophic and closed production systems could help reduce the environmental impact. The development of responsibly produced substitutes for fish meal and oil should be promoted. Studies should also be conducted to examine to what extent sustainable – preferably multitrophic – offshore aquaculture operations, possibly in combination with offshore wind farms, might reduce competition for land use in coastal areas.

Focus: energy from the sea

Energy systems have a key role to play in the transformation towards a low-carbon, sustainable society. A low-carbon energy supply requires a corresponding national energy policy. An international energy policy is also beneficial. Use of marine energy is currently dominated by oil and gas production, and mining and transport accidents can have catastrophic consequences for marine ecosystems. At the same time, emissions of methane and carbon dioxide during extraction, accidents and use are contributory factors to climate change. A climate-friendly energy policy therefore also requires a climate-friendly form of offshore energy generation, which is characterized by the deployment of offshore wind- and marine-energy technologies. The long-term goal is to phase out the offshore extraction of fossil fuels. Since some of the low-carbon marine-energy technologies are still at an early stage of development and show considerable potential, they should be supported by a targeted innovation policy. At the same time, a legal framework should be designed that ensures the protection of the marine ecosystems and a sustainable use of the seas.

In fossil-fuel prospecting far from the coast, a trend is emerging to work at ever greater depths. Floating platforms, underwater robots and horizontal drilling systems make it possible to operate even at great depths and in difficult-to-access marine areas such as the Arctic. It must be feared that the offshore extraction of fossil fuels will expand further, given that deposits are expected to be large and the global demand for energy is likely to rise. In addition, further technological developments could turn the mining of marine methane hydrates into an attractive business. However, the risks involved are still largely unknown at present. Marine methane hydrates are not needed either for a future low-carbon global energy supply or to cover the phase of converting the energy systems. Existing reserves and resources of conventional gas are more than sufficient for energy-system transformation. From the point of view of climate and marine policy, the WBGU advocates abandoning efforts to mine marine methane hydrates. The WBGU also recommends applying stricter environmental requirements when issuing drilling permits, and establishing an international liability regime for companies operating offshore oil and gas installations, as well as for marine mining. Moreover, humanity is only likely to have a fair chance of limiting anthropogenic climate change to 2 °C if the total amount of anthropogenic CO_2 emissions remains restricted during this century. Therefore, only a small percentage of known fossil fuel deposits should be used.

So policy-makers should promote the expansion and development of offshore wind power and other sustainable marine energy technologies, as well as transnational offshore power grids. Some countries are already successfully operating offshore wind farms, while others are still in the test phase. Stronger and more stable winds prevail at sea than on land, so that offshore wind energy can reach a higher level of capacity utilization and consistency. Using floating structures, offshore wind farms could potentially be operated in deeper waters and further away from the coast. The more renewable-energy technologies can be transferred to the ocean, the less energy has to be generated on land. The risks posed by renewable-energy technologies at sea are considerably lower than those of marine oil and gas extraction. Even so, here too there are potential dangers for marine ecosystems and species, for example from turning rotors, noise during the construction phase and electromagnetic fields created during the transport of electricity. This must be taken into account when building offshore grids and in future technological developments.

In the future it will also be possible to use the sea for other forms of renewable energy production. Although offshore bioenergy production – using algae for example – is still in its infancy, it seems to have considerable potential. So-called multi-use platforms could offer economic and ecological advantages for the global marine energy system of the future, since they not only generate, but also store sustainable energy. However, this requires an offshore energy-transmission system which is integrated into corresponding transport systems on land. In addition to oil and gas pipelines, other networks will be needed in the future to transport electricity and CO_2. Some of these transmission technologies could be combined. The WBGU's detailed recommendations are as follows:

- *Develop national energy strategies:* National energy strategies should be agreed all over the world, with development targets for renewable-energy technologies and therefore also for offshore-wind or sustainable marine-energy technologies. In addition, marine spatial planning and approval processes should be developed for offshore technical installations, as well as liability regimes. The WBGU recommends that the German Federal Government should conduct intensive scientific accompanying research. This could provide a source of recommendations for statutory requirements on the design, construction and operation of offshore wind farms and marine energy technologies.
- *Use marine spatial planning:* Since offshore wind and other marine renewable energy systems require space and compete both with existing uses of the oceans and with ocean and coastal conservation, the WBGU particularly recommends the application and further development of marine spatial planning. In view of the cross-border effects of marine technical systems on ecosystems and shipping, marine spatial planning should be coordinated at the level of regional seas agreements such as OSPAR or HELCOM.
- *Strengthen the regulatory framework:* Especially for gas and oil production, the WBGU recommends strengthening the regulatory framework, both in European waters and worldwide, in order to reduce the risk of accidents, improve damage-repair capabilities and regulate liability. For the European Union, the WBGU recommends stricter environmental regulations when issuing drilling permits. The existing EU liability regime for the operation of offshore oil and gas facilities should be extended in scope to the Member States' EEZ and the continental shelf. To this extent the Federal Government should push for swift adoption of the draft regulation which already exists.
- *Support innovation:* Innovation should be supported to send the right political signals to potential investors, as most marine technologies in the field of renewable energy generation are still far from mature. The WBGU recommends that the Federal Government should politically support the development of the relevant technologies and market integration and ensure that this is done in a participatory way. In international cooperation it should also encourage research into the environmental risks of marine technologies, develop new regulations and standards, and agree international treaties on environmental protection.
- *Build an offshore supergrid:* An offshore power grid interconnecting the various marine power-generating plants and different countries makes it easier to integrate fluctuating power generators by smoothing the generated output. This would reduce the need for storage facilities. The WBGU therefore recommends that the Federal Government should construct an offshore grid in the North Sea as soon as possible, as announced in the Energy Concept and the Development Plan for the Sea. The vision and planning of an integrated, transnational offshore power grid in Europe should in particular be fully coordinated with the national plans of the relevant countries bordering on the North Sea.
- *Refrain from marine methane hydrate mining:* Mining of marine methane hydrates is associated with a number of environmental risks that have not yet been quantified. At this stage, therefore, the WBGU recommends against it. Nevertheless, research should continue on the deposits, their stability and the environmental risks. However, since some countries, e.g. Japan, could start commercially exploiting methane hydrates within the next few years, the WBGU reiterates its recommendation from the 2006 special report on 'The Future Oceans' to carefully review the risks of methane hydrate mining in each individual case. The International Seabed Authority is responsible for methane hydrate deposits in the Area. Here too, the WBGU argues in favour of a ban on the mining of methane hydrates based on the common heritage of mankind principle, the systemic approach and the precautionary principle. Moreover, this fossil fuel is not needed for the sustainable and low-carbon global energy supply of the future. Given the likelihood that methane hydrates will soon be mined, the WBGU recommends, as a minimum solution, that the signatories to UNCLOS agree on international standards for the marine mining of methane hydrates; the Seabed Authority could then make these a requirement for licensing.
- *Develop regulations for sub-seabed CCS:* The WBGU does not regard the injection of CO_2 into ocean water as a sustainable option due to uncontrollable risks and the insufficient retention period. The WBGU's

assessment of the storage of CO_2 in stores under the seabed, however, is that it is less risky than storage in land-based locations; it therefore recommends focusing research on this form of use. Doubts about retention capacity should be carefully examined. CCS technology should not be used on a large scale until it can be proved in scientific studies that the required retention period of at least 10,000 years can be guaranteed. Furthermore, it should be clarified prior to use how long-term monitoring can be implemented. An (international) legal framework should be developed regulating not only liability for the escape of CO_2 over several decades, but also the climate-relevant question of long-term escape over thousands of years.

Research recommendations

Research has a key role to play in the necessary transformation towards a low-carbon, sustainable society. The transformation is a societal search process that should be supported by research. The aims of research should be to develop visions of sustainable ocean stewardship, describe different paths of development, and develop sustainable technological and social innovations in collaboration with politics, business and society. Scientific marine research in Germany is very well positioned by international comparison. However, greater cooperation between the natural, social and engineering sciences is essential if humanity is to interact with the oceans in a sustainable way. To develop the research landscape, the WBGU distinguishes between transformation research and transformative research.

Transformation research seeks to understand transformation processes in order to accelerate future transformations and improve their governance. It involves the interdisciplinary, scientific analysis of societal transformation processes as such, in order to explain factors and causal relations and identify the 'conditions of possibility' (Immanuel Kant) of social and technological innovation, including their potential effects on ecosystems. Transformation research also specifically addresses the forthcoming task of designing and governing the transformation by outlining visions and possible paths of transformation, identifying possible negative effects on the environment, and developing proposals for policy-making. The main areas of marine transformation research include the following: research on appropriate ocean governance in view of multiple uses of the sea; the significance of the oceans in the context of world society; intercultural research on ocean stewardship; radical changes in the use of the sea before and during industrialization, including interactions with ecosystems; and visions of future ocean use and assessing the different paths that might lead there. The WBGU recommends creating interdisciplinary research institutions and programmes to take up the issues outlined.

Transformative research encompasses all scientific activities that can generate the decisive innovations in the sectors relevant for a transformation towards sustainable ocean use – thus enabling the transformation in the first place. The WBGU particularly emphasizes the following research topics, which are all directly interconnected in the context of sustainable ocean stewardship: global change research provides the problem diagnosis and the fundamental system understanding that is essential for good ocean governance; governance research provides frameworks for institutions and policies and in this way enables targeted political action. Global change research and governance research together stimulate research in the particular fields of action. Food and energy are key issues of the Great Transformation towards a low-carbon, sustainable society, to which the oceans can make an essential contribution. In this report the WBGU focuses on these two key aspects – food and energy – and makes exemplary research recommendations for sustainable problem solutions, uses and specific governance mechanisms in these fields.

The following recommendations should also be supported by existing research institutions and programmes.

Global change research

Global change research focuses largely on physical and biogeochemical environmental changes that can be either natural or caused by humans. It increasingly also analyses the effects of the changes on societies and the options for combining economic and societal development with a reduction in harmful environmental impacts. A central theme of marine global change research is the interaction between climate change and the oceans: although seawater warming, changes in ocean currents and rising sea levels are recognized as problems and justify preventive action according to the precautionary principle, the upstream and downstream processes are only partially understood, and future projections and risk assessments still involve great uncertainty. This also applies to the receding sea-ice cover and the effects of ocean warming on the continental ice. Profound but insufficiently understood changes in ocean chemistry, such as acidification or the spread of oxygen-deficient zones in the world's oceans, are further issues that need more consideration. More intensive research is also needed into the effects on marine ecosystems of multiple stress factors such as warming, acidification, pollution and overfishing. Our understanding of the processes that are taking place is currently not keeping up with the pace of changes in the oceans. Even so, there is sufficient knowledge in many problem areas and action fields to take decisive action now and to tackle the reform of the existing ocean governance system in the manner proposed by the WBGU.

Research on ocean governance

Research should develop visionary plans for new, ocean governance structures that meet the challenges of the Anthropocene. Simultaneously there is a need for greater cooperation between global governance research – which focuses mainly on the social sciences and jurisprudential disciplines – and the natural and engineering sciences, in order to develop suitable governance patterns based on a better understanding of the interaction between the ecological, socio-economic and technical systems. Emphasis should, for example, be placed on the theoretical foundation and conceptual development of global guiding principles – such as the World Heritage principle – and their institutional and material design.

To enable corresponding steps towards transformation to be taken, governance research should contribute to a cross-sectoral and coherent analysis and assessment of governance structures, and to legal and economic conditions and requirements relating to the current and future use of the oceans. The focus here should be on the importance of the oceans as a global public good; on the institutional fragmentation of global ocean governance; on ways of steering and shaping new forms of ocean use (e.g. renewable marine energy, offshore aquaculture); and on improving interaction between regional and global governance.

In order to develop a polycentric form of global governance in the multi-level system, a further priority area for research should be the comparative analysis of mechanisms and institutions at the regional and national level, the aim being to identify examples of best practice and to draw practical conclusions on the fragmentation of ocean governance and possible ways of improving cooperation and coherence. Here, too, it is important to determine – through cooperation with the natural sciences – the effects the solutions might have on the ecosystems and whether they are appropriate with regard to real-life environmental problems.

Research should also be stepped up into policy instruments that do justice to the depth of human interference in the Anthropocene, e.g. research on marine spatial planning, user charges and the development of a global evaluation system for the marine environment (status and target indicators). It is necessary to study how such instruments can be designed and institutionally embedded into systemic multi-level governance.

Research on food from the sea

- *Sustainable fisheries:* Research on the sustainable management of fish stocks should concentrate in particular on the technical fine-tuning of fishing equipment to avoid by-catch and to catch the respective target species more selectively. Research should also aim to improve indicators of ecosystem linkages. In addition, there is a demand for methods that make it possible to estimate the maximum sustainable yield (MSY) even if little data is available. There is also a need for research on the use of marine protected areas as an instrument of fisheries management. As a contribution to food security there should also be research on how fish species which have hitherto only been used as forage fish can be used directly for human consumption. In addition, it would be useful for fishery governance if socio-economic research were conducted on the overall conditions and incentive structures for sustainable fisheries management. In this context Germany should emphasize research into sustainable EU fishing in third countries. Research on the economic assessment of biodiversity and marine ecosystem services, among other things, offers a starting point in this context. Further important research aspects include the fight against illegal, unreported and unregulated (IUU) fishing, as well as regulatory and implementation gaps in governance – and solutions for closing those gaps. Finally, a scientific consensus should be sought on the governance mechanisms that can be particularly recommended for promoting sustainable small-scale fisheries (e.g. value-chain optimization, social security for small-scale fishermen).
- *Sustainable aquaculture:* Research on developing environmentally friendly, integrated, multitrophic and closed aquaculture systems should be given priority support using the ecosystem approach as a basis. Research on offshore aquaculture should also cover synergies with other offshore installations such as wind farms. In view of initial successes and applications, research on substituting fish meal and oil in feeds should be further intensified; the possible repercussions of increased plant-based feed substitution on land use should also be studied in this context. There should be intensified research into the potential yields of sustainable aquaculture and

on their contribution to food security and poverty reduction. In particular, information is needed on the global yield potential of different aquaculture scenarios. Furthermore, different governance approaches should be examined together with their potential for supporting an environmentally and socially responsible development of aquaculture. National and international research cooperation to promote aquaculture research should be strengthened, particularly with and in developing countries.

Research on energy from the sea

Key technologies should be further developed for sustainable marine energy generation – including floating multi-use platforms that can integrate different power-generation technologies as well as algae cultivation. Also important is the development of ocean-based storage applications, such as deep-sea stores, the electrolytic production of hydrogen, and the transport of methane in the form of artificial methane hydrate. The further development of high-voltage direct-current transmission is a necessary prerequisite for setting up an offshore supergrid. As a general rule, the WBGU also recommends more research into risks and environmental hazards relating in particular to the cumulative and long-term effects of extracting fossil fuels, to storing CO_2 beneath the ocean floor, and to renewable energy-generation technologies. Special attention should be given to research into the interactions between magnetic fields and marine ecosystems and on reducing noise emissions during the construction of marine renewable-energy technologies.

Research policy

With regard to research policy the WBGU stresses the following recommendations:

- *Greater integration of interdisciplinary marine research into research programmes:* The WBGU recommends integrating sustainable marine research more closely into existing research programmes, with the social sciences interacting more closely with the natural sciences. At the EU level, a programme for sustainable marine infrastructures should be established at the European Academies Scientific Advisory Council (EASAC); calls for research-project proposals on the conservation and sustainable use of the oceans should be developed within the 8th EU Framework Programme for Research and Innovation ('Horizon 2020'). A cross-cutting subject on the conservation and sustainable use of the oceans – similar to the existing cross-cutting theme on sustainable land management – should also be integrated into the BMBF's Framework Programme Research for Sustainable Development (FONA).
- *Greater institutionalization of interdisciplinary marine research:* The WBGU recommends strengthening the institutional basis for interdisciplinary research relating to the conservation and sustainable use of the seas. The German Marine Research Consortium would seem a suitable nucleus for a corresponding strategic development of German marine research and should be strengthened in its role as a platform for coordination and communication. Possible ideas for strengthening the institutional base of interdisciplinary marine research include promoting networks; integrating missing disciplines into existing research institutions; setting up a new research institute that incorporates elements from the fields of economic, social and cultural sciences; and creating a new interdisciplinary institute. In addition, the WBGU recommends the establishment of an experimental alternative programme as a DFG Collaborative Research Centre whose approval criteria should combine interdisciplinarity, societal problem relevance and a connection with the conservation and sustainable use of the oceans. Because of the growing relevance of marine and polar policy in the context of security, environmental and science policy, the WBGU also recommends setting up a research centre for marine and polar policy.
- *Greater integration of science, politics and civil society:* When implementing technology-policy measures relating to the use of the oceans, the WBGU recommends integrating more research perspectives that deal with marine ecosystems and their protection, as well as technology assessment. Another recommendation is to develop proposals for an innovative marine science-policy interface. With a view to improving future collaborations between science and politics, the WBGU recommends analysing the experience gained from the Joint Initiative for Research and Innovation to encourage greater cooperation between science, politics, business and society. Sustainability should be at the centre of attention in this context. In addition, the WBGU recommends more involvement from civil society when it comes to setting the agenda and designing programmes of marine research, as well as awarding public research funds for this purpose. The WBGU recommends information and education campaigns to increase public knowledge about the ecological condition of the oceans and the scale of the threat to them. In addition, existing civil-society initiatives for the protection of the marine environment should be specifically supported by the government.

Epilogue

At the end of this report, the question remains as to how its many recommendations can be implemented at the local, national and international level. Experience shows that such processes take many years, and fundamental changes – or system changes – are often made possible by unforeseeable, new developments or events, as was shown by the German *Energiewende* (energy-system transformation) after the nuclear disaster in Fukushima. Even so, the oceans could be actively brought more into the public eye, and there are already signs of a trend in this direction: the United Nations declared 1998 the Year of the Oceans; World Oceans Day has been celebrated every year since 2009; and the oceans were high on the agenda at the Rio+20 Conference. This shows that there is a growing public awareness of the blue continent's problems. This growing attention could condense into a consensus on the conservation and sustainable use of the oceans in the form of a 'marine social contract'. This would be a major boost to the further development of a sustainable marine policy. As Elisabeth Mann Borgese put it, the issue is "to live with the sea". This report endeavours to make a contribution in this regard.

Introduction

Living with the sea forces us to think differently: to think in a new way and to act differently.
Elisabeth Mann Borgese, 1918–2002, marine conservation pioneer
("The Oceanic Circle – Governing the Seas as a Global Resource", 1999: 19, preface German edition)

Humans have been using the oceans since very early on in their history. Today, 40% of people live no more than 100 km from a coast, and more than 90% of world trade crosses the seas. Over the last 50 years humanity has triggered bigger changes in the oceans than have otherwise been seen in millions of years. The oceans are not only "rising high, turning sour and warming up" (WBGU, 2006), they are also heavily overfished and polluted and increasingly being tapped as the Earth's last great source of raw materials. This trend is gaining in momentum as a result of technological advances and improving access to hitherto ice-covered regions. At present something approaching a gold-rush mentality is developing among the countries bordering the Arctic, and the United Nations Environment Programme recently drew attention to the associated risks (UNEP, 2013). Overfishing, too, has so far been continuing almost unabated. The days are long gone when the oceans could be regarded as an inexhaustible source: they have become a fragile habitat intensively used – and sometimes overused – by mankind. Nevertheless, the seas fulfil irreplaceable functions for the entire Earth system, not least as a sink for CO_2.

Efforts to keep the seas in a good condition began as early as the 1960s. Since then, numerous international treaties and institutions have been initiated to promote the conservation and sustainable use of the oceans. A number of important pioneers have promoted a more sustainability-oriented attitude towards the seas. Arvid Pardo, for example, gave a historic speech to the UN General Assembly as Ambassador of Malta in 1967 in which he defined the oceans as the "common heritage of mankind". The global heritage idea was enshrined in the 1982 Convention on the Law of the Sea (UNCLOS), although its application was limited to the mineral resources in the seabed. Another influential personality was Elisabeth Mann Borgese, pioneer of marine conservation, whose 1975 book 'The Drama of the Oceans' was translated into thirteen languages. The French oceanographer and marine-conservation pioneer Jacques Yves Cousteau played on a completely different stage. His television documentaries brought the beauty of the underwater world into the living rooms of the 1970s and 80s and thus into many people's consciousness. Using a decommissioned minesweeper called Calypso, he explored the oceans, shot over 100 films and shaped the image of the sea for generations.

During this period the general public increasingly began to regard the oceans as an integral part of the global environmental system. This systemic view became established in international marine policy when it was enshrined in the Agenda 21 at the Rio de Janeiro Earth Summit in 1992 (UNCED). Looking back, Elisabeth Mann Borgese wrote: "UNCED performed a vital function in elucidating that the problems of ocean space are closely interrelated and not only among themselves but also with those of terra firma, the atmosphere and the outer space" (Mann Borgese, 1998: 21).

Finally, Elisabeth Mann Borgese's 1998 report to the Club of Rome entitled "The Oceanic Circle – Governing the Seas as a Global Resource" became a milestone in international marine policy. In it she developed an integrated view of the oceans and outlined what an effective, cross-sectoral form of global governance for the 'blue continent' might look like.

International marine policy gradually developed further in the following years. At the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg it was decided to set up a network of protected areas on the high seas. And at the Conference of the Parties to the Convention on Biological Diversity in Nagoya in 2010, the international community agreed to place ten percent of the world's marine areas under protection by 2020. However, we are still a long way from achieving this target. Although the participants at the Rio+20 conference in 2012 agreed to develop an additional implementing agreement on biological diversity on the high seas under UNCLOS, no date was set for beginning substantive negotiations – a poor result. In the same year, the World Bank initiated the Global Oceans Alliance, which can be expected to boost multilateral development cooperation on the conservation and sustainable use of the oceans.

As early as 2005 the General Assembly of the United Nations passed a resolution to establish a Regular Process for Global Reporting and Assessment of the State of the Marine Environment (the Regular Process). The 'first integrated global marine assessment' is supposed to be submitted to the UN General Assembly in 2015.

So there is no lack of efforts to improve the state of the oceans. Even so, the old problems have become more acute, new, additional ones have arisen, and the expansion of uses into the open sea – or hitherto inaccessible regions – continues due to new technological advances and climate change.

This critical situation prompted UN Secretary-General Ban Ki-moon to launch an initiative called 'The Oceans Compact: Healthy Oceans for Prosperity' at the Rio+20 Conference 2012. It is intended as a platform for developing a strategic vision for ocean-related activities at the United Nations. The creation of an Ocean Advisory Group was also envisaged with the Oceans Compact initiative.

Against this background, the present report reveals that long-existing challenges have intensified; it also places the future of the oceans into the context of the Great Transformation towards a low-carbon, sustainable society (WBGU, 2011). The report differs in this respect from the WBGU's 2006 book 'The Future Oceans – Warming Up, Rising High, Turning Sour', which concentrated primarily on the influence of climate change on the oceans.

The challenge in this century will be to reverse the negative trends, re-stabilize the ocean as a global common good, and return to a situation of sustainability. Will humanity assume responsibility for the way it treats the global common good that the oceans represent? The WBGU proposes looking at the oceans in their entirety as part of the 'heritage of mankind' and developing UNCLOS accordingly. This paradigmatically new perspective sets the present report apart from previous works. The topics food and energy are at the centre of attention. Oceans offer great potential for renewable energy in the form of wind, waves and tides. What role could they play for the global transformation towards sustainable energy systems? The world's population will grow to about nine billion people by the middle of this century. This means that not only a growing global appetite for energy, but also an greater demand for food will have to be satisfied. What role can and should food from the oceans play? What will be the impact of changes in diets in emerging and developing countries? And, most importantly, how can common action by the international community in the way they treat the seas be developed in such a way that future generations will inherit an intact marine environment? How can the conservation and sustainable use of the 'blue continent' be secured in the future?

Much will depend on ocean governance. The focus is therefore on the rules governing the conservation and sustainable use of the oceans, and above all on how we can ensure that these rules are implemented. In addition to providing answers to these questions, the present report aims to present an integrated vision on the long-term conservation and sustainable use of the oceans. A corresponding new marine policy should be a key project in the Great Transformation towards a low-carbon, sustainable society.

The Oceans in the Anthropocene 1

For the vast majority of human history people have believed the oceans to be endless and inexhaustible. As late as the 17th century it was assumed that the seas could never be emptied of fish and that shipping exerted no significant influence on the oceans (Vidas, 2010). Yet humankind actually began decimating marine life – initially on a localized scale – thousands of years ago (Census of Marine Life; McIntyre, 2010; Roberts, 2007). The extent of the damage caused by humans then reached a new dimension with the advent of industrialization.

Humankind has become a dominant factor in the Earth system. Increasingly, therefore, the current industrial age is being regarded as a new period in the history of the Earth, as the 'Anthropocene' (Crutzen and Stoermer, 2000). Humanity's collective ability to cause changes on a planetary scale has already endangered vital natural life-support systems, so the Anthropocene is also ushering in a new era of responsibility. In many areas, critical developments are emerging that demand swift corrective action. Examples include water resources, soils, forests – and the overexploitation of the sea. In its 2011 flagship report, the WBGU described the need for society and the economy to undergo a Great Transformation towards sustainability, and based its analysis of the vision's feasibility on the example of climate protection (WBGU, 2011). Central to this report is the idea of a new social contract that would enable governments and civil society to work together to shape this change process. The present report builds on the analysis from the 2011 report and focuses on the oceans.

First, this report explores the role the use of the oceans plays in the transformation towards sustainability. To protect the climate, global emissions of greenhouse gases must be reduced to an absolute minimum in the decades ahead. This in turn necessitates a transformation of the world's energy systems. Energy from the sea can play a part here and is therefore one of the two focal issues covered in the report. At the same time, as the WBGU showed in its report on the transformation (WBGU, 2011), sustainable land use is also of tremendous importance to the targeted transformation. Here too, there are interdependencies with ocean use via the human food system. Food from the sea is thus the other focal issue addressed by this report.

Second, the question arises as to what sustainability means for the oceans:. What influence has humankind exerted on the oceans? What critical developments are to be averted? What sustainability goals should be pursued? The issues at stake include preserving ecosystem services, such as material cycles, flood protection and primary production, as well as the direct use of resources and spaces. Many threats to the oceans do not arise directly from human use. One example is the influence of climate change, whose interactions with the sea have already been discussed in detail by the WBGU in a special report (WBGU, 2006). Similarly, chemical run-off and waste discharge are only directly related with the use of the oceans to a small extent. However, one of the biggest problems – the dramatic and virtually global depletion of fish stocks – is almost exclusively caused by overexploitation. Against better knowledge, overfishing is still common in many regions and will, sooner or later, deprive itself of its basis. As in the case of climate protection, so here: there are plenty of well-known solutions, and both political and economic tools are available but there is a lack of implementation.

No consistent answers have yet been put forward to the question of how we really want to use and, perhaps, shape the oceans in the Anthropocene. What is lacking, therefore, is a generally accepted, realizable, positive vision of sustainable human interaction with the oceans – both with respect to using the sea itself and in other areas that impact on the sea. The key question addressed by this report is therefore: what might sustainable interaction with the oceans look like in the context of the Great Transformation towards sustainability?

Maritime laws have been around for centuries. In the 17th century, the rise of the great seafaring nations' merchant shipping fleets, the conquest of fishing grounds and the exploitation of mineral resources created the

Box 1-1

Guard rails for marine conservation

To operationalize the concept of sustainable development, the WBGU has developed the idea of guard rails, to which we refer briefly here; in places we quote verbatim from previous reports (e.g. WBGU, 2004, 2006). Guard rails are limits on damage and can be defined quantitatively; a breach of these limits would give rise either immediately or in future to intolerable consequences so significant that even major utility gains in other fields could not compensate for the damage. Guard rails thus demarcate the realm of desirable and sustainable development. One of the guard rails proposed by the WBGU, for instance, is that a global temperature increase of more than 2 °C above pre-industrial levels should be avoided. Beyond that value, a domain of climate change begins that is characterized by non-tolerable developments and risks.

The guard rail approach proceeds from the realization that it is scarcely possible to define a desirable and sustainable future in positive terms, in other words as a specific target or state that should be achieved. It is, however, possible to agree on the boundaries of a domain that is acknowledged to be unacceptable and that society seeks to avoid. Within the guard rails, there are no further requirements at first. Society can develop in the free interplay of forces. Only if a system is on course for collision with a guard rail must measures be taken to prevent it crossing the rail. Compliance with all guard rails does not mean, however, that all socioeconomic abuses and ecological damage will be prevented, as global guard rails cannot take account of all regional and sectoral impacts of global change. Moreover, knowledge is limited and misjudgement is possible. Compliance with guard rails is therefore a necessary criterion for sustainability, but it is not a sufficient one.

The analogy of road traffic may serve to illustrate the guard rail concept. Guard rails have a function similar to that of speed limits, e.g. a limit permitting a maximum of 50 km per hour in built-up areas. The outcome of setting the limit at 40, 50 or 60 km per hour can be determined empirically, but in the final analysis the choice of figure is a normative decision, representing an expedient way to handle a risk collectively. Compliance with the speed limit cannot guarantee that no serious accidents will occur, but it can keep the risk within boundaries accepted by society. The guard rails formulated by the WBGU build upon fundamental norms and principles agreed by the international community in various forms. They can be no more than proposals, however, for the task of defining non-tolerable impacts cannot be left to science alone. Instead, it should be performed – with the support of scientific expertise – as part of a worldwide, democratic decision-making process. For instance, compliance with the climate guard rail (no more than 2 °C global warming) has now been adopted as a recognized goal in the context of the UN Framework Convention on Climate Change (UNFCCC).

Building on earlier reports, the WBGU has applied the concept of guard rails to marine protection in its 2006 report on the oceans (WBGU, 2006). In addition to the climate-protection guard rail, the need for which was substantiated by the ocean report, further guard rails were formulated with regard to the relationship between climate change and the oceans. The full set of guard rails is as follows:

- *Climate protection:* The mean global rise in near-surface air temperature must be limited to a maximum of 2 °C relative to the pre-industrial value while also limiting the rate of temperature change to a maximum of 0.2 °C per decade. The impacts of climatic changes that would arise if these limits were exceeded would also be intolerable for reasons of marine conservation.
- *Marine ecosystems:* At least 20 to 30% of the area of marine ecosystems should be designated for inclusion in an ecologically representative and effectively managed system of protected areas.
- *Sea-level rise:* The absolute sea-level rise should not exceed 1 m in the long term, and the rate of rise should remain below 5 cm per decade at all times. Otherwise there is a high probability that human society and natural ecosystems would suffer non-tolerable damage and loss.
- *Ocean acidification:* In order to prevent disruption of the calcification of marine organisms and the resultant risk of fundamentally altering marine food webs, the following guard rail should be obeyed: the pH value of near-surface waters should not drop more than 0.2 units below the pre-industrial average value in any larger ocean region (nor in the global mean).

need to regulate the use of the oceans. The pivotal question was: Who does the sea belong to and who may use its resources? The Dutch legal philosopher Hugo de Groot (Grotius) propagated the idea of the freedom of the sea (*mare liberum*), according to which all nations had the right to use the oceans. On the other hand, English legal scholar John Selden penned the doctrine of *mare clausum*, which allocated individual rights of use to individual countries. In the 20th century, these fundamental conflicts over territorial boundaries and the appropriation of resources were the principal concerns driving the development of the United Nations Convention on the Law of the Sea (UNCLOS), which was signed in 1982 (Shackelford, 2010). Even today, territorial issues and the related use of resources remain relevant, especially when new types of marine resources open up new areas of business, or when fossil resources in the Arctic come within reach and become available for exploitation.

Current risks to the marine ecosystem are joined by new risks arising from both old and new uses of the seas (fishery, energy production, the use of abiotic resources, etc.). These risks confront marine conservation with unprecedented challenges that lend substance to talk of *mare crisium* (Vidas, 2010), the sea in crisis. It is questionable whether the marine-conservation provisions contained in UNCLOS – which primarily focus on an obligation to cooperate on the part of the states parties – are commensurate with the scale of the marine crisis. UNCLOS does not oblige parties to exercise a "responsibility for the seas" (Vidas, 2010) which would define the content of such a responsibility and specify who specifically is responsible. The aims of a future ocean governance should be to overcome the marine crisis and ensure compliance with planetary boundaries and guardrails (WBGU, 2006, 2011; Rockström et al., 2009; Box 1-1). The extent to which the international law of the sea, as a multilateral treaty, can successfully regulate such a responsibility for the sea in the Anthropocene (Vidas, 2010; Gjerde, 2011) – and provide a suitable framework for a transformation towards sustainable use within the confines of planetary limits – is one of the key questions that this report examines and attempts to answer.

1.1 Use of the oceans

Humans have been using the oceans since very early on in their history. Analyses conducted by Halpern et al. (2008) show that human influence can be proved in all parts of the world's seas and oceans in the meantime. Today, 40% of people live no more than 100km from a coast, and more than 90% of global long-distance merchandise trade travels by sea. The sections that follow discuss the direct uses to which humankind puts the marine environment. The seas provide numerous ecosystem services from which humanity benefits (MA, 2005a), though not all of them are described in detail here. Many ecosystem services and their use depend on the marine biosphere and its innate diversity. Examples include the use of marine organisms for food, to generate power and for medical products. Others include tourism, functions that regulate the climate and interactions with the atmosphere, such as the absorption of CO_2 by the ocean and the production of oxygen (COML, 2011). Some of these uses generate direct economic benefit. The value of others is less easy to measure, but no less important.

1.1.1 The legendary sea and its cultural meanings

Any discussion of the use of the sea by humankind must also address its symbolic and cultural significance. One striking feature here is the lasting ambivalence of the oceans as a source of both inner longing and danger to humanity. Studies of the history of culture and mentalities (Corbin, 1994; Mollat du Jourdin, 1993) show that, for all their long-standing service as a source of food, a means of transport and a convenient place to dump waste, the oceans have primarily been emotionally perceived as a terrifying place and as a source of constant dangers – right up until the modern age. The Bible, for instance, shaped our collective imagination regarding the sea for many centuries. Since little was known about the world's oceans for long periods of human history, they were seen as a weapon of divine retribution and a constant source of potential disaster. They evoked the sinfulness of humankind and symbolized the possibility of universal chaos. Coastal areas and the *limes* between sea and sky on the distant horizon appeared as places of tension from which humans sought to escape, as hastily as possible, back to *terra firma*. Mediterranean, Celtic, Scandinavian, Slavic and Germanic myths alike are suffused with the fear of storms, floods, fog, sea monsters and shipwrecks (as are extra-European ones). Dying at see was the greatest fear of all: the corpse may never be found, and the departed spirit may be condemned to aimless, eternal wandering and be refused resurrection. Mollat du Jourdin (1993:248) assumes that is why "seafarers' religious convictions endured for so long". All kinds of taboos and superstitious practices were associated with the sea, which was perceived as a source of omens and evil premonitions. Its sheer boundlessness was a principal source of fear: "Defying space and time, the sea, with its permanence and endless expanse, surpasses the fleeting generations of a humanity that is tied to a limited space." However, "it challenges the constancy of the continents with its erratic moods, facing down human industry with a wall of strict silence. The sea forces humankind to give itself over to her completely, for she is the sovereign ruler" (Mollat du Jourdin, 1993:241).

Modern humanity has been loath to subject itself to such coercion. Once human worldviews and cosmologies had been secularized and were being examined from a scientific perspective, and new aesthetic interpretations had been developed, in the modern era seas and oceans were seen as marvels to be wondered at, as media for discovering the world. This has given rise to a "yearning for the sea" (Corbin, 1994). Fear of the elemental, untameable might of the oceans has been supplanted by a dream of happiness, materialized in an island of bliss, and by a sublimated projection of the concept of risk symbolized in the notion of 'setting sail'. De facto, the terrors of the sea are still there, but they are giving way to a fascination with, and objectivization of, any possible threats under the influence of developments in nautical technology, coastal fortifications and the system of international shipping. The emergence of modern nation states and economies was greatly expedited by the first wave of globalization (the 'Age of Discovery'), which took place on the world's oceans. International relations, international law and free world trade developed on this basis. Ships' loading capacity grew, as did their speed and safety (thanks to hull cladding, for example). Seafarers were now safer, thanks to improved hygiene, supplies of drinking water and medical care.

The sea thus took on a social and cultural role and actually became fashionable. Populations that lived near the sea discovered coastal areas and harbours as places they liked to visit for both aesthetic and utilitarian reasons. The 19th century saw the beginnings of beach tourism and peacetime sailing in the form of leisure cruises and boat races, and in the course of the 20th century both pursuits evolved from being the privilege of the aristocracy and the upper classes to become an egalitarian consumer good. It was during this phase that the various ways of using the sea as a common resource discussed in detail in this report gradually emerged and led to the degradation of the marine environment, primarily as a result of overfishing and waste dumping.

Resistance to this degradation began surprisingly early. As far back as the 1860s, the great French historian Jules Michelet sketched a systemic view of the overuse of the sea in his unusual book 'The Sea', even though he had never embarked on a sea journey of any real length. "The extermination of a single species can constitute a fatal intervention into the order, the harmony of the whole" (Michelet, 2006[1861]: 241). While humanity was losing its fear of the sea and becoming veritably cocky and arrogant towards the seas, Michelet's visionary perception allowed him to see the danger ahead – from the destruction of coastal fauna to the disappearance of amphibian mammals and the extermination of the whales, for example – and he advocated a holistic view of nature and culture. It was in this period that the (now inadequate) global and national rules governing the use and conservation of the seas were first negotiated and established (see the in-depth discussion in Chapter 3). Michelet anticipated them as follows: "The great nations [he was thinking of France, England and the USA] must reach an agreement and replace this chaotic state with a civilized state, in which reasoning man no longer squanders his own resources and does himself no further harm (…). The old, specialized rules of coastal fishing have become unusable in modern seafaring. A common code of the nations, applicable to all seas and oceans, is required – a code which defines not merely relations between humans, but also the relationship between humans and the animal kingdom" (Michelet, 2006[1861]: 242f.). Born of a cultural history of the sea that stayed close to the tenets of nature, it was not until the 1950s that more detail was added to this sketched outline of a global respect for the oceans.

Today, the cultural perception of the sea is dominated by icons, narratives and experiences relating to tourism. Examples include leisure cruises, sailing trips, holidays on the beach, (the battle for and against) nature conservation areas, diving, island life, whale watching, burials at sea, extreme sports, etc. Another aspect is the symbolic interpretation of seafood as a global source of nutrition with cultural variations: fish (e.g. the sushi craze outside of Japan), galley cuisine, frozen products for fast foods, and so on. Awareness of locally differentiated threat scenarios is likewise spreading; one example is the rising sea level, which is of particular importance to island and coastal dwellers (AOSIS, 2013). Coastal landscapes are special symbolic spaces created by socioprofessional milieus with a solid or more dubious reputation (fishermen, traders, seamen, pirates, smugglers, etc.). Coastlines and islands are changed in both their physiognomic attributes and their symbolism by the forces of the sea. Scientific oceanology, too, indirectly picks up the mythical themes of the sea: fantasy creatures, deities (Poseidon, Neptune), sea monsters, piracy, high and low tides (the lunar rhythm), getting lost and making discoveries, sunken treasures, messages in bottles, the wind and the waves, Christian seafaring. All these aspects are peddled in an assortment of literary and visual narratives: in seamen's language, high-end fiction (Herman Melville, Moby Dick), film and photography, popular music (shanties, global hits like *La Paloma*) and also in art. These products of popular mass culture and advanced civilization form a kind of global maritime knowledge that is of significance in relation to political decisions as well as sociocultural preferences.

Yet the oceans also constitute cultural spaces of their own, as elaborated – in paradigmatic fashion – by Paul Gilroy's *Black Atlantic* (1993), for example. Drawing on the biographies of numerous Afro-American intellectuals (such as W.E.B. Du Bois, Olaudah Equiano and Richard Wright) and musicians (such as Jimi Hendrix), Gilroy tells the cultural history of the Black Atlantic Diaspora: the history of people and cultural practices that are neither purely African nor American nor European. Rather, they represent something that only emerged as a result of exchange and transfer (in some cases brutally forced by slavery) between these cultural regions that surround the Atlantic. The same is true of southern Europe's 'Mediterranean culture', which is said to possess some shared distinctiveness beyond the national peculiarities of the Mediterranean countries. This otherness serves as a narrative that gives the southern European region a collective identity onto which northern Europeans project their own yearnings (e.g. for 'Mediterranean flair'; Leggewie, 2012).

At least in a neo-mercantile sense, the countries of the European Union form one of the biggest maritime powers in the world. Even though their naval fleets have long-since ceased to rule the waves, their merchant and fishing fleets remain one of the cornerstones of economic globalization, and European consumers remove a substantial proportion of the ocean's food and raw-material resources. The Europeans possess long coastal strips on the Baltic and the North Sea, the Atlantic, the Mediterranean and the Black Sea. Elementary tasks of marine conservation need to be addressed in these places due to the consequences of tourism, discharges from agricultural and industrial uses and offshore drilling.

For diplomat and poet Alexis Léger, alias Saint-John Perse, the ocean was a question that posed itself to the "great unifiers of peaceable peoples! The sea, which forges links and alliances!" (Mollat du Jourdin, 1993). It was from this understanding that the notion of the common heritage of mankind grew. The majority of Europeans are not very aware of this, and this is also true of the German public and the political elites, neither of whom are more than vaguely aware of how directly and indirectly dependent they are on maritime fields. This is all the more surprising, given that Germany ranks among the leading nations in marine research and that many Germans profess to be friends and lovers of the sea – witness the popularity of coastal and water-sport tourism, journals like *mare* and countless clubs and associations relating directly or indirectly to the sea. This discrepancy also explains the fact that, despite a growing number of consumers who are rethinking their nutritional and shopping habits in relation to marine products and now consult official certifications, the number of German 'change agents' who concern themselves specifically with marine and maritime topics (rather like the 'grassroots' movements seen on land) tends to be lower than in other countries. The same applies to corporate-responsibility activities engaged in by companies.

1.1.2
Food from the sea

Closely linked to its cultural importance is the use of the sea for human sustenance. The seas have traditionally served humankind as a source of food: sea fish and other marine organisms are rich in valuable proteins, vitamins, minerals and fatty acids.

With regard to fishing, Jackson et al. (2001) distinguish between three phases in the human use of marine ecosystems. These three phases are distributed in terms of geography and evolved at different times. The first phase is the early use of coastal-water ecosystems for subsistence purposes involving relatively simple technologies. The second is the colonial phase in which coastal and continental-shelf regions were exploited by colonial powers, who channelled their profits into the nascent market economy. The third is the global phase of intensive and more extensive exploitation of fishing grounds, driven by global consumption patterns and often accompanied by the collapse of fish stocks. Yet even the original forms of ocean use applied hundreds or thousands of years ago were enough to bring significant change to fished populations. Archaeological finds on the Caribbean island of St. Thomas, for instance, point to a sharp decline in the size of the reef fish eaten there between the initial settlement of the island around 1500 BC and 560 BC (Pinnegar and Engelhard, 2007).

Commercially significant fish were already being caught on the continental shelf around North America and Europe centuries ago. Later, this development spread around the globe. Pole-and-line fishing gave way to beam-trawl fishing in the 18th century; and the latter practice was intensified in the 19th century with the deployment of diesel- and steam-powered ships (Jackson et al., 2001). The first steam ships built especially for fishing were deployed in the North Sea in the 1880s – and quadrupled the catches compared to sailing boats (Mackinson, 2001; Pinnegar and Engelhard, 2008). In Australia, too, fishing spread on a large scale along the Great Barrier Reef and the country's subtropical east coast in the mid-19th century. In the first half of the 20th century, Australia then imported its first steam ships, whereupon catches of the most widely fished species quickly declined and, later, collapsed entirely (Klaer, 2004).

Today, the global fishery industry is in a critical state. Despite the increased effort being put into fishing and the fact that hitherto unexploited regions (such as the deep sea) are now also being fished, yields have been stagnating for years. Today, nearly 90% of global stocks are classed as either overfished or completely exhausted (FAO, 2012b: 11; Sections 1.2.2 and 4.1). Growing worldwide demand for fish and seafoods can no longer be satisfied by fisheries alone; it is therefore increasingly being serviced by aquaculture, mostly in inland waterways, but also in coastal regions and in the sea.

Aquaculture has a very long-standing tradition. It was, for example, practised in fish ponds in China as early as 4,000 years ago. As of the 1st to 3rd centuries AD, farmers in China also began to breed fish in rice fields (FAO, 2000). In the course of the 12th and 13th centuries, the construction of pools and dams for breeding freshwater fish spread across large swathes of Europe. When the practice peaked, 25,000 hectares of land in Upper Silesia and 40,000 hectares in France were used for fish farming in freshwater pools (Roberts,

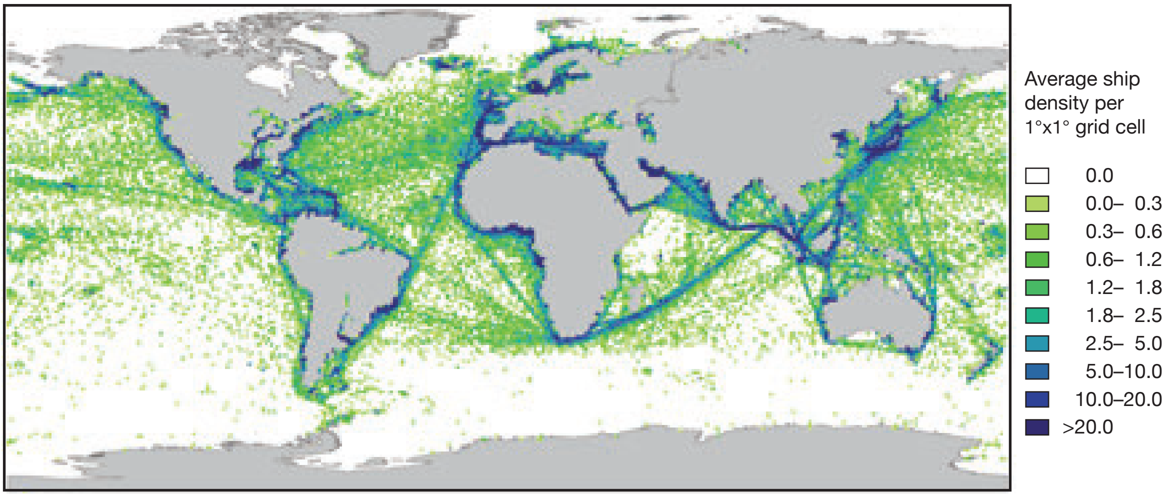


Figure 1.1-1
Average density of global shipping traffic. For each 1x1 grid cell, the figure shows the average number of vessels in the period from November 2009 to January 2010.
Source: Eiden and Goldsmith, 2010

2007:26). It was probably the low-cost development of the teeming marine hunting grounds that ultimately stifled demand for freshwater fish and, towards the end of the Middle Ages, brought freshwater aquaculture to a standstill (Roberts, 2007).

The world's oldest coastal aquaculture farms probably emerged in Egyptian brackish water pools 2,000 or 3,000 years ago. On Java, the farming of milkfish in brackish water dates back 600 to 800 years. The cultivation of algae began around 400 years ago in Japan, shellfish farming about 600 years ago in France. Most other types of coastal aquaculture are relatively young, having emerged only in the latter decades of the 20th century (Edwards and Demaine, 1998).

Since the 1970s, aquaculture (mainly the freshwater variety, but also marine aquaculture) has experienced a very pronounced worldwide upswing in terms of both production volume and economic significance. Today, it is one of the fastest growing branches of the economy, especially in Asia. In 2010 aquaculture already contributed around 47% of global fishery and aquaculture production for human consumption, and the trend is rising (FAO, 2012b:24, 26). Saltwater and brackish-water farming today accounts for approximately 38% of total aquaculture (excluding plants) in volume terms. In marine aquaculture, shellfish farming dominates by far in volume terms (roughly 75%), followed by fish and crustaceans (FAO, 2012b:34, 36; Section 4.2.2.1).

At present, aquaculture is in many cases linked to considerable negative effects on the environment and ecosystems, primarily through pollution, the transmission of diseases and the threat to the gene pool of wild fish stocks (Tacon et al., 2010; Section 4.2.2.3). The farming of carnivorous species continues to be a particular problem, because this branch of aquaculture remains dependent on catches of forage fish, which ultimately exacerbates the overfishing of marine stocks (Naylor and Burke, 2005; Bostock et al., 2010; Section 4.3). However, production systems (such as recycling systems, integrated multitrophic systems and feed substitutes) are being developed to help reduce the negative impact of aquaculture production (Sections 1.3.4, 4.2.2.4, 4.3.3).

1.1.3
Ocean shipping and maritime trade

Humans have also been using the oceans as a means of transport since very early on in their history. While air traffic is increasingly shaping human mobility around the globe, the sea has remained by far the most important means of intercontinental transport for trade in raw materials and freight.

Maritime global trade

Global long-distance merchandise trade is conducted almost exclusively (95%) by sea (Flottenkommando der Marine, 2011:94) and has witnessed forceful growth in recent years. Few ocean regions are still completely devoid of shipping transport (Figure 1.1-1). Container shipping in particular – and especially maritime trade with Asia – has been growing and continues to grow. Oil and petroleum products accounted for 32.7% of all goods traded by sea in 2010. The five most important bulk commodities – iron ore, coal, bauxite, aluminium oxide and phosphate – accounted for 27.7%, while other freight goods made up 23.5% (Figure 1.1-2).

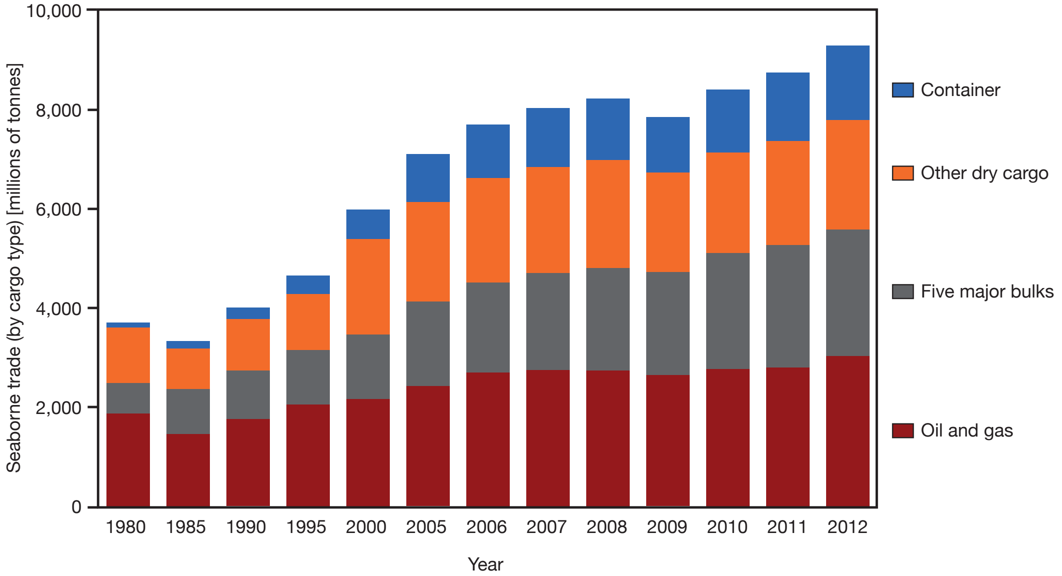


Figure 1.1-2
International seaborne trade. The five most important bulk goods are iron ore, coal, bauxite, aluminium oxide and phosphate.
Source: UNCTAD, 2012

16% of all goods traded by sea were transported in containers in 2010 (UNCTAD, 2011:10). Asia has today become the foremost maritime trading region, followed by America and Europe (UNCTAD, 2011). The volume of international maritime trade quadrupled in the space of 40 years compared to 1968. In 2009 regular (non-chartered) shipping lines alone carried goods worth a total of US$4.5 billion (World Shipping Council, 2012), equivalent to nearly a tenth of global GDP. The transport of oil and bulk materials such as coal and iron ore adds up to a similar amount.

Germany's dependence on maritime trade

About a quarter of the freight transported to Germany comes across the sea. In 2010 the proportion of goods transported to Germany via shipping routes stood at 21.5% in value terms and 25.9% in volume terms. Even though Germany's share of global maritime trade is only 3% (2010), the country has the third-largest merchant fleet in the world (Table 1.1-1), although 85% of the tonnage is shipped under foreign flags (UNCTAD, 2011:11). In terms of the size and capacity of its commercial container fleet, Germany actually ranks number one in the world (Table 1.1-2). That said, about 70% of the world's container-ship capacity is not registered in the country of ownership, but plies its trade under foreign flags (Flottenkommando der Marine, 2011:39).

The leading maritime trading nations, including Germany, register a substantial proportion of their merchant fleet under other flags, in particular those of Malta, the Bahamas, the Marshall Islands, Liberia and Panama.

Container freight and passenger transport

The world's seaborne container freight industry is dominated by a small number of large shipping companies. The 15 biggest container shipping lines control around 67% of the container vessels and 78% of slot capacity (figures valid in early 2011; Flottenkommando der Marine, 2011:35). The biggest container freight company of all is Maersk Line, whose 530-vessel fleet adds up to 2.05 million TEU (Twenty-foot Equivalent Units). The Swiss shipping line MSC occupies second place with 387 vessels and 1.78 million TEU, followed by the French shipping group CMA-CGM (299 vessels and 1.13 million TEU). The two largest German shipping companies, Hapag-Lloyd and Hamburg Süd, rank fifth and twelfth respectively (Flottenkommando der Marine, 2011:35).

Compared to freight transport vessels, maritime passenger transport plays only a minor role. In 2011 only 4,131 out of a total of 47,833 commercial vessels were passenger ships. There are currently around 300 cruise liners in the world, and about 19 million passengers booked cruises in 2011. Since 1990, the cruise industry has posted annual growth rates upward of 7% (Box 1.1-1). Numerous new vessels are currently under construction: by 2014 alone, these new ships will allow the volume of passengers carried to exceed 21 million (Cruisemarketwatch, 2010).

Table 1.1-1
Countries and territories with the largest owned fleets.
dwt = deadweight ton
Source: UNCTAD, 2011:43

Country or territory of ownership	Number of vessels			Deadweight tonnage [million dwt] rounded			Percentage [%]	
	Under national flag	Under foreign flag	Total	Under national flag	Under foreign flag	Total	Under foreign flag	Global tonnage
Greece	758	2,455	3,213	65	138	202	68.05	16.17
Japan	724	3,071	3,795	19	178	197	90.40	15.76
Germany	442	3,356	3,798	17	98	115	85.06	9.17
China	2,044	1,607	3,651	46	62	108	57.20	8.63
South Korea	736	453	1,189	18	29	47	61.78	3.79
USA	971	1,001	1,972	24	22	46	47.46	3.71
Norway	818	1,166	1,984	15	28	43	65.45	3.43
Hong Kong SAR	399	313	712	24	13	37	35.18	2.97
Denmark	383	592	975	14	21	35	60.13	2.81
Taiwan	97	565	662	4	29	33	87.57	2.63
Singapore	659	362	1,021	19	13	32	40.90	2.53
Bermuda	17	268	285	2	28	31	92.48	2.44
Italy	616	220	836	17	7	23	29.03	1.86
UK	366	412	778	9	13	22	60.01	1.78
Turkey	551	648	1,199	8	12	20	60.22	1.58
Russia	1,406	485	1,891	6	14	20	71.55	1.56
Canada	210	226	436	2	17	19	87.06	1.53
India	460	74	534	15	3	18	19.01	1.45

Environmental impact of marine freight transport

Marine freight transport is powered predominantly by diesel engines and accounts for approximately 3% of global greenhouse-gas emissions. According to the International Maritime Organization (IMO), this share could roughly triple between now and 2050 (UNCTAD, 2011:27).

After dipping in the 1990s, global sulphur emissions have recently been climbing again, driven by coal-fired power generation in China, but also by the growth in ocean shipping (Smith et al., 2011). The bulk of the fleet that plies the high seas currently uses heavy fuel oil (HFO) with an extremely high sulphur content of up to 4.5%. By comparison, EU standards prescribe that the diesel fuel used in road transport may contain only 10 ppm, i.e. a sulphur content of 0.001%. At present, the main instrument for reducing sulphur emissions (as well as other forms of pollution caused by shipping) is the MARPOL convention, together with its various protocols (Section 3.3.2.5). This convention aims to reduce sulphur content in heavy fuel oil to 0.5% by 2020 and creates the possibility of reducing it to 0.1% as early as 2015 in some countries.

Furthermore, ballast water facilitates the spread of invasive species of flora and fauna across the often large distances between loading and discharge, in addition to the frequent pollution of the seawater it causes.

Noise pollution, too, has increased sharply parallel to the higher volume of freight transported across the world's oceans. Apart from propeller noise, prospecting for oil and gas (using what are known as air guns) and the widespread use of sonar technology are likewise problematic (IFAW, 2008).

Waste disposal and the discharge of waste water are another growing problem. True, MARPOL standards govern waste disposal and waste-water discharge and define minimum distances from the coast. Yet the volumes involved are considerable and can cause damage, especially in view of the local concentration of emissions in the case of large vessels. For example, a single large cruise liner generates around 160,000 litres of waste water and up to two million litres of service water

Table 1.1-2
The ten biggest container-ship owners (by nationality).
TEU = twenty-foot equivalent unit
Source: Flottenkommando der Marine, 2011

Countries	Under national flag		Under foreign flag		Total	
	Number	[1,000 TEU]	Number	[1,000 TEU]	Number	[1,000 TEU]
Germany	291	1,205	1,485	3,603	1,776	4,808
Japan	2	9	320	1,187	322	1,197
Denmark	89	499	135	512	224	1,010
PR China	184	415	148	354	332	770
Greece	31	178	180	549	211	727
Taiwan	26	52	157	504	183	556
France	24	159	77	350	101	509
South Korea	69	63	65	293	134	356
UK	31	151	38	203	69	355
Singapore	128	276	28	69	156	345
Global total	**1,309**	**3,686**	**3,050**	**8,700**	**4,845**	**14,066**
of which EU 27	525	2,260	1,985	5,363	2,510	7,623

per day, most of which is simply discharged into the sea untreated. On cruise liners, marine sanitation devices (MSDs) are most frequently used for waste water fed into the sea near coasts. MSDs grind and disinfect waste water before it is discharged into the sea. A study conducted in 2000 showed that 79 out of 80 Alaska cruise liners investigated did not comply with the environmental standards prescribed by the MSD procedure (Klein, 2009:3). In recent years, the cruise industry has introduced improved technical cleaning systems known as advanced waste-water treatment systems (AWTS). However, these systems also leave a residue of pollutant waste water (mainly from toilets) – primarily the plant nutrients nitrogen and phosphorus (Klein, 2009). This cleaning system is already compulsory for some regions, such as Alaska's Inside Passage. The discharge of service water (shower water, water from washing machines, etc.), which accounts for the largest volume disposed of by cruise liners, is largely unregulated.

1.1.4 The sea as a dump for waste and waste water

Consciously or subconsciously, humankind has long used the sea as a dump for waste, sewage and toxic substances of all kinds. It has become a sink for all kinds of often harmful substances which find their way into the sea, having been fed into rivers or the groundwater, dumped by ships (Section 1.1.3) or drilling platforms, flushed out of aquaculture farms, absorbed from the atmosphere, discharged from land, or leaked in the course of oil extraction (Section 1.1.5). For a long time, waste constituted humankind's most pronounced interference with the deep sea, because its inaccessibility kept it safe from direct intervention. However, this impact has since been surpassed by the powerful influence of fisheries and the extraction of fossil fuels and minerals, and in the future even this could be overtaken by the consequences of climate change and CO_2 absorbed by the sea from the atmosphere (Section 1.2.5; COML, 2011).

A large proportion of the inputs that find their way from the land into the sea originate from agricultural and industrial production or from household and municipal sewage. The substances involved include nutrients, pesticides, heavy metals, toxic substances used in industrial production, as well as plastic and other waste. Radioactive inputs and dumping are two further sources. Coastal regions are worst affected by pollution and its consequences, because the concentration of substances is greatest here. At the same time, unpopulated regions far removed from urban centres – places such as the Arctic and the deep sea itself – are also under threat from pollution caused for example by plastic waste and toxic substances.

The following section quotes a number of examples and cites the volumes involved to illustrate the scale of substance input to the seas. The impact of pollution and the associated threat to the environment and humankind are described in detail in Sections 1.2.3 and 4.4.4.

Box 1.1-1

Coastal and marine tourism

Today, tourism is one of the world's largest branches of industry, and tourism in coastal regions (for bathing and beach holidays) has traditionally played an important role (Miller, 1993; Hall, 2001). In recent years, marine tourism (deep-sea diving and fishing, boating and sailing and, in particular, leisure cruising) has also considerably gained in popularity (Hall, 2001). Given the growing prosperity in many developing and newly industrializing countries and the associated formation of middle classes within these societies, it is to be expected that the trend towards global growth in tourism will continue, also driving an expansion in maritime tourism.

Although it is generally assumed that coastal and maritime tourism have a significant impact on the environment, factual knowledge of the subject is extremely fragmented and so far relates only to the impact on specific regions or certain species (Hall, 2001). To give examples of the direct environmental impact of tourism activities, Hall cites mangrove deforestation; the destruction of coral reefs by diving, snorkelling and 'reef walking'; large-scale coral extraction for use in souvenirs or jewellery; and the production of cement for hotels and airports on reef islands. Indirect consequences, which cannot be attributed exclusively to tourism, include increases in nutrient and waste-water discharges and the worsening problem of waste in coastal areas (Hall, 2001). In nautical tourism the main damage is caused by anchors. In addition, the environmental consequences of the fast-growing leisure-cruise segment are also significant. While cruising was long regarded as a luxury reserved for the elite, the industry has been expanding worldwide since the early 1990s and today constitutes a form of mass tourism. Some observers therefore also speak of the "McDonaldization" of cruise tourism (Weaver, 2005), a phenomenon associated with a substantial environmental impact and new requirements for regulation.

Nutrients from agriculture

Inorganic fertilizers have been manufactured on an industrial scale as plant nutrients for use in agriculture since the late 1940s (Mackenzie et al., 2002) and have been used in increasing volumes ever since. The anthropogenic production of reactive nitrogen has increased tenfold since industrialization (from approximately 15 to approximately 156 Mt N per year); today it actually exceeds natural flows. Its use is expected to increase even further to approximately 267 Mt N per year by 2050 (Galloway et al., 2004; Bouwman et al., 2009). A significant proportion of these nutrients end up in inland waterways and coastal regions. As a result, marine inputs of phosphorus have risen from an estimated 1.1 Mt per year in the 'pre-agricultural' age to approximately 9 Mt per year today (Rockström et al., 2009). These inputs can lead to increased algae growth and eutrophication, plus a growing lack of oxygen and damage to local ecosystems (Sections 1.2.6 and 4.4.3).

POPs and heavy metals as examples of chemical pollutants

Chemical pollutants that find their way into the sea include heavy metals such as lead, mercury and cadmium, and what are known as persistent organic pollutants (POPs). The latter include the insecticide DDT, the polychlorinated biphenyls (PCBs) that used to be used in industry, and polyfluorinated compounds (PFCs). Some of these substances were, and still are, manufactured for agricultural or industrial use, others are created as by-products of certain industrial and combustion processes. Heavy metals, on the other hand, are also specifically extracted or used in the mining of other metals (WHO, 2007a). It is still difficult to trace the sources and emissions of POPs globally, because production and usage data are often confidential or not regularly recorded. However, several global and, above all, regional emissions registers have now been set up (Lohmann et al., 2007). Data series for the EU and studies of marine organisms show a decline in POP inputs (Islam and Tanaka, 2004; Denier van der Gon et al., 2005; Lohmann et al., 2007) and heavy metals into the sea – e.g. in parts of the North Atlantic (OSPAR, 2010b). The primary threats posed by POPs and heavy metals are that their accumulation in the food chain can harm marine fauna and, ultimately, human health too (Sections 1.2.3.1 and 4.4.4).

Plastic waste and microplastics

Global plastic production has increased more than a hundredfold since the 1950s and today stands at over 280 million tonnes a year, of which about 20% is manufactured in the EU (Figure 1.1-3). On average, global production of plastic increases by about 9% per annum (PlasticsEurope, 2012). Disposable packaging accounts for a large proportion of production (about 38% in Europe; UNEP, 2011c).

Every year, large quantities of plastic waste find their way into the sea, although the exact amounts are difficult to quantify. The vast majority comes from land-based sources such as rivers and beaches (Andrady, 2011:1597; Cole et al., 2011). Marine-based sources include shipping traffic and drilling platforms. The total volume of plastic waste in the ocean is currently estimated at approximately 100 million tonnes (UNEP, 2011c). Little is known about the lifespan of plastics in marine environments. Estimates assume a period of several hundred years (UNEP, 2011c). Ultraviolet (UV) radiation, mechanical and biological processes can break down larger pieces of plastic into microplastics, and the latter are also specifically manufactured as an industrial material (granules) and can find their way into the sea from production centres or during transportation (UNEP, 2011c; Cole et al., 2011). Larger pieces of plastic and microplastics pose a serious threat to the marine environment and marine organisms (Section 1.2.3.2; 4.4.4).

Radioactive substances

Anthropogenic radioactive substances have been finding their way into the environment since the 1940s and, because of the ratio of land to sea on our planet, usually end up in the sea (Aarkrog, 2003; Sections 1.2.3.3 and 4.4.4). The largest source is the global radioactive fallout from tests of nuclear weapons conducted in the Earth's atmosphere (mainly in the 1950s and 1960s); their effects are still measurable today (UNSCEAR, 2000). The 1986 Chernobyl reactor accident is a further major source (Aarkrog, 2003), although the Fukushima accident in Japan in 2011 surpasses the effects of Chernobyl on the sea (Buesseler et al., 2011). The fourth major source is the – still legal – practice of feeding radioactive waste water into the sea from nuclear fuel-reprocessing plants (Livingston and Povinec, 2000). Other anthropogenic sources, such as the dumping of radioactive waste and smaller accidents at nuclear power stations, can have a local or regional impact, but play a less important role on a global scale (Aarkrog, 2003). However, the radioactive substances (like other pollutants too) can be quickly spread around the world by ocean currents (AMAP, 2010).

1.1.5
Energy from the sea

The extraction of fossil energy carriers from the sea has grown in importance over the years. Still negligible as late as the mid-20th century (Priest, 2007), offshore extraction accounted for 37% of the world's oil extraction and 27% of its natural-gas extraction in 2007 (BGR, 2009: 44, 80). For both oil and gas there is a noticeable trend towards more offshore extraction compared to extraction on land. Offshore natural-gas extraction, for example, increased its share of gas production by 20% between 2001 and 2007 alone (BGR, 2009). Reserves are defined as deposits that can be quantified with great accuracy and extracted at any time today without technical or economic problems – and about 26% (of oil reserves) or a third (of natural-gas reserves) are situated offshore. New technologies are increasingly making it possible to tap oil wells and

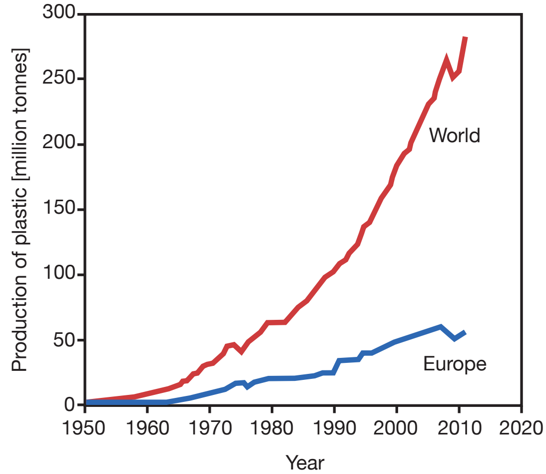


Figure 1.1-3
Global production of plastics. The figures include thermoplastic polymers, polyurethanes, elastomers, adhesives, coatings, sealants and polyproylene (PP) fibres. They do not include PET, PA and polyacrylics.
Source: based on PlasticsEurope, 2012

gas fields in ever deeper waters. In the Gulf of Mexico, for example, offshore oil production was in decline in 2003. Not until it became possible to extract oil at depths of more than 1,500 m was this trend reversed (Kerr, 2012). Technologies are now also being developed that enable oil and gas to be extracted in ice-covered waters.

However, the international public has also become aware of the dangers involved in this form of extraction – at the latest since the Deepwater Horizon oil rig exploded in the Gulf of Mexico in April 2010, spilling 4.4 million barrels of oil into the sea (according to estimates by Crone and Tolstoy, 2010).

A study by the US National Academy of Science (Committee on Oil in the Sea, 2003) came to the conclusion (albeit before the above-mentioned disaster) that only about 5% of anthropogenic oil input into the oceans worldwide is caused by prospecting for and extracting oil, while as much as 22% is attributable to oil transport. By far the biggest share of anthropogenic oil inputs into the sea – 70% – is caused by the *use* of oil, i.e. by ships, cars or the run-off from land (from increasingly sealed urban spaces, for example). Yet although prospecting, extraction and transport account for only a small proportion of oil inputs, they cannot be neglected, as they still have the potential to cause significant damage because of the concentrated volumes involved. By contrast, inputs from the use of oil tend to be continuous and are usually distributed over wide areas. In addition, a volume of oil comparable to that which comes from anthropogenic sources seeps naturally into the oceans from sources on the seabed. It is in the nature of things that this seepage often occurs in regions where oil is extracted, because the oil deposits are located there, and this makes it difficult to unambiguously identify the causes in some cases.

Alongside oil and conventional natural gas, the sea also contains deposits of gas hydrates, i.e. ice-like solid-state compounds of water and methane gas. Similar to terrestrial gas hydrates in permafrost regions, marine methane hydrates occur at low temperatures and under high pressure. In the sea, they are found at depths in excess of 400m, usually on the edges of continental slopes. Identifying the dimensions of deposits is difficult: current estimates vary between 500 and 3,000 Gt of carbon (WBGU, 2006), i.e. up to 300 times the current annual fossil carbon emissions. Deposits have been confirmed off the coast of the USA, Canada, Russia, Japan and some countries in Central America and West Africa. Further deposits are suspected off the coasts of India, China, the Philippines, South Africa, Australia, New Zealand and various South American countries (Tréhu et al., 2006). Japan, India, China, Canada and the USA are researching ways to extract marine gas hydrates for commercial use. If it became possible to do so for marine methane hydrates, available fossil-energy resources will increase considerably and the transition to an energy system based on renewable energy sources will probably be further delayed. Moreover, it must be assumed that, as with the spreading commercial extraction of shale oil and shale gas, more countries than in the past will be able to satisfy their demand for gas from their own resources and will no longer be dependent on imports. However, a shift in demand for gas and in gas trade flows as a result of the extraction of marine methane hydrates – as the International Energy Agency (IEA) already expects as a result of the exploration of shale gas – will very probably have implications that are difficult to foresee but that could alter the conditions determining international climate policy.

The seabed is increasingly attracting attention as a dump for unwanted substances left over from the extraction of fossil energy carriers. Since as far back as 1996, the Norwegian Statoil group has been injecting about a million tonnes of CO_2 a year into a sandstone formation 800 to 1,000m below the seabed (WBGU, 2006:86; Schrag, 2009). The CO_2 in question is generated locally in the process of offshore gas extraction, so it is not specially transported to this storage area. Due to public opposition to carbon capture and storage (CCS) projects on land, even the offshore storage of terrestrial CO_2 close to heavily populated coastal areas appears attractive (Schrag, 2009). Up to now, however, there is no experience with storing a flow of CO_2 as large as would be generated by CO_2 capture in power plants. Nor have the dangers of leakage from the stores been sufficiently clarified.

Renewable energy sources from the sea are of a much more recent vintage than the use of fossil energy carriers from the sea. Ocean energy in the narrower sense includes technologies to use the water's kinetic energy, temperature gradients and salt concentration gradients. Although some of the basic principles have been known for decades or even centuries, technological development did not begin to make progress until the 1970s (Lewis et al., 2011). With the exception of tidal power plants, these technologies are still at the development or demonstration phase. At the end of 2009, installed capacity barely reached 300 MW (Lewis et al., 2011). Accordingly, ocean energy tends to be regarded more as a long-term option in the energy system. Offshore wind power is likewise a relatively new application. At year-end 2009, a mere 1.3% of global wind-power generation capacity was installed offshore (Lewis et al., 2011). However, renewable energy from the sea has the potential to make a sustainable contribution to a global energy transformation towards sustainability (Section 1.3.1 and Chapter 5).

1.1.6
Marine mining and resource extraction

Marine mining refers to the extraction of marine mineral resources as opposed to the production of oil and gas (Scholz, 2011:72). It includes the extraction of sand, gravel and salt. Shallow shelf and beach regions are used primarily to extract diamonds, tin, titanium and gold. On a localized scale, coral extraction and pearl harvesting is also significant in the coastal zones. Massive sulphides and sulphide sludges are extracted from the deep sea and phosphorites from shelf edges. Manganese nodules and gas hydrates have also recently been prospected in the deep sea (Section 1.3.2). Extracting these resources can, in some cases, cause considerable damage to the environment, e.g. by destroying natural habitats and the seabed itself (ICES, 2000; Sutton and Boyd, 2009).

Sand and gravel

Of all marine mineral resources, the ocean sediments sand and gravel are extracted in the highest volumes (Rona, 2008:632). Extracting sand and gravel from the sea is economically attractive because quarrying comparable amounts on land would be significantly more expensive (Scholz, 2011). Beaches are the most important source of sand. Sand and gravel can be used universally, for example in the construction industry (concrete), to fortify beaches or for coastal protection. In 2000 marine sand and gravel extraction had a market value of around US$3,000 million at a price of US$15 per tonne (Rona, 2008:632). Industrial-scale extraction of sand and gravel began in the 1960s and has increased since then (ICES, 2012a:6).

Two forms of suction-dredging are used to extract marine sediment, and each has different effects on the environment (von Nordheim and Boedeker, 1998:22). Stationary dredging creates holes up to 10m deep and between 10 and 50m in diameter. This causes long-term, in some cases permanent changes to the marine environment. Dragline dredging uses suction to remove the sediment from the seabed over a flat plane and covers much larger areas. The resultant furrows are approximately 30cm deep and 2m wide. In this case, regeneration is much faster than in the case of stationary dredging (von Nordheim and Boedeker, 1998:22). Numerous studies have examined the consequences of sand and gravel extraction for benthic fauna. Studies of places where extraction is pursued intensively, e.g. off the UK coast, reveal disruptions to the seabed and to resettlement by seabed fauna even 4 to 6 years later (Boyd and Banzhaf, 2005; Costello et al., 2008; Foden et al., 2010). The extraction of sand and gravel also has external effects on fishery by increasing the mortality of eggs and larvae due to sediment disturbances, and this ultimately leads to diminished catches (Kim and Grigalunas, 2009; Stelzenmüller et al., 2010).

Diamonds, gold and other minerals

The mineral raw materials found in the sea often contain a large proportion of precious metals, which makes them a coveted resource. Seabed mineral extraction concentrates on diamond mining off the coasts of South Africa and Namibia, and on tin, titanium and gold mining along the coasts of Africa, Asia and South America (Maribus, 2010). The shelf edges also have deposits of phosphorite, which is extracted for use in fertilizer production. There are also sulphide ore sludges, whose main components are iron, copper, zinc and manganese, as well as massive sulphides, which have formed as crusts on the seabed. Massive sulphides contain mostly copper and zinc, as well as smaller quantities of technical metals such as indium, geranium, bismuth, selenium and tellurium (Scholz, 2011:73). The extraction of massive sulphides is almost ready for commercial realization (Section 1.3.2).

Coral

Coral is used in many and varied ways, including the production of lime, mortar and cement for local construction activities. Lime and coral granules are used as fertilizers in agriculture. Coral is also used to make jewellery and is traded as aquarium decorations (Clifton et al., 2010; Moberg and Folke, 1999). Extracting coral to produce jewellery has caused severe damage to, and even destroyed, coral ecosystems, for example in the Philippines, the Indian Ocean and Indonesia (Charles, 2005; Kumara et al., 2005).

Coral extraction (primarily) for building materials is concentrated in tropical coastal regions, especially in South and Southeast Asia, the Pacific region and East Africa. In these areas it is one of the main causes of reef destruction. In addition, the use of coral (soft coral, for example) for pharmaceutical purposes is a promising approach, since many species of coral produce chemicals to protect themselves (Box 1.2-4; Section 1.3.3).

Oil and gas reserves are also suspected beneath old coral reefs, and the potential extraction of these resources would pose a serious threat to the sensitive coral. Not enough research has yet been conducted into the impact of coral extraction on the marine environment (Caras and Pasternak, 2009). However, local studies indicate that reef ecosystems change significantly after such interventions (Guzmán et al., 2003) and are scarcely able to recover, especially where there are additional pressures such as overfertilization and overfishing (Box 1.2-4). To take an example: 974,000 m^3 of coral was extracted from the lagoon around Moorea (French Polynesia) between 1968 and 1987 to build the island's main road. This caused serious and lasting damage to the coral reefs. Today, coral extraction is prohibited in Moorea (Charles, 2005:46). The destruction of coral reefs can have far-reaching consequences. On Bali, for example, where coral was extracted on a small scale to produce lime, the coral cover was found to have receded substantially, causing a dramatic worsening of coastal erosion (Caras and Pasternak, 2009). On the Maldives Islands, coral extraction for the construction industry led to a drastic reduction in fish stocks and the number of fish species (Clifton et al., 2010). For this reason, coral extraction is now banned in many countries, although such prohibitions have been unable to stamp out the practice everywhere. Yet some success has been achieved – in India, for example – in reducing illegal coral extraction (Wilkinson, 2008). Even so, a study in Indonesia's Wakatobi National Park shows that the reef has still not fully recovered in terms of its biodiversity and the proportion of living coral even 20 years after intensive coral extraction was stopped (Caras and Pasternak, 2009).

Sea salt

Large quantities of salt are produced in salt-evaporation ponds and, above all, in desalination plants. Feeding seawater into artificial 'salt pans' is a method that has been used for many centuries to extract salt by evaporation in coastal regions. Compared to salt mines, this is a relatively ecofriendly way of producing salt. Salt is produced all around the Mediterranean (in France, Spain, Portugal and Italy), but also in the coastal regions of the Black Sea, Africa, India and China. It is estimated that 30% of the world's salt production (2009: 260 million tonnes; Lohmann, 2012: 149) is derived from seawater and salt ponds (K+S, 2013). Desalination not only produces salt, it also purifies freshwater for use in irrigation and as drinking water. Seawater is also used to cool power plants.

1.1.7 The economic value of marine ecosystems

It is difficult to calculate the economic value of marine and coastal ecosystems. To date, the only study of the overall value of marine ecosystems – whose methodology, it must be said, is extremely controversial – is a paper by scientists who worked with Robert Costanza and is dated 1997. The study put the total value of the global biosphere at around US$33,000 billion per annum (at 1994 prices), of which roughly two thirds, i.e. roughly US$21,000 billion per annum, was accounted for by marine and coastal ecosystems (Costanza et al., 1997). Of this US$21,000 billion, US$8,400 billion was assignable to the oceans and US$12,600 billion to the coastal ecosystems, i.e. to estuaries, seagrass beds and kelp forests, coral reefs and the continental shelf. According to this study, the value of marine and coastal ecosystems was thus equivalent to about 80% of global GDP at the time, which stood at around US$27,000 billion (at 1994 prices; IMF, 2012). Even though these numbers are based on simplified and methodologically debatable calculations, they at least give an idea of the magnitude of the value of marine ecosystem services (UNDP and GEF, 2012a). To this day, scientists assume that marine and coastal ecosystems account for two thirds of the Earth's total natural capital (Beaudoin and Pendleton, 2012).

Calculations such as those conducted by Costanza et al., 1997, also highlight the tremendous methodological challenges that confront attempts to measure the overall economic value of marine and coastal ecosystems, as not all aspects of these ecosystems can usefully be expressed in monetary terms. Examples include the nutrient cycle, the way ecosystems work and genetic resources (Noone et al., 2012). One of the problems with the estimates of Costanza et al. (1997) is that, for want of available studies, not all biomes and not all types of ecosystem services were taken into account in the overall estimate. Moreover, the studies referred to were based on the willingness of the population alive at the time of the survey to pay, while the valuations of future generations were disregarded entirely. The findings of these studies were linearly extrapolated to the global level, which caused inaccuracies. Nor were tipping points or irreversible issues factored into the study. Lastly, it also added together different subtotals – a practice that does not do justice to the complex interdependencies between different biomes and ecosystem services.

More recent studies have attempted to improve on the weaknesses of Costanza et al. (1997). To date, however, there is no topical, comprehensive evaluation of the global marine and coastal ecosystem services that also takes account of interdependencies between the different ecosystems. Few studies have yet concerned themselves with the value of marine ecosystems, and of those that do, even fewer examine deep-sea ecosystems (Naber et al., 2008). Evaluation studies exist for individual ecosystem services or biomes, especially for coral reefs, coastal ecosystems and mangroves (TEEB, 2009; Beaudoin and Pendleton, 2012). For instance, TEEB (2009), working on the basis of various studies, puts the value of coral reefs as high as US$1.2 million per hectare per annum. Another example is a UNEP study of the annual value of the ecosystems in the Mediterranean, whose minimum estimate came to €26 billion for 2005. This figure includes the provision of food, recreational uses, climate regulation, the regulation of natural hazards and waste assimilation (UNEP-WCMC, 2011). All these studies underscore the considerable economic importance of marine and coastal ecosystems.

1.2 Threats to the oceans

The direct and indirect use of the oceans has already led to profound changes that greatly impact on the ocean ecosystem and the ecosystem services used by humanity. Moreover, trends show in many cases that the threat to the oceans caused by human activity is still growing.

1.2.1 Physical destruction of ecosystems

The most striking forms of human interference with marine ecosystems relate to the physical destruction of habitats, above all in coastal areas. The factors driving this destruction include tourism, the expansion of urban infrastructure, shrimp aquacultures, and the development of ports and the dredging this involves (CBD, 2010c). According to estimates by the FAO, approximately one fifth of the world's mangroves were

Box 1.2-1

Economic losses caused by the conversion of mangroves for shrimp aquaculture in Thailand

Since 1961 Thailand has lost about 50–60% of the mangroves that originally grew in its coastal areas as a result of conversion. About 50–65% of these conversions relate to the development of shrimp farms (Hanley and Barbier, 2009). Mangroves serve primarily as a nursery and breeding ground for fish, as well as providing natural coastal and storm protection. Furthermore, they are often used as a source of firewood, resin and small crabs and crustaceans (see also Box 4.3-4).

A comparison of the utility value of shrimp farms with that of mangroves in the period from 1996 to 2004 shows that the annual value of mangroves exceeds that of shrimp farms by an estimated US$10,000 per hectare (at 1996 prices). The high utility value of mangroves is primarily explained by their importance for storm protection. Even the net benefit over the same period of restoring degraded mangroves whose use has been changed is between US$1,300 and US$3,000 – which is higher than their value when used for shrimp farms, which is around US$1,000 to US$1,200 per hectare (Hanley and Barbier, 2009).

However, this does not mean that every conversion of mangrove forests leads to economic losses. Nonlinearities must also be taken into account when calculating the value of ecosystem services. For example, it is generally assumed that the value of mangroves for storm protection is particularly high in the first 100m by which the mangroves extend into the sea, after which their value declines. After carefully weighing up the costs and benefits, it can therefore be entirely justifiable from an economic point of view to allow those parts of the mangrove forests that are less important for storm protection to be used for shrimp farms (Hanley and Barbier, 2009; UNEP-WCMC, 2011).

However, an overall evaluation of the benefits is often made more difficult by the fact that ecosystems are mutually dependent on each other. For example, mangrove forests also fulfil an important function for coral reefs, especially that of filtering out terrigenous sediment and nutrient load. These externalities are usually ignored in cost-benefit analyses. As a result, the calculation of the benefit – and similarly the calculation of the damage – usually only indicates a minimum value.

lost between 1980 and 2005. Seagrass meadows and salt marshes are also seriously affected: in total, a third of seagrass meadows and a quarter of salt marshes have been lost. The 'Census of Marine Life' concludes that humanity has destroyed a total of 65% of seagrass meadows and coastal wetlands over the centuries (COML, 2011). Even more seriously endangered are shellfish reefs, for example an estimated 85% of oyster reefs have been destroyed worldwide (CBD, 2010c). The most prominent example of the loss of coastal ecosystems is certainly tropical coral reefs, 20% of which have been destroyed and a further 20% degraded over the past centuries (MA, 2005a: 515). According to Burke et al. (2012), 60% of the world's coral reefs are now directly at risk from local stress factors such as overfishing, destructive fishing methods, pollution and physical destruction. Also important are global factors such as rising ocean temperatures (Section 1.2.4), which make reefs more vulnerable. Although tropical coral reefs cover only 1.2% of the world's continental shelves, they are important for around 25% of ocean fish species (CBD, 2010c) and are home to around a quarter of all marine species (see also Box 1.2-4).

Specific ecosystem services can have considerable value, especially compared to the benefits of converting ecosystems – as shown by the conversion of mangroves in Thailand (Box 1.2-1). Especially in the least developed countries, environmental and natural capital comprise approximately 36% of total assets (World Bank, 2012a). Destroying this capital robs these countries of a significant part of their resources.

Less well known is the direct damage humanity causes to deep-sea ecosystems, such as seamounts and cold-water corals, which have only become accessible more recently as a result of modern fishing methods. Bottom trawling in particular can have a disastrous impact here, comparable with that of tropical deforestation (CBD, 2010c; Section 4.1.2.3). Puig et al. (2012) demonstrate that bottom trawls cause large-scale changes to the morphology of continental slopes, similar to the influence of agricultural ploughing on land. Data on the high seas is much more limited than on coastal regions. As easily accessed areas become overfished, fishing shifts more and more to areas that are more difficult to access (Section 4.1.1) and increasing destruction can be expected here. Increasing oil and gas exploration similarly has an impact, and marine mining is also likely to have a negative effect in the future (Smith et al., 2008: Section 1.3.2).

Conservation of marine ecosystems is still very underdeveloped compared to the conservation of terrestrial ecosystems. Marine protected areas (MPAs) cover only 1.6% of the world's oceans in total (Bertzky et al., 2012). To date, conservation efforts have concentrated strongly on the continental shelves; in area terms, MPAs cover 4% of countries' exclusive economic zones (EEZs) and 7.2% of coastal waters (Bertzky et al., 2012). In 2010, though, the first network of protected areas on the high seas was set up, located in the North Atlantic (O'Leary et al., 2011). This means that the current level of protection still falls far short of the target agreed at the 10th Conference of the Parties

Box 1.2-2

Blue Carbon

The term 'blue carbon' is used in the context of international climate policy to mean the carbon captured by plants and soils in marine and coastal ecosystems (Nellemann et al., 2009). The main discussion is about the recognition of climate-protection measures that are related to these ecosystems – i.e. measures aimed at avoiding the destruction and degradation of ecosystems and the related CO_2 emissions, or at protecting the ecosystems and thus retaining their function as 'sinks'. Less frequently discussed are measures for managing ecosystems so they can absorb as much CO_2 as possible.

Blue carbon – sources, sinks, reservoirs

The debate about blue carbon usually looks at just a few selected coastal ecosystems, their carbon reserves and their function as a CO_2 sink or source. The ecosystems included in this context are mangrove forests, sea-grass meadows, salt marshes, and very occasionally kelp (i.e. brown algae). Coral reefs are usually excluded, perhaps because they represent more of a CO_2 source than a sink for the atmosphere over time periods that are relevant for human society (Laffoley and Grimsditch, 2009).

Coastal ecosystems function as CO_2 sinks when the volume of carbon that is transformed into organic material by photosynthesis – and ultimately absorbed and stored by the soil in the long term as organic carbon (sedimentation) – is greater than the volume of carbon that is released through the leaves or by plant respiration. As with other wetlands, some types of coastal ecosystems can also build up large local carbon sinks in the soil (Donato et al., 2011) and offer a greater 'sink capacity' per unit of surface area than terrestrial ecosystems. However, due to the limited overall surface area of coastal ecosystems, their global significance for the climate is limited.

Duarte et al. (2005) estimate total organic sedimentation in the oceans at 0.22–0.24 Pg of carbon per year, with vegetated coastal habitats contributing about 50% of this (1 Pg of carbon = 1 Gt of carbon). By comparison, global CO_2 emissions from fossil sources currently (2010) correspond to more than 9 Pg of carbon per year, and they are growing at around 3% per year (Peters et al., 2012). This means that even the annual increase in CO_2 emissions from fossil sources considerably exceeds the total sink function of blue carbon. Clearly, the blue carbon sink can do little to counter global CO_2 emissions, and measures to combat the loss of this sink can hardly be seen as a relevant component in global climate protection.

Table 1.2-1 provides an overview of the various estimates of the sink function of individual coastal ecosystems, current or estimated emissions resulting from the destruction or degradation of the ecosystems, and the total carbon deposits stored in the ecosystems which could be released.

The impact on climate from emissions caused by the destruction of coastal ecosystems is also comparatively small. According to Siikamäki et al. (2012), around 6.5 Pg of carbon is stored in mangrove forests globally, including in their soils. Even the complete destruction of all the world's mangrove forests would thus release less CO_2 into the atmosphere than the amount released in one year by the use of fossil fuels. Murray et al. (2011) estimates the "total carbon stock at risk" in mangrove forests, sea-grass meadows and salt marshes at around 12 Pg of carbon. By comparison, the potential CO_2 emissions from global fossil reserves alone (excluding resources and other deposits) total 1,500 Pg of carbon (WBGU, 2011).

What blue carbon is not

In the debate about blue carbon, it is sometimes claimed that around half of global net primary production – the production of biomass with the help of photosynthesis – takes place in the oceans (Nellemann et al., 2009). However, this does not mean that a large amount of biomass is found in the oceans. Indeed, the average life span of organic plant biomass in the oceans is just two to six days, compared to 19 years on land (Field et al., 1998). This is why, despite the high level of productivity, just 0.2% of global plant biomass is to be found in the oceans. For the CO_2 cycle, this means that although a large amount of CO_2 is absorbed by marine plant organisms during their growth phase, it is not stored for long in the biomass in the form of carbon; most of it is immediately released again. Only the proportion of the absorbed CO_2 which is stored over the longer term is relevant for the CO_2 sink function. Net primary production on its own is thus not a good indicator of a CO_2 sink, and mentioning it in connection with blue carbon is misleading.

The oceans do indeed absorb a considerable proportion of anthropogenic CO_2 emissions. The ocean sink was estimated at 2.4 Pg of carbon in 2010, corresponding to around a quarter of that year's anthropogenic emissions (Peters et al., 2012). A further quarter (2.6 Pg of carbon) was absorbed by the terrestrial biosphere over the same period. While the land sink is predominantly determined by plant growth, the ocean sink is initially purely physico-chemical in nature. Thus, as the CO_2 concentration in the atmosphere increases, the upper layer of water in the ocean absorbs CO_2 until the partial pressures of the surface water and the atmosphere reach an equilibrium. The global CO_2 absorption rate of the oceans is determined firstly by the CO_2 concentration in the atmosphere and secondly by the speed of the circulation processes in the oceans, which exchange surface water whose CO_2 content is in equilibrium with the atmosphere with water containing less CO_2 from deeper layers (e.g. Doney, 2010). What is known as the 'biological pump' also contributes to this downward transportation of carbon: dying organisms sink, and their organic substance decomposes at different depths of water. Nutrients and carbon are released in this way, some of which return to the top water layer by vertical mixing. Others, however, sink to lower layers of water, where they are isolated from the atmosphere for longer periods of time. Attempts to increase primary production and thus strengthen the biological pump by adding external nutrients (e.g. iron) to the surface of the ocean – thereby expanding the ocean sink ('iron fertilization', WBGU, 2004; Smetacek et al., 2012) – fall under the general heading of 'geo-engineering'. It is unclear at present how effective, if at all, such measures might be and what unintended side-effects they would have; this is a matter of scientific debate (Lampitt et al., 2008). Commercial ocean fertilization measures have been rejected in international agreements (e.g. in decisions taken in the context of the CBD, the London Convention and the London Protocol), except in the case of scientific experiments. The ocean sink just described and possible measures to increase it through ocean fertilization are not generally what is meant when people speak about 'blue carbon'.

Conservation of coastal ecosystems should not focus on climate protection

The ecosystem services provided by coastal ecosystems are diverse, ranging from protecting coastal areas from storms,

Table 1.2-1
Coastal ecosystems and the carbon cycle. Global sink function, current global CO_2 emissions from destruction and degradation, and total stored carbon that could be released from selected coastal ecosystems. The figures in each case are the range of values given in the literature. The row 'Total: mangroves, sea-grass meadows and salt marshes' refers to values in the cited literature and is not the sum of the figures given for individual ecosystems in the rows above.
Source: WBGU, based on: [a] Laffoley and Grimsditch, 2009; [b] Breithaupt et al., 2012; [c] Donato et al., 2011; [d] Pendleton et al., 2012; [e] Murray et al., 2011; [f] Siikamäki et al., 2012; [g] Kennedy et al., 2010; [h] Fourqurean et al., 2012; [i] Duarte et al., 2005

Ecosystem	Global sink function	Global CO_2 emissions from destruction and degradation	Total stored carbon that could be released
	[Pg C per year]	[Pg C per year]	[Pg C]
Mangrove forests	0.018–0.026 [a, b]	0.024–0.12 [c, d]	1.2–6.6 [a, e, f]
Sea-grass meadows	0.027–0.11 [g]	0.014–0.3 [h, d]	2.2–8.4 [a, e, h]
Salt marshes	0.027–0.04 [a]	0.005–0.065 [d]	0.4–1.3 [a, e]
Total: mangroves, sea-grass meadows and salt marshes	0.11 [i]	0.04–0.28 [d]	12.1 [e]

flooding and erosion and providing a filter for nutrients and other runoff substances, to making a contribution to food security by providing habitats for fish and seafood. Mangroves, for example, are extremely important for other ecosystem services, especially for protecting the coast, providing a breeding ground for fish and acting as a filter for sediment and nutrients running off the land. Furthermore, coral reefs, sea-grass meadows and mangrove ecosystems are all interlinked, so sea-grass meadows and coral reefs also suffer without an intact mangrove belt.

There are thus many arguments in favour of protecting coastal ecosystems, and climate protection should not be regarded as the primary reason. In particular, there is little sense in focusing the protection of coastal ecosystems on those that provide the biggest sink function. Given the speed with which emissions are growing due to the use of fossil fuel, even the fact that the carbon stored in the soil through coastal ecosystems can remain there for thousands of years is of little relevance to the climate this century. Based on sedimentation figures given by Duarte et al. (2005), coastal ecosystems would need roughly a century to capture and permanently store a single year's anthropogenic CO_2 emissions. What the conservation of coastal ecosystems needs instead is an integrated approach which addresses the totality of biological diversity and ecosystem services.

In the WBGU's view, there is no reason why CO_2 emissions from coastal ecosystems should not be included in the national inventories in which countries report on their climate-relevant emissions to the UNFCCC, especially as Article 4.1(d) of the UNFCCC explicitly calls for the preservation of sinks and carbon stores – also in coastal and marine ecosystems. Reporting them separately under a 'blue carbon' heading seems both misleading and inappropriate, however. Rather, coastal ecosystems should be integrated into the existing schemes. For instance, the protection of mangroves should be included in deliberations on designing a REDD-plus regime under the UNFCCC. The IPCC is currently developing possible guidelines for the inclusion of wetlands in national inventories, also covering coastal wetlands, which include mangroves, salt marshes and sea-grass meadows (IPCC, 2013).

The WBGU has recommended treating emissions from land use and land-use change separately from fossil-fuel emissions. This is because the two types of emissions differ in terms of basic characteristics (measurability, reversibility, long-term controllability, interannual variability; e.g. WBGU, 2009:39, 2010:231). This recommendation applies in the same way to the protection of coastal ecosystems. Given the unambitious emission-reduction targets in many countries, including new 'blue carbon' methods in the Clean Development Mechanism (CDM) would not be effective: reducing CO_2 prices in carbon markets in the short term by including new offsetting methods would not serve the goal of climate protection. On the contrary, what is urgently needed is CO_2 prices that are high enough to drive the transformation of the energy systems forward (WBGU, 2011). Financial support to help developing countries maintain their coastal ecosystems should therefore be activity-based and come from a fund – rather than be emissions-based and funded via the carbon markets.

to the Biodiversity Convention (CBD): i.e. that MPAs should cover 10% of the oceans by 2020. Moreover, the WBGU has proposed designating at least 20-30% of the total area of marine ecosystems as an ecologically representative and effectively managed integrated system of protected areas (Box 1-1; WBGU, 2006). The WBGU reiterates this recommendation in the current report (Section 7.3.9.1).

The protection of coastal ecosystems in particular has also been a matter of debate recently within the framework of the UNFCCC, although in this context primarily with regard to its mitigating effect on climate change. The WBGU outlines its position on this issue – known as 'blue carbon' – in Box 1.2-2.

1.2.2 Overfishing

Overfishing – the sustained decimation of fish stocks by fishing at volumes above the level of natural regeneration and migration of fish – is regarded as one of the main causes of the loss of biological diversity and ecosystem services in ocean ecosystems (Section 4.1.2.3). Overfishing results in shifts in the age and size structure of fish stocks and changes in the makeup of ecosystems. It has become a global problem: according to FAO statistics, 30% of global stocks are currently overfished and a further 57% of stocks are already being fully exploited (FAO, 2012b: 11; Section 4.1). Large predators such as tuna and cod are particularly at risk due to overfishing. Since the beginning of industrial fishing, their biomass has declined by at least two thirds worldwide, with some people putting the losses as high as 90% (Section 4.1.2.3). Predators like these have a determining influence on ecosystem structures and food webs, so their decimation can have a knock-on effect on other species – e.g. an increase in populations of smaller fish, leading in turn to a decimation of their own food sources. In this way overfishing can cause fundamental changes to the make-up of the ecosystems affected. Other possible effects include changes in the populations of herbivorous fish – which can have an impact on coral reefs and kelp cover – and changes in the level of carbon uptake (Jensen et al., 2012). Depending on fishing methods, non-target species can also be adversely affected directly by fishing, for instance as a result of by-catch when non-selective fishing methods are used. In some areas the problem of overfishing is exacerbated by destructive fishing methods, e.g. bottom trawling, which can result in the physical destruction of ecosystems (Section 1.2.1).

For humanity, the clearest sign of overfishing is the fact that more and more effort is required to maintain current catch volumes, since the easily accessible fish stocks are being reduced more and more (Section 4.1.1). The impact of fishing on the marine ecosystems was long underestimated. As fishing efforts have increased substantially, and new fishing grounds in distant regions or very deep waters have been developed over the past decades, this impact has grown drastically. From a global perspective, fishing is in a worrying state today. However, there are positive signs that this is increasingly being recognized. Fishing regulations have been greatly improved in some regions, leading to regional reversals in the trend. A transformation in management towards a sustainable way of thinking based on the ecosystem approach could achieve an improvement in the situation, with stocks being built up again, yields boosted and further damage to ecosystems avoided. The good news is that a transformation of fisheries towards sustainability is possible – and indeed in some areas has already begun.

Overfishing is discussed in detail in Section 4.1.

1.2.3 Impacts of marine pollution

1.2.3.1 Results of chemical pollution

More than 300 chemical substances are classified as dangerous for the marine environment (OSPAR, 2010b). Some of them, e.g. persistent organic pollutants (POPs) and heavy metals, have been entering the seas for decades and can cause serious damage to marine fauna. These pollutants accumulate in marine organisms through the food chain and can later be ingested by humans when they eat those organisms (Section 4.4.4).

Because of their durability, POPs can be transported by air and sea currents to regions located far away from the pollution sources, e.g. to the Arctic, where they have been shown to accumulate in the organs of top predators such as polar bears, whales and seabirds in concentrations that are sometimes harmful to their health. This can cause reproductive disorders and a greater susceptibility to illnesses (OSPAR, 2010b). However, little is known to date about the specific effects of POPs on the animal and human organism, and there is scant data on the impact of POPs on human health (Domingo et al., 2007; Islam and Tanaka, 2004). But they are suspected of being carcinogenic and of causing hormonal and other disorders (Platt McGinn, 2000; UNEP-AMAP, 2011).

By contrast, the impact on health of the heavy metal mercury, which can enter the human body through the consumption of fish and seafood, is well known. Mercury has a toxic effect on the central and peripheral nervous system; children, newborns and foetuses are particularly at risk (WHO, 2007b). Mercury can also cause developmental disorders of the embryo in marine mammals, like in humans. As in the case of POPs, studies have often been based on laboratory tests with individual substances, so the impact on entire ecosystems and the cumulative effects are largely unknown (UNEP, 2002; Nakayama et al., 2005). However, accumulated levels in animals at the end of the food chain are now so high that people are advised against consuming fish

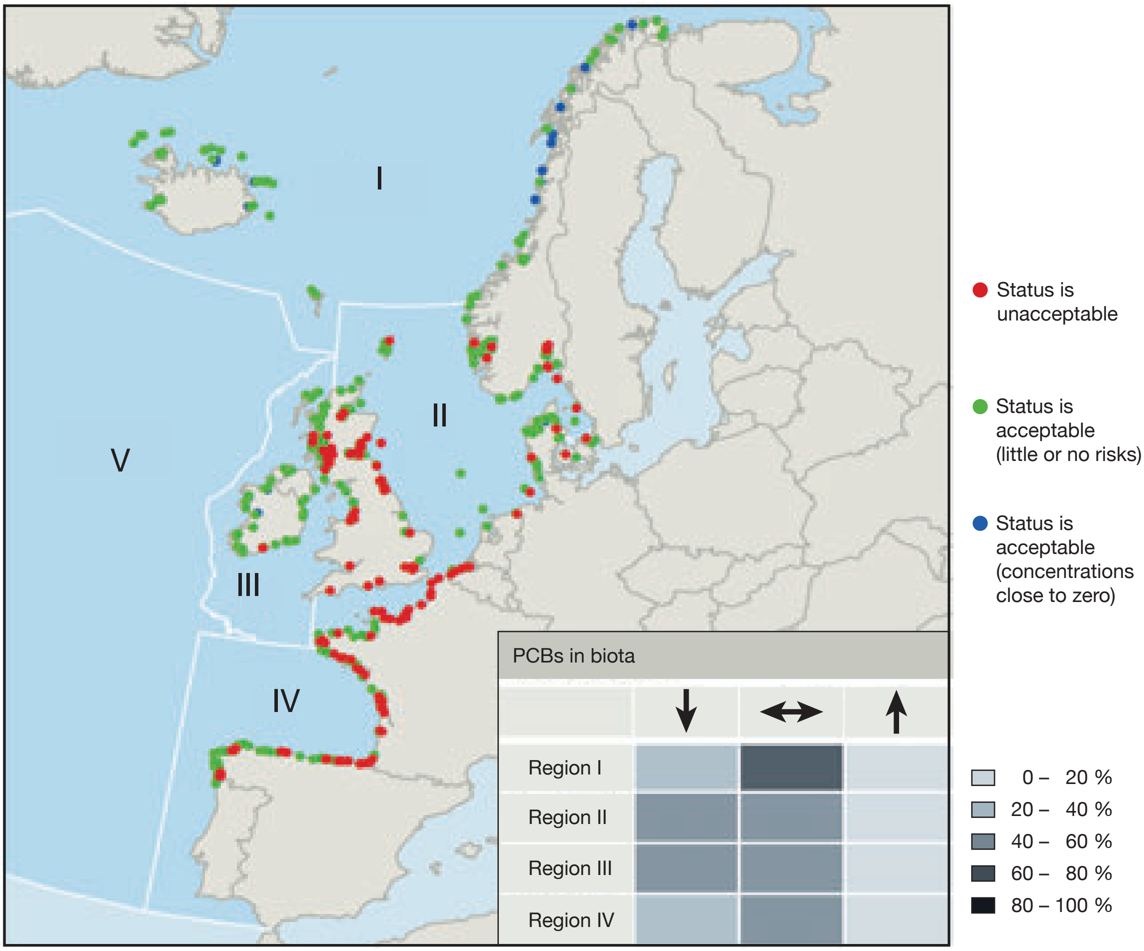


Figure 1.2-1
PCBs found in marine organisms (fish and seafood). The red dots indicate high concentrations considered by OSPAR to represent an unacceptable risk of chronic damage to marine organisms or to be above the threshold for human consumption. Green dots indicate acceptable concentrations representing no risk to the environment or humans. The figures refer to studies from the period 2003–2007. The inset shows trend analyses of time series with data from five or more years in the period from 1998 to 2007 for the various regions. The grey-shaded areas indicate the shares with a falling trend (↓), no trend (↔), or a rising trend (↑).
Source: OSPAR, 2010b:45

and whale meat in certain regions.

Despite declining concentrations in sediments and organisms – which is partially the result of existing regulations such as the Stockholm Convention on Persistent Organic Pollutants – in certain regions of the Northeast Atlantic specific contaminants such as PCBs and mercury remain at levels thought to pose a risk to animal and human health (Figure 1.2-1). In addition, the long retention period of some environmental toxins underlines the need for preventative regulations covering all pollutants (OSPAR, 2010b).

1.2.3.2
Results of plastic pollution

For the last 40 years or so, larger pieces of plastic and microplastics (between <10 mm and <1 mm; Cole et al., 2011) have been accumulating on beaches, in remote regions, on the high seas and in large ocean gyres due to their durability (Barnes et al., 2009; UNEP, 2011c; Maribus, 2010). Plastic-waste pollution has become an environmental problem that must be taken very seriously (Section 4.4.4). The impact of larger pieces of plastic on marine organisms and the environment are well known and frequently publicized by environmental organizations and others. Pictures of dolphins, seals, turtles and sharks strangled or drowned in fishing nets or pieces of plastic, and of dead birds are distressing. Apart from such deaths, animals are also often injured,

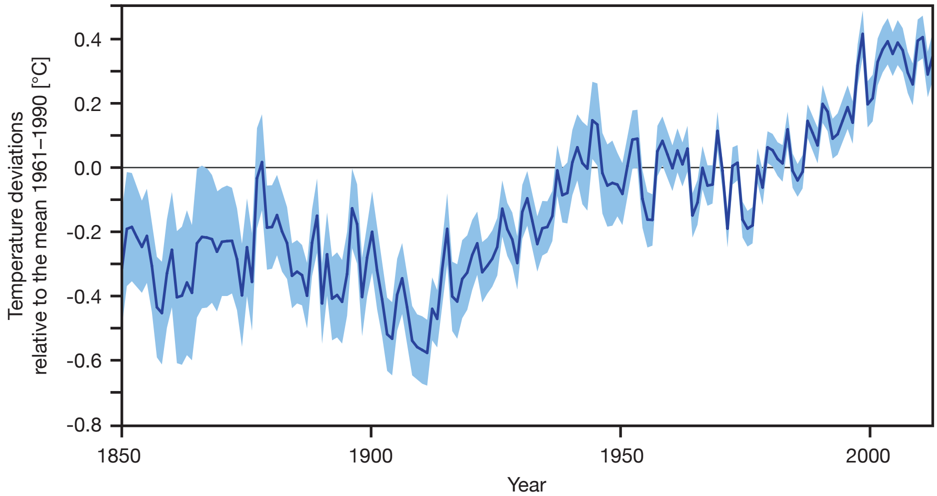


Figure 1.2-2
Evolution of the global near-surface ocean temperatures from 1850 to 2012: annual average figures and the range of uncertainty.
Source: WBGU, based on data from the Met Office, 2012

and some – especially seabirds – swallow plastic parts, which can result in malnutrition or blockages (Young et al., 2009).

At present little is known about the impact of microplastics on the marine environment and marine organisms, and what happens to them, but they have been found in the tissues of several marine animals (Maribus, 2010). Microplastics can bind toxic substances which, if they accumulate in the food chain, can harm animals and ultimately humans (Cole et al., 2011; Andrady, 2011).

1.2.3.3 Radioactive contamination

Nuclear radiation can cause genetic changes, reproductive disorders and cancer. It thus has the potential to harm marine organisms and humans through their consumption of radioactive substances. However, average doses caused by radionuclides affecting marine organisms and humans are well below international and EU thresholds, except in the case of pollution from incidents such as the Fukushima disaster. But most contamination comes from natural sources (UNEP and GPA, 2006; Livingston and Povinec, 2000). Natural background radiation can be up to 1,000 times higher than the current anthropogenic contribution. The long-term effects of radioactive pollution and its accumulation along food chains do present problems, however. Potentially there are also new sources of radioactive material, such as decommissioned nuclear vessels (AMAP, 2010). Further efforts should therefore be made to reduce the emission of anthropogenic radioactive substances into the marine environment and to prevent future accidents and emissions (OSPAR, 2010b; Section 4.4.4).

1.2.4 Warming

In its special report *The Future Oceans – Warming Up, Rising High, Turning Sour* (WBGU, 2006), the WBGU describes in detail the problem of rising water temperatures, ocean acidification and sea-level rise. The increase in the CO_2 levels responsible for acidification as well as the rise in global temperatures and sea levels continue today.

The concentration of CO_2 in the atmosphere reached a new high in 2012: an average of 394 ppm. On average over the available data series, in 2010 the global temperature hit its highest level since records began (WMO, 2010) – despite continuing low brightness levels of the sun, which in 2010 and the preceding years was at its weakest level since satellite measurements began in the 1970s (Gray et al., 2010). The persistent warming trend is even more marked if the effect of known short-term fluctuations like El Niño are factored out from the global temperature (Foster and Rahmstorf, 2012).

Near-surface ocean temperatures are also rising; they are already about 0.7°C higher than in the second half of the nineteenth century (Figure 1.2-2).

The deeper layers of seawater have warmed to a much lesser extent (less than 0.004°C between 1955 and 1998). The temperature difference between the ocean surface and the layers beneath it has therefore increased, leading to a more stable stratification of near-surface waters (Gruber, 2011). Both the higher ocean temperatures and the more stable stratification – as well as the related reduction in the oxygen content (Section 1.2.6) – have marked effects on ocean ecosystems. In particular they lead to changes in the composition of species, geographical shifts in populations and alterations to food webs (Section 4.4.1).

Over the last few decades, the summer ice cover of the Arctic Ocean has shrunk by at least a half. A new record low was reached in September 2012 (NSIDC, 2012a). The changes in the Arctic, their impacts and their associated requirements, are discussed in this report in a series of boxes (Boxes 1.2-3, 3.4-1, 4.1-1 and 5.1-2). In the Antarctic Ocean, by contrast, the winter ice extent has expanded by a few percent in recent decades (a trend of +0.9% per decade; NSIDC, 2012b). This slight increase – despite the warming that is also observed in the Antarctic – is attributed to an increase in the winds that blow the sea ice northwards away from the continent of Antarctica during the winter months (Holland and Kwok, 2012).

1.2.5
CO_2 input and acidification

The oceans play a key role in the carbon cycle on our planet. Up to now, they have absorbed about one-third of total anthropogenic CO_2 emissions, which stem mainly from fossil sources and land-use changes (Khatiwala et al., 2012). This amount corresponds to 45% of fossil CO_2 emissions. The oceans contain a total of about 38,000 Gt of carbon, 50 times more than the carbon content of the atmosphere and 20 times more than that of the terrestrial biosphere and the soils (WBGU, 2006). Prior to industrialization the ocean gave off around 0.6 Gt of carbon to the atmosphere at its surface every year, approximately the same amount that entered the ocean in the form of organic matter flowing in from rivers (Watson and Orr, 2003). Since the carbon in the organic matter ultimately stems from the atmosphere via photosynthesis, this exchange did not change the CO_2 content of the atmosphere and the system was in equilibrium. Only when the anthropogenic interference in the carbon cycle began – above all through the burning of fossil fuels – did the ocean become a carbon sink. If the CO_2 concentration in the atmosphere increases, the ocean absorbs CO_2 until the partial pressures of the surface water and the atmosphere return to equilibrium.

Because the ocean and the atmosphere are linked in this way and strive towards equilibrium, emissions of CO_2 into the atmosphere inevitably lead to a transfer of CO_2 to the ocean. Each year the ocean absorbs more than 2 Gt of carbon (7.3 Gt of CO_2) in the form of CO_2 from the atmosphere (Le Quére et al., 2009). This input is therefore directly and entirely caused by humanity.

The CO_2 dissolves in the seawater, forming a weak acid. In other words, the input leads to a lowering of the pH value, and this is known as 'acidification' (Caldeira and Wicket, 2003). The pH value of ocean surface water has already dropped by 0.1 units since the beginning of industrialization, corresponding to a 30% increase in the acid content. The link between the rise in atmospheric CO_2 concentration and the acidification of the oceans is well understood and subject to less uncertainty than climate change (Feely et al., 2009). For every 100 ppm of CO_2 increase in the atmosphere, the global mean pH value of ocean surface water falls by around 0.07 units (Gruber, 2011). For example, should the CO_2 concentration rise to 800 ppm by the year 2100, the mean pH value of the ocean surface water would fall by a further 0.3 units and reach 0.4 units below its pre-industrial level (Feely et al., 2009). The acidification of the oceans can only be reversed over an extremely long time scale.

As the pH value changes, so does the concentration of carbonate ions in the seawater. These ions are needed by marine organisms to build their calcium carbonate shells and skeletal structures. In this context some organisms form aragonite, which is slightly more easily dissolved, while others form the less soluble calcite. It is therefore especially important for ocean ecosystems to have a sufficient supersaturation with respect to aragonite in the seawater.

Simulations by Steinacher et al. (2009) show that the Arctic may see the biggest pH changes in the future. Climate change boosts the processes here, since CO_2 uptake increases in reaction to melting sea ice and freshwater inflow reduces saturation. Some areas of the Arctic may experience temporary aragonite undersaturation as early as the next decade. If CO_2 emissions follow a business-as-usual scenario, the entire water column in the Arctic will become undersaturated within this century. Steinacher et al. (2009) conclude that limiting the atmospheric CO_2 concentration to no more than 450 ppm is the only way to avoid the risk of major changes to ocean ecosystems.

A report by the British Royal Society (2005) attracted a great deal of political attention to the topic of ocean acidification for the first time. In 2006 the WBGU proposed the following guard rail for ocean acidification: the pH level of the uppermost ocean layer should not fall by more than 0.2 units compared to pre-industrial levels in any major ocean region. Rockström et al. (2009) propose using aragonite saturation as an indicator: this should not fall below 80% of its pre-industrial level.

Box 1.2-3

The Arctic in the Anthropocene

Unlike the Antarctic, which is an ice-covered continent surrounded by the sea, the Arctic is an ocean – much of which is covered by ice all year round – surrounded by land. At the same time the Arctic, with its marine and terrestrial ecosystems, is a unique natural environment that is worthy of special protection, being home to communities of organisms that are able to survive in extreme environmental conditions. Compared to climatically milder latitudes, the Arctic has a lower diversity of species, and the vegetation period is comparatively short due to the long polar night. These two factors contribute to the fact that the Arctic ecosystems are much more fragile and sensitive than those at temperate latitudes. The Arctic Ocean has productive marine ecosystems with large fish stocks (Box 4.1-1).

The Arctic plays a special role in the global climate system as an early-warning system for change. The ice cover ensures that part of the solar radiation that hits the Arctic is reflected, so as the snow and ice masses melt, darker land and sea surfaces are revealed that absorb the solar radiation, thus speeding up the warming process. Along with other factors, this means that global warming is manifested in the Arctic as a rise in temperatures that is well above average; the Arctic therefore is currently subject to particularly fast alteration due to climate change. This leads to fundamental changes in the characteristics of Arctic ecosystems, including habitat loss and a loss of biological diversity; the Arctic's human population also faces new challenges (AMAP, 2012).

The melting of the Arctic ocean's ice cover continues unabated; indeed, it is proceeding much faster than expected (Figure 1.2-3). The Arctic sea ice is diminishing not only in extent but also in terms of its thickness. As a result, the summer ice volume has already dropped by as much as 80% over the last forty years (Laxon et al., 2013).

The melting of the sea ice impacts on the layers of the ocean beneath it. This can lead to stronger plankton growth due to the greater amount of sunlight reaching it, thus increasing the amount of food available for some species. The result can be increased overall productivity. At the same time, the loss of the ice means the loss of its protective function and its role as a habitat. Sea ice is used by various mammals as a platform for rearing their offspring or for hunting. Many species of small crustaceans also live in or on the sea ice, forming a basic food source for various birds, fish and whales, including Arctic cod (AMAP, 2012). A reduction in the population of certain species of seals, caused by the disappearance of the sea ice, can already be observed.

For the human societies it is the changes in access to the Arctic regions that are of particular significance (AMAP,

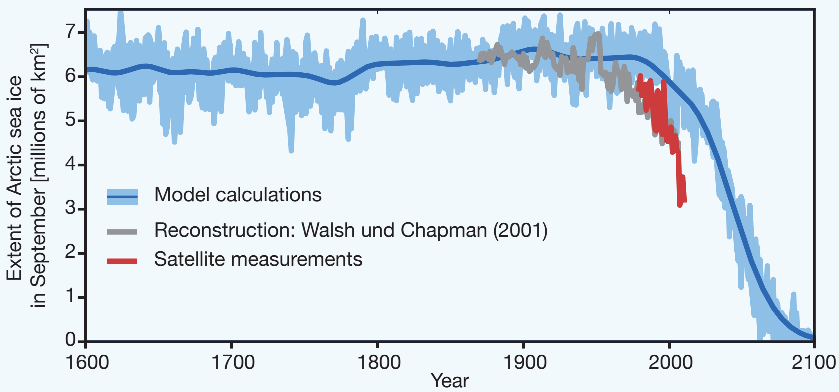
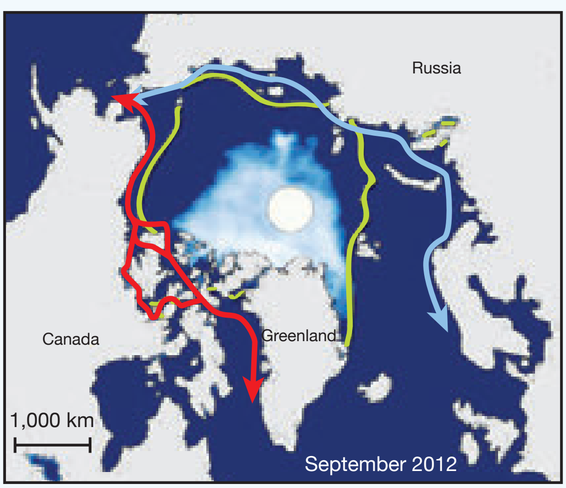


Figure 1.2-3
Area of Arctic sea ice in September according to observed data, a reconstruction (Walsh and Chapman, 2001) and a series of model calculations by the Max Planck Institute for Meteorology, Hamburg (quoted in Jungclaus et al., 2010).



Northwest Passage
Northeast Passage
Average ice cover in September for the years 1979 to 2000

Figure 1.2-4
Shipping routes and ice cover in the Arctic. The figure shows sea ice in September 2012 based on satellite data and the course of the Northwest Passage (red) and the Northeast Passage (blue). The yellow line indicates the average ice cover in September for the years 1979 to 2000.
Source: WBGU, on the basis of NASA, 2013

2012). Some regions that were previously covered by sea ice are becoming easier to access, while transport and traffic across the ice is becoming more difficult. The Northeast and Northwest Passages (Figure 1.2-4) were both free of ice for the first time in late August 2008. Since then the Northeast Passage has already been navigated by numerous freight ships. The Arctic Ocean is expected to be largely ice-free during the summer months within the next 30 to 40 years.

As the Arctic sea ice melts, interest in the resources thought to be located in the region is growing (Box 5.1-2). Mining the Arctic's mineral resources involves considerable environmental risks. It is more difficult to deal with problems or accidents in the Arctic than in other regions. Because of the large distances involved, support ships are not available as quickly as elsewhere. Moreover, during the winter it is almost completely dark for half of the year, and the ice presents additional dangers. The increase in shipping levels is also expected to place an additional burden on the environment. In addition, deposits of soot on the ice from ships' exhausts reduce its ability to reflect sunlight (albedo) and lead to further warming.

Indigenous population groups are also affected by the consequences of global warming and environmental pollution in the Arctic. Hunting, food availability and moving about are becoming extremely difficult as the sea ice increasingly melts and the permafrost thaws (Seidler, 2011; AMAP, 2012). What is more, the thawing of the permafrost and increased coastal erosion endanger the stability of the infrastructure such as roads and houses. In some traditional hunting regions the ice is now too thin to support dog sledges. As the ice retreats, traditional hunters find it harder and harder to reach their prey that live on the ice edge. The animals they kill contain increasing levels of poisons such as mercury or persistent organic pollutants (POPs). The insidious poisoning of the Arctic habitat often leads to a deterioration in the health of the Arctic residents; the harmful substances are passed on to children through their mother's milk and accumulate over time.

The Arctic shows the challenges of the Anthropocene very clearly. Humanity is changing the natural environment here to such an extent that there will inevitably be great changes in the way the Arctic is used and in local human living conditions. The challenge will be to keep human influence within limits and to use the new possibilities in a responsible fashion (see also Boxes 3.4-1, 4.1-1 and 5.1-2).

Irrespective of how the threshold level of damage is precisely defined, compliance with it can only be achieved by limiting the rise in atmospheric CO_2 concentration, i.e. by reducing anthropogenic CO_2 emissions. If it proves possible to stabilize the CO_2 concentration in the atmosphere at a level below 450 ppm, the reduction in the mean global pH value would be around 0.17, and the guard rail proposed by the WBGU would be adhered to (WBGU, 2006). Whether this guard rail can be complied with will therefore depend essentially on climate-change mitigation policy. The current growth of global CO_2 emissions is unrelenting, however, averaging 2.7% a year over the last decade (Olivier et al., 2012).

In its 2006 report the WBGU recommended that climate policy should consider all the effects of greenhouse-gas emissions on marine habitats, i.e. including the direct impact of CO_2 input on marine ecosystems. This could make it necessary to view CO_2 not only as part of a group of various greenhouse gases whose relative importance is solely defined by their warming potential; regardless of reductions in other greenhouse gases, the CO_2 concentration also needs to be stabilized at a level that allows compliance with the guard rail proposed by the WBGU (WBGU, 2006).

1.2.6
Low-oxygen zones

The distribution of oxygen in the ocean is of great importance for the marine biosphere. Dead zones (oxygen-deficient zones) in coastal waters have become a worldwide problem that is destroying the structure and function of ecosystems (Zhang et al., 2010). The main drivers of oxygen deficiency near coastlines is the input of nutrients from rivers and via the atmosphere. But as climate change advances, a reduction in oxygen concentrations is also expected in the open seas, caused by the warming and increasingly stable stratification of the upper layers of water (Gruber, 2011; Keeling et al., 2010). Warming surface water reduces the solubility of oxygen in seawater, and the more stable stratification reduces the transportation of oxygen-rich surface water to deeper layers where the oxygen is continuously being consumed by marine organisms (Deutsch et al., 2011).

Dead zones of the first category are found along heavily populated coasts where there is intensive farming or raw sewage is discharged into the sea. The nitrogen input, which has increased dramatically since the 1960s as a result of the 'Green Revolution', usually reaches the oceans via rivers. Europe's coastline, the North American East and West Coasts, the Gulf of Mexico, Japan's coastline and the southern part of the Brazil's coast are regions with high inputs of fertilizers from farming (Figure 1.2-5). Coastal zones in developing countries are affected by raw sewage, usually offshore from megacities, albeit to a much lesser extent.

The future extent of oxygen reduction in the oceans due to climate change will be largely determined by the amount of heat the ocean absorbs (Gruber, 2011). The biggest loss of oxygen in this context is expected in mid- to high-latitude regions; tropical and subtropi-

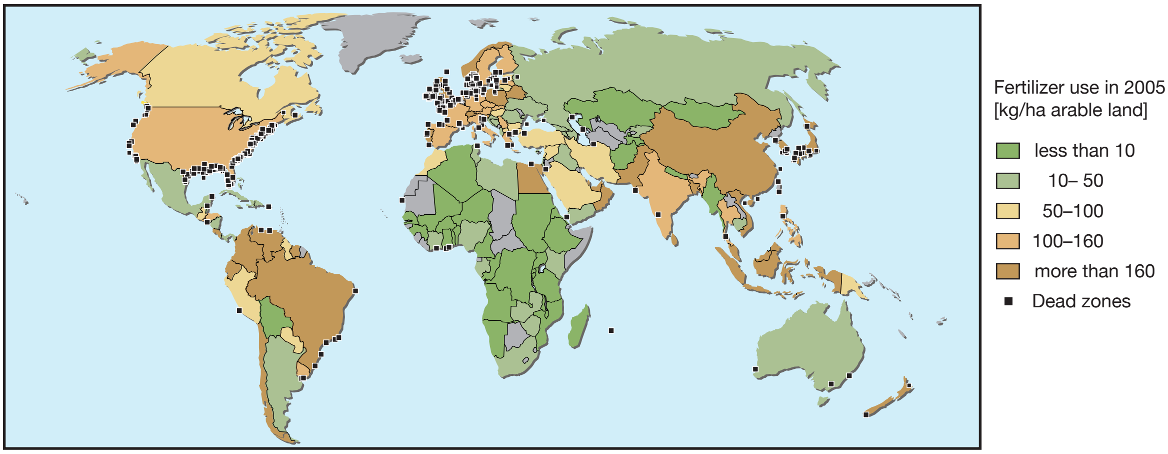


Figure 1.2-5
Global distribution of dead zones caused by eutrophication (black squares) and specific fertilizer use. Dead zones make it difficult for marine organisms to survive.
Source: UNEP, FAO, IMO, UNDP, IUCN, World Fish Center and GRID Arendal 2012: UNEP, 2012a

cal regions, which are lower in oxygen and less productive in any case, show fewer changes in model simulations (Gruber, 2011). Research here is still in its infancy and the uncertainties are correspondingly high. In the global mean, oxygen could fall by 1 to 7% this century (Keeling et al., 2010). Measurements show that the oxygen concentration has already fallen and low-oxygen zones have expanded in most regions of the tropical oceans over the last 50 years (Stramma et al., 2010). A reduction in oxygen can also be observed in the North Pacific (Keeling et al., 2010).

Overall, it has only recently been established that climate change can significantly alter the concentration of oxygen in the oceans. Further research is needed in order to make more precise forecasts possible. However, all indications are that oxygen reduction can reach a level where marine habitats and fishery are adversely affected (Section 4.4.3; Keeling et al., 2010; Stramma et al., 2011). Ocean acidification (Section 1.2.5), too, can in turn contribute to reducing the amount of oxygen in the oceans (Hofmann and Schellnhuber, 2009).

Like ocean acidification and warming, the reduction in the level of oxygen in seawater due to climate change is practically irreversible on timescales that are relevant for human society (Gruber, 2011). Figure 1.2-6 gives an overview of the regions that are particularly threatened by these global stress factors, based on analyses by Gruber (2011).

1.2.7
Sea-level rise

The global sea level has risen by 3.2 mm a year since satellite measurements began in 1993 (Figure 1.2-7). That is almost double the mean rate of increase over the whole of the twentieth century, and triple the rate at the beginning of the twentieth century.

New paleoclimate data from sediment deposits have for the first time allowed a detailed reconstruction of changes in the level of the North Atlantic over the last two thousand years (Kemp et al., 2011). They reveal that the rate of increase in the twentieth century was three times larger than in any other century in the past and also match data from tide gauges, which have been available since 1750.

Evaluations of the tide gauges for the German Bight also show an increase in local sea levels of approximately 40 cm since 1840 and an accelerating rate of increase over the past fifty years (Wahl et al., 2011).

Over a timescale of centuries to millennia, sea-level rise is primarily determined by the stability of the large ice sheets in Greenland and the Antarctic. Together, they contain enough ice to raise the level of the sea worldwide by 65 m. Losing even a small percentage of this ice would thus have massive consequences for the coasts. New data from NASA show that both ice sheets have been losing mass at increasing rates in recent decades (Rignot et al., 2011).

It is known that the Greenland ice sheet has a critical warming threshold – a so-called 'tipping point' – above which a vicious circle begins which would probably ultimately lead to almost the complete loss of the ice sheet and a consequent rise in sea levels of around

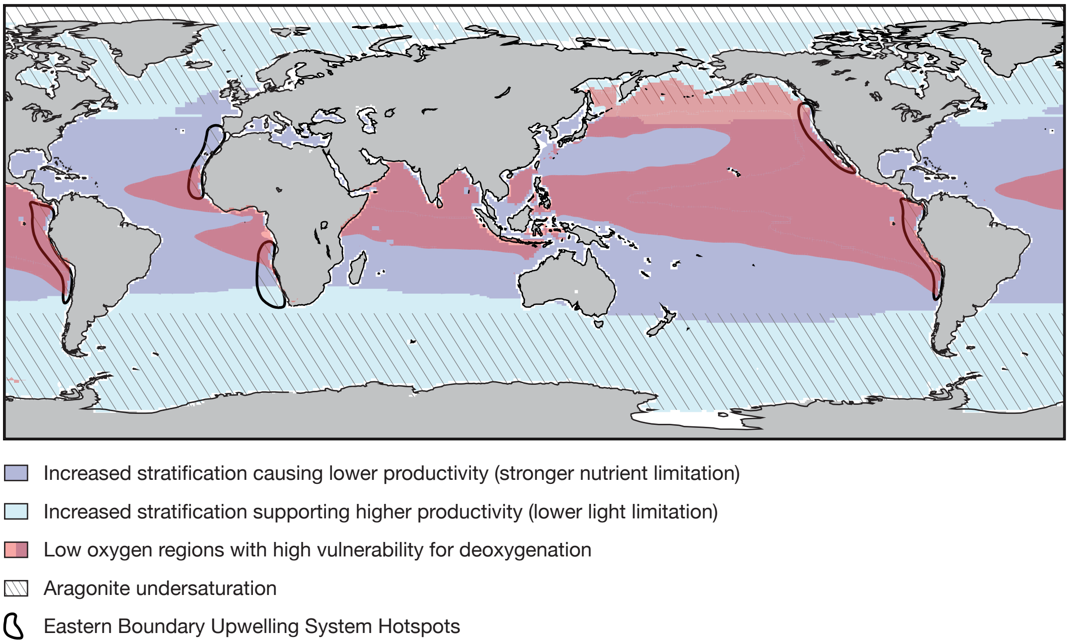


Figure 1.2-6
Regions that are particularly vulnerable to stress factors caused by anthropogenic CO_2 emissions such as ocean warming, ocean acidification and deoxygenation. The warming of seawater increases stratification, the impact of which can differ from one region to another. Lower latitudes, which already have a high level of stratification and whose productivity is nutrient-limited, are likely to show reduced productivity. Higher latitudes, on the other hand, have generally greater mixing; the limiting factor is exposure to light, so that increased stratification may raise productivity.
Source: Gruber, 2011

7 m. The last IPCC report in 2007 was working on the assumption that this tipping point might lie between 1.9 and 4.6°C of global warming. However a new, much more detailed analysis suggests that it is more likely to lie between 0.8 and 3.2°C of global warming (Robinson et al., 2012). Applying the precautionary principle is particularly important here because the reaction of the great ice masses to warming is initially very slow but then almost unstoppable over many centuries.

The sea level will not rise uniformly around the globe, because a number of physical effects lead to regional deviations. Overall, a bigger increase is to be expected in the Tropics and a smaller one at higher latitudes (Perrette et al., 2013). Besides regional differences in sea-level rise, areas of land can also subside or rise locally: for example subsidence due to groundwater tapping (as in Venice) or oil drilling (as in New Orleans), or the ongoing post-glacial rebound of land masses after being depressed by the Ice Age ice masses (as in Scandinavia). The most immediate consequences of rising sea levels are felt where a rising sea level meets a sinking coastal region.

1.2.8 Aggregated effects

Human influence on ocean ecosystems varies greatly depending on the location. According to an analysis by Halpern et al. (2008), the strongest cumulative effects on ecosystems are found in the continental-shelf and coastal regions, as both land-based and ocean-based factors exert an influence here (Figure 1.2-8). According to Halpern et al., therefore, large regions with a strong human influence are found in the North Sea and the Norwegian Sea, in the South and East China Sea, in the eastern Caribbean, off the East Coast of North America, in the Mediterranean, the Persian Gulf, the Bering Sea and the waters around Sri Lanka. With the exception of atmospheric inputs, which can be particularly high in the Arctic, the human impact is currently still weakest in the Polar regions, especially in areas where permanent or seasonal ice makes human access difficult. However, human influence on the ecosystem can be expected to increase strongly as the sea-ice cover shrinks (see also Box 1.2-3). The influence in more sparsely populated areas tends to be smaller, but shipping, fishing and climate change also greatly affect more remote regions such as the Patagonian coast (Halpern et al., 2008).

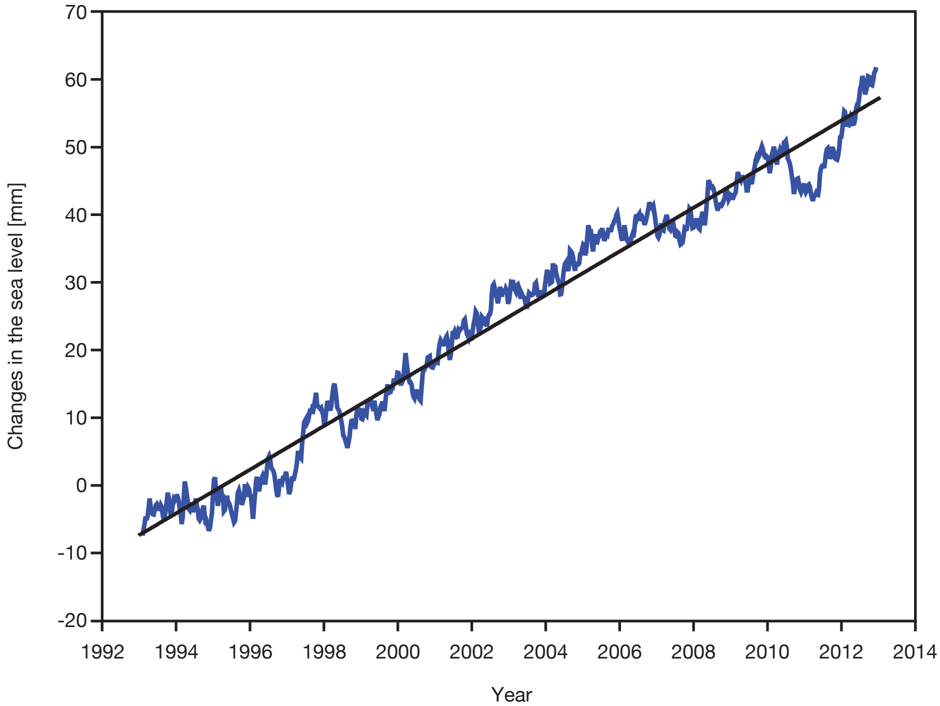


Figure 1.2-7
Rise in the global sea level since 1993 as measured by satellite. Each figure shows smoothed measurement data over 60 days.
Source: Nerem et al., 2010, 2013

In a more recent study, Halpern et al. (2012) present an index for assessing the health of the marine ecosystems and benefits of human uses in an integrated way. So far the analysis has only looked at countries' exclusive economic zones (EEZs), but there are plans to include the high seas. The index is based on ten targets considered to be generally accepted, ranging from extractive uses – such as food from the sea (fishery and mariculture) and artisanal fishing and natural products (coral, plants) – to possible uses for tourism and subsistence, immaterial qualities such as a 'sense of place', to carbon storage, coastal protection, water quality and biodiversity. Various indicators are used to assess the extent to which these targets are met. Sustainability – in the sense of the long-term perpetuation of the use in question – is included in the assessment. While some areas such as fishery (25 points out of 100), mariculture (10 points) and tourism (10 points) do relatively badly in terms of the global mean, the total global index is 60 points out of 100. A negative trend is seen for roughly half of the targets. There is also a geographical breakdown of the index, which shows that only 5% of countries score more than 70 points out of 100 and 32% score less than 50. Of course, the index is based on highly simplified assumptions and, as such, only provides an initial general overview of the situation. Yet it creates a meaningful framework for refining the analysis later on with better data.

What matters for the individual marine ecosystems is the overall impact of direct and indirect human influences: the overlapping of local and global influences, and the combined effects of past or present activities by different parties acting in different places and at different times. Some of these changes in the oceans are irreversible, while others can be reversed; very few are easy to control.

Often the sum of the individual influences only represents the lower limit of actual damage. In the case of coral reefs, for example, it is clear that the various different effects mutually interact and accelerate until there is a danger of large marine ecosystems suddenly tipping over into a different state. For example, coral reefs can recover quickly from specific events that cause damage – high-temperature peaks, mechanical damage from hurricanes or shipping accidents, individual overfertilization events – but this is only true if they have not been previously damaged and are not under stress from overfishing or general overfertilization, say. If they are, a sudden restructuring of the coral ecosystem becomes more likely, for instance from a hard coral reef to soft organisms and algae-dominated systems. This is associated with an often irreversible disappearance of biological diversity and key ecosystem services (Box 1.2-4).

Similar conclusions apply to the entire marine sphere. In many areas the oceans are heavily overused, and their ecosystem function is threatened by a whole raft

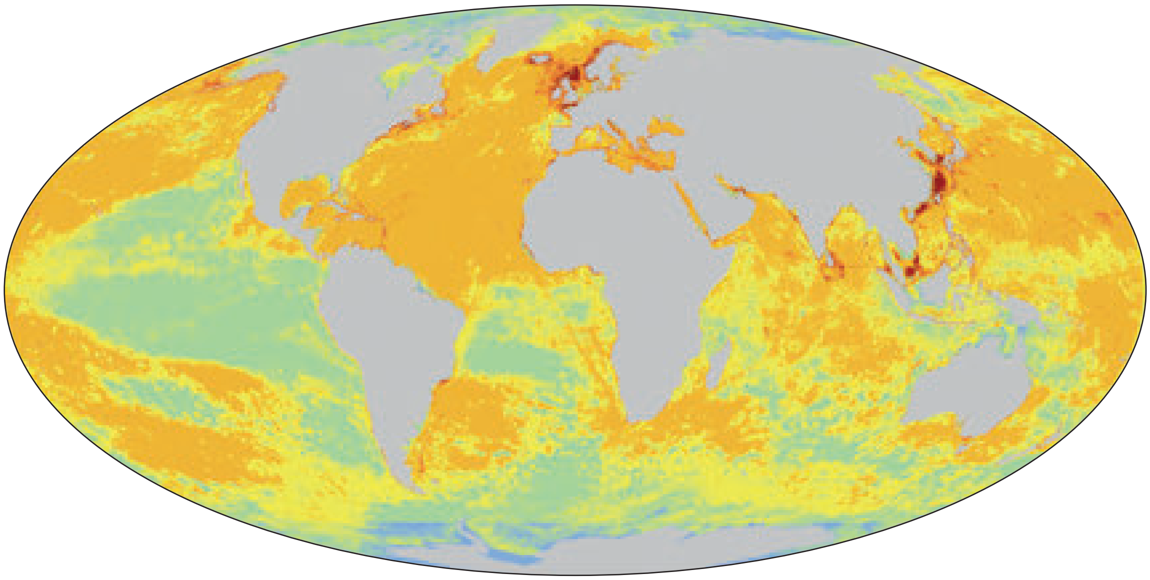


Figure 1.2-8
Cumulative impact of human activity on the oceans. The figure shows an index based on both the strength of anthropogenic driving factors and their (assumed) impact on existing ecosystems. 17 different anthropogenic drivers and 20 ecosystem types are taken into account. In the study the index ranges between values of 0.01 to 90.1. These were categorized by the authors. Figures over 15.52 are classed as indicating a very strong impact of humanity, figures below 0.14 as indicating a very weak impact.
Source: Halpern et al., 2008

of stress factors, with local cumulative effects combining and overlapping with global effects. This mixture generates interactions that could lead to regional or even global tipping points in the ocean systems being reached (Scheffer et al., 2001). An international expert workshop on the threats to the oceans puts it as follows in its final report: "This examination of synergistic threats leads to the conclusion that we have underestimated the overall risks and that the whole of marine degradation is greater than the sum of its parts, and that degradation is now happening at a faster rate than predicted" (Rogers and Laffoley, 2011). This could result in the loss of marine species and entire ecosystems within decades. If no corrective action is taken, humanity could trigger the next globally significant species extinction in the oceans through the combined effects of climate change, overuse, pollution and the destruction of ecosystems (Rogers and Laffoley, 2011). However, it is almost impossible to predict the cumulative or synergistic impacts of different anthropogenic stress factors working in parallel in the oceans by means of existing ecosystem models (Boyd et al., 2010). Much more research is also needed to enable a better assessment of possible tipping points in the various marine ecosystems.

What is beyond doubt is that a change of mentality – and above all action – is urgently needed if the large-scale loss of marine ecosystems and ecosystem services is to be avoided. Some positive trends already exist (in fishery, for instance; Section 4.1) proving that better management can achieve a turnaround towards an environmentally compatible, sustainable use of the oceans.

1.3 Possible new uses

In addition to present-day uses, new, future technologies and ocean uses are emerging which on the one hand may pose additional challenges for the protection of the oceans, but on the other offer opportunities for their sustainable use.

1.3.1 Renewable energy

At present, the renewable energy generated on or in the sea still only makes a marginal contribution to global energy supplies (Section 1.1.5). The oceans are the biggest solar collectors in the world and absorb approx-

Box 1.2-4

Coral reefs in the Anthropocene

Coral reefs represent the most biologically diverse ecosystem in the oceans. To date, approximately 800 species of reef-building coral and 4,000 species of fish associated with reefs have been identified in today's reefs. Furthermore, hundreds of thousands or even millions more species such as sponges, sea urchins, crabs, molluscs, etc. also live in them (Knowlton, 2008; Burke et al., 2011). Tropical, reef-building corals are restricted to a narrow range of environmental conditions. Because the specialized single-celled algae (zooxanthellae) that live in symbiosis with coral need light, they only thrive in shallow water, generally much less than 100m deep. They also need warm, thermally stable conditions where the water temperature does not fall below 18°C. The third important factor is a sufficient concentration of carbonate in the seawater (Hoegh-Guldberg, 2011). Reef-building corals are therefore principally found in the shallow, low-nutrient waters of the Tropics, in latitudes up to about 30° north and south. Some corals also occur in cooler and deeper waters, but these types of coral feed heterotrophically, do not live in symbiosis with algae and are therefore not reliant on sunlight. They too can build extensive carpets and sometime reefs in deep water which are important breeding grounds for fish (Freiwald and Roberts, 2005).

Coral reefs provide humanity with a number of different ecosystem services. 275 million people live within 30km of a coral reef, in other words in regions where reef fish make an important contribution to their supply of protein (Burke et al., 2011). Coral reefs are also very significant feeding or spawning sites for many lagoon and deep-sea fish species. In addition, they are an important factor for the pharmaceutical industry (see Section 1.3.3; Bruckner, 2002; Cesar et al., 2003; Sipkema et al., 2005; NCR, 2011) as well as for tourism: they attract divers and snorkelers and are the source of the white sandy beaches. Their calcium carbonate structures protect approximately 150,000km of coastline from erosion in over 100 different countries (Burke et al., 2011).

Coral reefs are a tragic example of the negative impact of overlapping local and global stress factors in the Anthropocene. Some pressure from human activities is generated locally – partly by poor land-use practices which lead to sediments, nutrients and pollutants being released and washed into the sea, damaging the reefs. In addition, overfishing – and above all fisheries using destructive methods (dynamite, cyanide, heavy fishing rigs) – reduces the populations of key species on the reef, damaging the function of the ecosystem and reducing productivity. After ecosystem damage, for example, macroalgae gain an advantage over the coral in their growth because there is less feeding pressure from the selectively caught fish that normally feed on these algae. Burke et al. (2011) conclude that more than 60% of all coral reefs are directly and immediately threatened by local stress factors such as overfishing, destructive fishing methods, coastal development, the discharge of pollutants (either directly into the sea or via rivers), and direct physical destruction. The most important factor in this context, which is faced by more than 55% of reefs, is overfishing. An area where research is just beginning is the pollution of coral by heavy metals (Berry et al., 2013).

Added to these local stress factors are the effects of global environmental changes, especially the impacts of rising greenhouse-gas emissions and climate change. Since 1979 a new phenomenon has been described with increasing frequency across a growing geographic area: that of coral bleaching (WBGU, 2006). Coral bleaching is the loss of the single-celled algae (zooxanthellae) that live in symbiosis with the corals. If a coral is subjected to a stress situation – which can be produced both in nature and in the laboratory by high or low temperatures, intensive light, changes in salinity or other physical, chemical and microbial stress factors – the algae can be ejected from the coral tissue. The living tissue of the corals is pale or transparent without the algae cells, so the white limestone skeleton shines through – hence the term coral bleaching. To some extent this phenomenon is reversible, because zooxanthellae can be re-absorbed by the body tissue. Hughes et al. (2007) report that reefs with intact fish stocks recovered from bleaching much more quickly than reefs with fewer plant-eating fish. If the coral bleaching continues for a longer period of time, however, the coral starve to death as they rely on the nutrients provided by their symbiosis with the algae. Between 1998 and 2007 nearly 40% of coral were subjected at least once to temperatures high enough to trigger serious coral bleaching. Looking at the combined impact of local stress factors and thermal stress from ocean warming, 75% of reefs can currently be considered threatened (Burke et al., 2011).

The future of coral reefs in the Anthropocene

Population growth, the growing demand for fish and agricultural products, and further coastal development are set to increase the pressure on coral reefs. However, the fastest-growing threat to coral reefs is the continuing increase in emissions of CO_2 and other greenhouse gases (Burke et al., 2011). Especially CO_2 not only leads to higher temperatures but also to an acidification of the oceans, thus reducing the concentration of carbonate ions in seawater (Section 1.2.5). Seawater must be sufficiently supersaturated with carbonate ions for the calcification process to be possible. Calcification is not only the basis of coral-reef growth, it also helps to counteract the process of reef erosion. Hoegh-Guldberg et al. (2007) point out that calcification in coral reefs disappears as soon as aragonite supersaturation falls below a value of 3.3 – which is to be expected in large parts of the ocean when atmospheric CO_2 concentration reaches 480 ppm. Besides increases in the temperature and acidification, there are other factors related to climate change that also affect coral reefs. The rising sea level (Section 1.2.7), possible changes in the intensity of storms, droughts, and changes in sediment flows can all have a strong regional impact on coral reefs (Hoegh-Guldberg, 2011). While the geological evidence shows that coral reefs grow well when sea levels rise, and are thus able to maintain their protective function for the lagoons and coastlines located behind them, this is only true if growth conditions are otherwise intact. Acidification, for example, reduces the calcification rate and hence ability of coral reefs to grow and 'keep up' with rising sea levels; overfishing and overfertilization cause more algae to grow on the coral and so reduce its potential for growth and regeneration. Many types of coral have already been seriously decimated by overfertilization; one example is the elkhorn coral, which is adapted to hurricanes through its ability to regenerate quickly. Some coral reefs might re-form as different types of coral communities with much reduced ecosystem services (Leinfelder et al., 2012; Seemann et al., 2012). However, most reefs are not resilient enough to withstand the pressures of a combination of factors. They tip over into other ecosystem states such as soft-organism or microbe dominance, which have nothing more in common with productive, highly diverse coral reefs (Bellwood et al., 2004; Hoegh-Guldberg et al., 2007).

Frieler et al. (2013) demonstrate that if global temperatures rise by more than 2°C, coral reefs will no longer be prominent within coastal ecosystems. Even making optimistic assumptions about the thermal adaptability of coral, and assuming that ambitious climate-protection measures are put in place, thus limiting global warming to 1.5–2°C, a third of coral reefs worldwide can be expected to be degraded in the long term.

Burke et al. (2011) estimate that, by the 2030s, 90% of all coral reefs will be threatened by local human activity, warming and acidification. For 60% of coral reefs, this threat will be 'high', 'very high' or 'critical'. Up until this point in time, the threat from warming will be stronger than the threat from acidification, although approximately 50% of coral reefs will be affected by both factors. By 2050 the authors believe that the risk will be high, very high or critical for 75% of coral reefs, and medium-high for most of the rest. Only in a few regions in Australia and the South Pacific might there still be coral reefs left that are only subject to a low level of threat.

Coral reefs are resilient systems, well able to withstand temporary disturbances as long as they are not already damaged. But if these temporary disturbances occur too often, or if some of them continue for a long time, coral reefs offer a sad example of one tipping-point triggering the next in a cascade effect. Coral reefs thus provide an accurate monitor of the extent, frequency and speed of environmental changes in the Anthropocene. How these changes develop over time will determine whether coral reefs are able to retain their resilience (or even improve it), whether they partially transform into other ecosystems with far fewer ecosystem services for humanity, or whether they quickly disappear in a cascade of tipping points. The result would be the loss of 'blue pharmacies', providers of natural coastal protection, fishing grounds and above all fascinating geo-biological systems at least for the duration of the Anthropocene.

imately 1 million exajoules per year, a gigantic amount of energy – although technically and economically only a very small proportion can be made available for human use (GEA, 2012: 432).

The theoretical potential of offshore wind and ocean energy (tidal currents, wave energy, ocean-current energy, sea-temperature gradient), together with the advances in technological development that have already been made, suggest the use of the oceans for a future sustainable energy system. It can also be assumed that advancing technology developments will help defuse competition over ocean use, since, on the one hand, the amount of space required will be reduced by the integration of different uses and, on the other, it will be possible to generate power using wind and ocean energy further away from intensively used coastal regions. If properly planned, harnessing energy from the sea could involve much less conflict than on land.

Depending on locational conditions and societal preferences, future marine energy generation, as proposed by the WBGU, would consist of a modular system combining various marine energy technologies (such as offshore wind-power generation and macro-algae cultivation) with modern forms of storage (spherical storage tanks and methanization) via a modern offshore transmission grid. This vision is discussed in detail in Chapter 5.

1.3.2
Raw materials

The demand for mineral raw materials has risen significantly in recent years, driven by fast-growing, newly industrializing countries like China and India. This is also being reflected in rising world-market prices. The rise in commodity prices between 2003 and 2008 and the prospect of finite resources on land has re-awakened interest in the economic development of a wide range of raw-materials sources in and below the seas. Explorations of marine deposits began as early as the 1970s and 80s in response to a report by the Club of Rome (1972 – Limits to Growth). These activities were closely related to the negotiations on the UN Convention on the Law of the Sea (UNCLOS) and the establishment of the International Seabed Authority.

A wide range of deposits and sources are possible sites for future commercial use in the regions of the Earth covered by the oceans. These differ in terms of their geological origins, mineral composition and size of deposit. Numerous base metals (manganese, cobalt, nickel) are used in the steel industry, and there have been growing signs in recent years that the demand for many other elements is likely to rise because they are needed for the technologies of the future. These include, for example, lithium (rechargeable batteries), tellurium (solar cells), neodymium (magnets for engines and generators), tantalum (microelectronics), platinum and scandium (fuel cells), and many more (IZT and ISI, 2009).

Massive sulphides

Massive sulphides are sulphur-containing metal ores found in regions of volcanic activity along plate boundaries, usually at depths of between 1,500 and 3,500 m (Baker and German, 2008). These deposits are of economic interest primarily because of the base metals (cadmium, lead, copper) and precious metals (gold, silver and platinum) they contain (Glover and Smith, 2003; Baker and German, 2008).

Approximately 40% of all known deposits are located within the exclusive economic zones of nation states and are therefore not subject to the jurisdiction of the International Seabed Authority (Hoagland et al., 2010). The present state of knowledge makes it impossible to estimate the total size of the resource with any certainty, especially since the thickness of the strata can only be reliably measured by laborious drilling. According to current estimates, the total exploitable resource amounts to approximately 600 million tonnes, which is equivalent to about 30 million tonnes of copper and zinc (Hannington et al., 2011). In the view of Hannington et al. (2011) this will not be sufficient to cover growing demand in the long term.

The extraction of massive sulphides will soon be commercially viable. Several companies (some of which are listed on the stock market) are involved in intensive exploration efforts and plan large-scale implementation in the coming years (Schrope, 2007; Baker and German, 2008). At present it is impossible to estimate whether the companies' activities will become economically profitable in the near future or whether these efforts are motivated more by the hope of securing strategic advantages.

Manganese nodules

Manganese nodules are predominantly found at depths of between 4,500 and 5,500 m – on top of usually very fine sediment. The 3-10 cm large nodules can cover up to 70% of the ocean floor. On average, manganese nodules contain about 28% manganese, 1.3% nickel, 1.1% copper, 0.2% cobalt and about 0.7% other trace metals such as molybdenum, lithium, and neodymium (Kuhn et al., 2010), so that the nodules' metal value (March 2011) is approximately €370 per tonne (Kuhn et al., 2011). In particular, the relatively high proportion of (heavy) rare earths may be of relevance to their future strategic importance (Hein, 2012).

Mero (1965) estimated the total deposits of manganese nodules at 1,500 billion tonnes, although this figure was subsequently reduced to 500 billion tonnes (Archer, 1981). Furthermore, it will only be possible to extract a small proportion of this economically in the future. With a global annual production of 20 million tonnes (0.004% of deposits), this would already account for a third of the current world production of cobalt and manganese (German Parliament, 2012).

The so-called Clarion Clipperton Zone in the central Pacific Ocean has particularly rich deposits and has been designated by the International Seabed Authority as an exploration and potential mining area. Here, Germany has acquired the exploration rights with a subsequent mining option for the period from 2006 until 2021 for an area of 75,000 km². After the completion of these pilot surveys in 2021, the International Seabed Authority will decide whether the exploration phase (including environmental impact studies) will be followed by commercial deep-sea mining.

The technology for extracting manganese nodules could be available relatively soon. However, transporting the nodules to the ocean surface is even more problematic than in the case of massive sulphides because of the greater water depth involved. In addition to the demands relating to water depth, another key challenge for the environmentally sustainable development of this resource is the large quantities of very fine sediment that is released into the water column during mining. Manganese nodules seem unlikely to be developed until a few years after extraction of massive sulphides begins, since the latter are to be found in shallower water; they also offer very high yields and have fewer negative environmental effects. Another contributory factor here is that the approval process for manganese nodules will be more complex because of the deposits' position in international waters.

Cobalt crusts

Cobalt crusts (also known as manganese crusts) are playing a relatively minor role in the current debate, even though they occur at relatively shallow depths of between 400 and 4,000 m and are of economic interest due to their high content of cobalt, titanium, cerium, nickel, platinum, manganese and other metals (Hein, 2002). Cobalt crusts reach a thickness of up to 25 cm. However, separating them from the rock immediately beneath them complicates extraction, since otherwise the purity of the ore is reduced and worthless stone is transported to the surface of the sea at great expense (Hein, 2002).

Environmental impact of mining mineral resources on the seabed

Extracting the different resources involves a number of risks that apply to all three types of deposits. The mining leads to an increase in shipping traffic and, consequently, to more material emissions and a higher accident risk. Furthermore, removing or churning up deposits destroys the benthic habitat of the upper layer of the sea bed together with the fauna that grow there. Three factors are relevant to evaluating this kind of intervention.

The first step is to estimate how big an area will be destroyed. On this issue, clear distinctions can be made between the three resources. In the case of massive sulphides, a relatively small layer is removed that can be more than 100 m thick, i.e. only a comparatively small area is destroyed. By contrast, removing cobalt crusts, which are only up to 25 cm thick, leads to the destruction of much larger areas of habitat on the seabed. However, mining manganese nodules would affect the biggest area. Glover and Smith (2003) estimate that the area that would be destroyed by two or three mining projects over a period of 15 years could total up to 180,000 km² – the equivalent of half of the area of the Federal Republic of Germany. In addition to the immediate region of the mining operations, the area affected depends largely on the spread of the additional input of sediment. Because the individual particles are so fine, the dispersed sediment spreads across large distances and remains in the water column for a long time. Under the prevailing hydrological conditions, however, about 99% of the particles dispersed close to the ground undergo sedimentation within a month at a distance of less than 100 km from the extraction point (Rolinski et al., 2001). This leads to high sediment inputs in the vicinity of the mining area, causing considerable stress to the marine fauna. Similarly, plumes of sediment also arise during transport to the sea surface as a result of the sediment that sticks to the manganese nodules. However, the quantities of sediment introduced into the water column in this way are orders of magnitude smaller than the sediment churned up near the bottom (Oebius et al., 2001). The sediment inputs into the water column are spread over very large areas (probably 10^5-10^6 km²; Rolinski et al., 2001), so that the resulting deposition rates are significantly smaller than the natural sedimentation rate in the region (Jahnke, 1996).

Further decisive factors are the uniqueness of the destroyed fauna (e.g. endemic species) and the speed of repopulation. In general, biological processes in the deep sea progress very slowly due to the low temperatures and the usually low level of food availability, so that recolonization is also relatively slow. In the case of manganese nodules, mining removes the only solid substrate. Repopulation studies conducted on experimental mining areas have shown that, although they were largely repopulated within a few years, the composition of species still differed from the reference surfaces 26 years after the intervention (Miljutin et al., 2011). Whereas active hydrothermal deposits of massive sulphide are characterized by a special fauna, the fauna in inactive areas differs little from what is found on normal hard substrate. For this reason, current mining plans for massive sulphides are concentrating on such inactive sites. To date there is little information on the environmental effects of any mining of cobalt crusts. However, seamounts, on which cobalt crusts are to be found, often represent the only elevation within a wide radius, so that endemic species have developed relatively often here – and these would be threatened by any mining.

At present it is impossible to estimate the extent of any future use of raw materials from the sea. In WBGU's view, it is extremely important that new uses do not become another large-scale threat to marine ecosystems that are already exposed to multiple stress factors. Among other things this will depend on how the International Seabed Authority (Section 3.2.3) fulfils its role and regulates mining activities in the future. The future use of mineral resources is not a major focus of this report and is therefore not dealt with in greater detail here.

1.3.3
Marine genetic resources

Another use of the sea that might become increasingly important in the future is the use of marine genetic resources. The study of species generally has an immense influence on medical research and drug development (Chivian et al., 2008). Marine organisms are especially interesting for medical research for several reasons. There is evidence to suggest that, at least in the case of microorganisms, the level of diversity in the sea is considerably greater than previously thought and might be greater than it is on land. Furthermore, their genetic blueprints and metabolic pathways are particularly diverse, partly because of the extreme conditions in the deep sea (Sogin et al., 1996). They are therefore especially significant and valuable for human medicine (Bathnagar and Kim, 2010). Bioprospecting – i.e. the exploration of biological material for the purpose of processing it for potential industrial use (WBGU, 2001) – is actually more often successful in marine ecosystems than on land (Arrieta et al., 2010). Yet only a fraction of the oceans has been studied so far, and knowledge of the deep sea in particular is still very sparse (Pimm et al., 2008).

Despite the large gaps in knowledge, marine organisms are a rich source of bioactive substances, which often exhibit properties that are not found on land (ten Kate and Laird, 2000: 44). The list ranges from antiviral substances from red algae to anticarcinogens from brown algae, bryozoans and sponges, to pain-relieving agents from cone snails and antibiotics from coral (Chivian and Bernstein, 2008; Leary et al., 2009). These examples underline the considerable option value of genetic resources from the seas (Section 1.4.1). This wealth is only beginning to be used, so that only few drugs from marine genetic resources have been approved to date. Research into marine genetic resources is generating more and more interest, and the global market for biotechnology products is showing annual growth rates of 4–5% (Imhoff et al., 2011).

Marine biotechnology has also experienced a dynamic development in Europe in recent years (Børresen et al., 2010). The seas are regarded as one of the most important and promising sources of future natural active ingredients for medical research and other applications such as dietary supplements, enzymes and cosmetics (UNU, 2007; Børresen et al., 2010).

In bionics, too, the study of marine organisms is playing an important role in the development of new materials and structures (e.g. silicon-based biomaterials from sponges: Wang et al., 2012). The biological and genetic blueprints of marine species thus represent a significant future resource for research and development (Erwin et al., 2010; Imhoff et al., 2011.).

Up to now, studies of marine genetic resources have generated over 18,000 natural products and 4,900 patents (Arrieta et al., 2010). However, it is difficult to estimate the value of these resources. A review article by Leary et al. (2009) puts the current sales value of selected products which originate from marine genetic resources and are used in the pharmaceutical industry, the enzyme market and the cosmetics industry at about US$1.5 billion per year. However, these figures only represent a selection of the products and are subject to uncertainties. Børresen et al. (2010) estimated the global market for products and processes from marine biotechnology at US$2.8 billion in 2010. Other sources quote much larger numbers (Slobodian et al., 2012). To date there are few scientific studies assessing marine biological resources or ecosystem services, and this applies especially to the deep sea (Armstrong et al., 2010). However, there are proposals aimed at tackling these gaps in knowledge within the TEEB project (The Economics of Ecosystems and Biodiversity; Beaudoin and Pendleton, 2012).

Whatever the exact value of marine genetic resources may be, it is hardly taken into account at all when decisions are made on human interaction with marine ecosystems – with the result that marine habitats are still being destroyed while scientists are simultaneously exploring these valuable sources for new drugs and materials. There have already been cases where, after an organism's promising effect has been discovered, the organisms themselves can no longer be found at the original locations because the area has been destroyed in the meantime (Newman et al., 2008). Yet when a species has become extinct, its anatomical, genetic, biochemical and physiological blueprints, which may be of great value to medicine or for other uses, are irreversibly lost (WBGU, 2001: 19). Since gene banks, zoological and botanical gardens and other ex-situ collections can only hold a fraction of biological diversity, there is no alternative to protecting species and ecosystems in situ (WBGU, 2001: 130). For this reason, too, marine conservation is of special importance (Arrieta et al., 2010; Sections 3.6.2, 7.3.9).

Not enough is known about the possible effects on the marine environment of using genetic resources (Leary et al., 2009). Taking samples from marine organisms, especially from those living near the ocean floor, always involves interference and can potentially also cause damage. However, greater problems arise when interesting organic products are removed from natural ecosystems in large quantities. This can lead to the overuse of the desired marine organisms and to collateral damage to the ecosystems as a result of the collection activity. However, compared to other human activities in the sea, notably fishing, the interventions seem to be rather minor overall; they can furthermore be avoided by cultivating the marine organisms or producing the active ingredients synthetically (Hunt and Vincent, 2006).

While access to marine genetic resources is clearly regulated in the territorial seas and the EEZs, there are regulatory gaps when it comes to areas seaward of national jurisdiction, in the high seas and in the "Area" (Figure 3.2-1), which have increasingly been attracting the attention of international politics in recent years (UNU, 2007; Glowka, 2010; Leary, 2012; Fedder, 2013). They will be taken up again in the discussions on the new Implementing Agreement on Biological Diversity on the High Seas (Section 3.3.2.2) and in the recommendations for action (Sections 7.2.3.1, 7.3.4.2).

1.3.4
New developments in marine aquaculture

Industrial aquaculture has grown strongly over the last few decades, and this has brought with it not only economic gains, but also regional environmental problems and negative social effects. For several years now, above all two developments in marine aquaculture have been important when it comes to new production systems and technologies: integrated multitrophic aquaculture (IMTA) and offshore aquaculture – as well as combinations of the two approaches (Ferreira et al., 2012; Section 4.2.2.4).

IMTA is the integrated cultivation of species at different levels of the food web, such as fish, algae, filter feeders and detritus feeders. The aim is to increase the environmental compatibility and profitability of aquaculture compared to monocultures by making better use of feeds, waste and energy – to be achieved by breeding additional marketable organisms (Troell et al., 2009). Multitrophic aquaculture has been a tradition for centuries in Asia, primarily using ponds on land, and the principles of IMTA are well researched under tropical conditions. However, the approach is still in its infancy in the coastal regions of temperate latitudes. Moreover, it is much more difficult to measure the effectiveness and effects of IMTA in open waters because of the hydrodynamic conditions (Holmer, 2010; Ferreira et al., 2012). Outside Asia, experiments have been conducted since the 1970s involving the intensive cultivation of seaweed and mussels for treating sewage, and, since the 2000s, for making use of effluents from aquaculture operations. In addition, the rapid growth of mariculture and the relocation of fish farms to regions further from the coast (e.g. in Norway, Chile, Spain, Ireland and the USA; Holmer, 2010) has generated renewed interest in IMTA. However, most studies of this approach focus on relatively small, land-based systems, few deal with IMTA in open waters. In the last 15 to 20 years, research has concentrated mainly on the integration of seaweed, mussels or oysters with fish farms (Troell et al., 2009).

The integration of multitrophic systems into offshore aquaculture could reduce the level of pollution of adjacent waters with nutrients, which is a result of the openness of the system and the incomplete use of feed. This could improve the level of social acceptance of such fish-farming facilities. Some commercial offshore IMTA systems already exist in China, and in other countries they are moving towards commercialization. However, further research is needed to adapt to different environmental conditions and transfer methods to other species (Troell et al., 2009).

Offshore aquaculture (i.e. aquaculture under harsh marine conditions and usually several nautical miles away from the coast) offers a possible solution to growing conflicts for space in coastal regions, which are under ever-increasing pressure. However, the commercial use of aquaculture in waters far from the coast is only just beginning, due to the considerable technical challenges and high costs involved (Bostock et al., 2010; Holmer, 2010); one example is in the USA (Naylor and Burke, 2005). It is estimated that the majority of the aquaculture industry will not move into offshore regions over the next 10 to 20 years (Dempster and Sanchez-Jerez, 2008). Partially or completely submersible cages in coastal waters currently offer a much more readily available alternative for reducing usage conflicts in coastal areas, since they involve less danger of collisions or storm damage, and conflicts with the coastal population caused by aesthetic problems can be avoided. This technology is already in use in Italy, Hawaii and New Hampshire/USA. For the time being, technical and operational obstacles are standing in the way of wider dissemination (Dempster and Sanchez-Jerez, 2008).

One possible future technology is fish cages that float freely with the currents in the open sea, like the ones that were successfully tested recently for the first time off Hawaii. According to the operator, the fish fattened very quickly and showed very good health values; there were only small losses (Kampachi Farms, 2011). The spherical cages are already being used off the coasts of Korea, Panama, Mexico and the USA, although in these cases they are anchored to the sea floor (Sims and Key, 2011; Lubbadeh, 2013). Another potentially interesting idea might be integrating aquaculture with renewable energies, e.g. breeding mussels and algae on offshore wind farms (Buck et al., 2008). Furthermore, several EU pilot projects are currently researching the development of new multifunctional platforms in which energy generation from renewable sources is combined with aquaculture and transport-related services (Section 4.2.2.4).

Closed-cycle systems on land are another new technology in which, for example, organisms can be bred in marine water (e.g. Stockstad, 2010). This is not discussed further here since it does not involve the use of coastal or marine areas: the production is not connected to the sea (see Section 4.3.2.4).

The production systems mentioned here can help reduce some environmental stresses and conflicts. However, the potential danger and the waste burden of large future offshore aquaculture plants are not yet known at present (Troell et al., 2009; Holmer, 2010). Moreover, as long as marine fish are bred, the problem remains of being dependent on catches of forage fish to produce fish meal and oil for the feed, although here, too, research has made progress in recent years (Section 4.3).

1.4 Shaping the future of the marine ecosystem

As became clear in the previous sections, humans have already interfered profoundly with the marine ecosystems. The Anthropocene also manifests itself in the oceans, and this signals the dawn of a new era of human responsibility for shaping the future of marine ecosystems. A return to a situation in which people's influence reverts back to pre-industrial levels seems neither possible nor desirable. Similarly, continuing the current momentum of anthropogenic changes cannot be the goal either, since this would put the maintenance of ecosystem functions and services at great risk. The question remains, therefore, what should guide the interactions between humanity and the oceans in the future. This implies a challenge for science to explore and explain the range of possibilities for future developments by assessing the consequences of different options. The question as to which principles should be used as a basis for assessing policy options and creating norms to guide actions is a question of ethics (WBGU, 1999b), while deciding which consequences and developments are desirable must be a societal issue.

In the WBGU's view, it is time to develop a new ethics for the Anthropocene. One starting point here is to avoid the kind of anthropogenic developments that are threatening the life-support systems of present and future human civilization.

1.4.1
Primary principles and values

In its 1999 report entitled *Environment and Ethics*, the WBGU initially describes two different positions from which ecosystem services and biodiversity can be assessed: anthropocentrism and biocentrism (WBGU, 1999b). The anthropocentric view places humanity and their needs at the fore; Nature's own original demands are alien to this view. Interventions in nature are allowed if they are useful to man. A duty to make provisions for the future and to conserve nature exists in the anthropocentric view only to the extent that natural systems are classed as valuable to people today and subsequent generations and that nature can be classed as a means and guarantor of human life and survival. In the biocentric concept, which forms an opposite pole to the anthropocentric view, the needs of humanity are not placed above those of nature. Here, every living creature, whether human, animal or plant, has intrinsic rights with regard to the chance to develop its own life within the framework of a natural order. Merit for protection is justified in the biocentric view by an inner value that is unique to each living creature. Nature has a value of its own that does not depend on the functions that it fulfils today or may fulfil later from the human point of view (WBGU, 1999b).

Neither pure anthropocentrism nor pure biocentrism seemed acceptable to the WBGU at the time; rather, the Council preferred a moderate form of anthropocentrism. From this perspective, humanity and their needs are in the foreground, but the value of the biosphere for humans is defined very broadly. In WBGU's 1999 report, distinctions were made between the following value categories in the process of determining the 'total economic value' of biospheric services:

- *Use-dependent values:* This category contains economic benefit – for instance for purposes of production or consumption – (e.g. cereals as food, wood for bioenergy, relaxation in a natural landscape), functional benefit (ecosystem services, such as the protection of coasts by mangroves or the hydrological cycle), and symbolic value for religious or spiritual uses (e.g. sacred trees or heraldic animals).
- *Non-use-dependent values:* This category includes the existence value, which expresses the human being's appreciation of the existence of nature, species or ecosystems without this being linked to any specific benefit.
- *Option values:* These relate to the potential uses that lie in the future, are not specifically foreseeable today and are therefore difficult to assess, e.g. the potential medical benefit of genetic resources in drug development (Section 1.3.3).

In practice, moderate anthropocentrism and moderate biocentrism are likely to lead to similar conclusions when it comes to action norms. Until such time as a new ethics has been developed for the Anthropocene, the WBGU will also draw upon this view in the present report.

1.4.2
Guiding principle for human interaction with the oceans

In the WBGU's view the challenge for human interaction with the oceans in the Anthropocene is to combine two goals. The first is to keep or reach a 'good state' for the oceans which secures marine biodiversity and ecosystem services in the long term for both the present and future generations. The second goal is to make it possible for the oceans to be used in a sustainable way, so they can make important contributions to food and energy supplies and, in more general terms, to the necessary transformation towards sustainability. Stewardship of the oceans should take its orientation from the following three fundamental approaches.

1.4.2.1
Think systemically: Regard and maintain the sea as an ecosystem and as part of the Earth system

An ecosystem is a dynamic complex of plants, animals, micro-organisms and the nonliving environment, all interacting as a functional unit (MA, 2005a). Humankind depends fundamentally on ecosystem services, which in turn depend on the maintenance of biological diversity (CBD, 2010a). At the same time, human beings are an integral part of the ecosystems. The WBGU believes that humanity should strive for healthy, productive and resilient marine ecosystems, including their biological diversity.

A precondition for achieving this goal is avoiding damaging effects on the oceans that can threaten ecosystems. These include pollution (contaminants, nutrients, sediments), acidification, climate change, etc. It is also essential to avoid the overexploitation of marine biological resources and to prevent the ongoing drastic loss of marine biodiversity. Developed in the context of the Convention on Biological Diversity (CBD, 2000, 2004c), the ecosystem approach is in the meantime a widely recognized concept in the intergovernmental field and beyond; it is used in many areas of ecosystem management. For example, the implementation plan of the Rio+10 Summit in Johannesburg calls on countries to establish the approach in fisheries by 2010 (WSSD, 2002: §29d), and the FAO regards the ecosystem approach as a way to achieve sustainability in fisheries and aquaculture (FAO, 2003, 2009a, Sections 4.1.3.1, 4.2.3.1). The WBGU supports this approach. However, it remains relatively abstract and needs to be fleshed out for each specific application.

The marine ecosystems are furthermore integral parts of the Earth system. Acting as a huge store for heat and carbon, it plays a major role in determining the Earth's climate, partly via the ocean currents. Coral reefs and mangroves once protected tens of thousands of kilometres of mainland and island coasts from storms and floods. Not only in the oceans, but also in other parts of the Earth system, do critical developments take place that run counter sustainable development; one important example is anthropogenic climate change. Managing the ocean's ecosystems cannot, therefore, be viewed in isolation, but must always be assessed in the context of its interaction with other subsystems of the Earth system. For example, marine conservation that does not consider the requirements of climate protection or the protection of the terrestrial biosphere is not to be recommended. In many cases, this view in turn indirectly serves marine conservation, since the subsystems of the Earth system interact: for example, a reduction in CO_2 emissions simultaneously slows down ocean warming and acidification. Not least, a systemic perspective includes taking into account the guard rails for ocean conservation developed by the WBGU (Box 1-1).

1.4.2.2
Act in a precautionary way: Take uncertainty and ignorance into account

The precautionary principle has been established for a long time in the context of environmental and development policy. According to this principle, "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UNCED, 1992a). This is of particular importance for the oceans because many systemic relationships have only recently become known, and in many cases the complex interactions render precise predictions about future developments impossible. Many marine ecosystems are simultaneously subjected to several sources of stress – such as the growing acidification of sea water, the input of pollutants and overfishing, or the physical destruction of ecosystems, whose interactions are poorly researched (Section 1.2.8). For these reasons, it is often not clear whether, and under what circumstances, extensive damage might be done to ecosystems. Furthermore, the ocean is characterized by high levels of inertia, so that many effects of human activity only become visible after a delay and corrections take time. In the WBGU's view, therefore, it is appropriate to exercise great caution in the use of the seas. In addition, decisions on human interaction with the oceans should be flexible and reversible to make it possible to respond to new scientific evidence on the effects of human actions.

1.4.2.3
Cooperate: overcoming the tragedy of the commons

Many parts of the oceans are freely accessible as 'commons', often without any restrictions or monitoring. Many human interventions follow the pattern of the frequently-described 'tragedy of the commons', according to which freely available, but finite resources are under threat from over-exploitation (Hardin, 1968). At the same time, the oceans are being exposed to all kinds of new uses. Examples include shipping routes opening up as the Arctic ice melts, prospecting for and extracting energy and mineral resources in the deep sea, generating renewable energy on and in the sea, and offshore aquaculture. These uses generate new pressures of use and pose new threats to marine ecosystems, sometimes in a cumulative way. In many cases, they also are competing with each other. Studies conducted by Ostrom et al. (1999) on local common goods (water, lakes, pasture land) show that the overuse of common goods is primarily due to a lack of rules, for example the fact that no rights of use are allocated. In the WBGU's view the aim must be to continue to allow the use of the seas as a common good, but to subject this use to clear rules to avoid overuse.

In the WBGU's view, regarding the sea as the 'common heritage of mankind' is a good starting point for rules on the sustainable use of the sea. This concept has already been enshrined in international law in relation to the mineral resources of the seabed outside national state jurisdiction under the UN Convention on the Law of the Sea (UNCLOS; Section 3.2). The WBGU proposes applying this principle consistently to the oceans, which should thus belong to all people, both today and in the future (Section 7.2.1). The concept should be linked with the idea of humanity taking on responsibility in the Anthropocene and with the concept of sustainability. Finally, a clear assignment of rights of use and duties to protect the heritage of mankind, as well as an equitable distribution of the benefits and costs that are involved, could prevent the unregulated access to the marine ecosystems and the overexploitation that often results. In this way, the character of the oceans can be preserved as they are – as a global common good that is accessible to all and whose use can benefit everyone – while at the same time the requirements of maintaining the life-support systems are taken into account.

1.4.3
Exemplary specification of the guiding principle for the sustainable stewardship of the marine ecosystem

Starting with a global transformation towards sustainability, in which climate change is of particular importance, the WBGU has examined the necessary transition to a low-carbon society in detail in a previous report (WBGU, 2011). The use of the sea plays a major role in two of the three transformation fields for climate protection identified by WBGU: in the 'energy' transformation field, where the use of marine energy can contribute directly to the transformation of the energy systems, and in the 'land use' transformation field, which is linked to the supply of food from the sea via nutrition. The WBGU takes up these two transformation fields in the present report and analyses them in relation to the seas. It asks what contribution can a sustainable use of the seas make to the two key areas of human need – energy and nutrition – and to their transformation:

- How can energy be generated in and on the seas in a sustainable and climate-friendly way?
- How can fishing be made sustainable, and how can food be sustainably produced in aquaculture in such a way that marine ecosystems are protected?

The overarching, key question, however, is how further overexploitation can be prevented, and how a sustainable use of the oceans can be implemented in practice:

- What kind of governance of the oceans is required that is equal to the challenges of the Anthropocene?

Global Society and Social Contract 2

2.1 Global society and world's oceans

2.1.1 The global society in the Anthropocene

A crucial factor in the further development of ocean governance as proposed by the WBGU is the fact that the oceans are the medium of globalization and the 'liquid' foundation of the global society. While man appears in the Holocene – as stated metaphorically (although scientifically not quite correctly) in a novella by the Swiss novelist Max Frisch (1979) – by analogy, humankind become aware of their global socialization and responsibility in the Anthropocene. This awareness originated and became consolidated when people began discovering the globe by transcontinental seafaring and the related observations of the sky. On the oceans, humanity arrived at a global self-awareness in the Hegelian sense, beginning with the raids of the Vikings, who travelled as far as North Africa and North America in the 9th–11th centuries. This was after the Phoenicians, Greeks and Romans had already created the first ocean-related, regional identities by colonizing the Mediterranean. The Romans did this in the form of a political empire (mare nostrum) and a universal legal system. The Hanseatic League and colonial expeditions of the European powers in the 'Age of Discovery' consolidated this global awareness and spawned both a maritime culture and a law relating to the oceans. This law has universal or global features inasmuch as it cannot be based on territorial delimitation and defines the high seas as a global common good and, by analogy, as the 'heritage of mankind'. This potential needs to be further developed in the sense of a global social contract, as people became aware of global interdependencies and 'glocal' governance.

The world's oceans were the natural environment of the emerging international system of states. The emergence of modern statehood and the global economy was largely driven by the first wave of globalization, which took place on the world's oceans, during the period of early and high colonialism – under the aegis of first the Portuguese and Spanish, then the Dutch, British and finally the US Americans. International relations, international law and free world trade developed on this basis. Globalization, which began about five hundred years ago, is characterized by the open sea. Expansion into the sea differed significantly from expansion on land because it was not guided or impeded by boundary marks. This spontaneous, practical universalism and cosmopolitanism characterizes the law of the sea and globe-spanning trading and transport relations, always in a dualism relationship to the development on land, which was based on constitution, concentration and cooperation, but also on the compartmentalization and the exclusivity claims of nation-state systems.

At the same time the oceans took on mediating functions. This is especially true of the coastal cities, which were forever seeking to extend their freedom from the stranglehold of national or imperial orders by global networking. Tourists and all those who lived near the sea discovered the coasts as a preferential aesthetic-utilitarian space and, in the 19th century, the beaches as a place of recuperation and as summer resorts. Then came cruise tourism, which evolved in the course of the 20th century from a privilege of the aristocracy and upper classes to maritime mass tourism. In this phase there was a huge increase in the various ways in which the common good (i.e. the world's oceans) was used; these uses are described in more detail below. This led to overuse and pollution (Chapter 1). This was also the period in which the first regulations (now recognized as inadequate) on the use and conservation of the oceans were issued at the national, regional and global levels (du Jourdin, 1993; Rothermund, 2002; Weigelin-Schwiedrzik, 2004; Benjamin, 2009; Abulafia, 2011; Thornton, 2012; Winchester and Müller, 2012; Kupperman, 2012; Arthus-Bertrand and Skerry, 2013; Hattingois-Forner, 2013; Roberts, 2013).

2.1.2
The emerging global society and global society theory

Recent decades have seen global trends such as the development of a global market economy, a worldwide communications and knowledge infrastructure, a globe-spanning transport network and a civil society that increasingly operates in global networks. These global trends have become concentrated, leading to the gradual formation of global interdependencies. These global interlinkages are exerting a growing influence on developments in the individual nation states. As a major transport medium for both goods and people, the oceans are still playing a key role in the development of these global relations. Today, approximately 95% of global long-distance freight tonnage is shipped by sea (Flottenkommando der Marine, 2011:94). Maritime passenger and freight traffic now covers the entire globe (Figure 1.1-1).

Further important components of global interdependencies today are the human induced global environmental changes which affect the marine ecosystem either directly or indirectly via the impact of land-based activities on the sea. If the collective scale of human activity in the Anthropocene has become a dominant planetary force, and the global society has risen to become the key subsystem of the Earth system, then this affects not only the surface of the land, but also the world's oceans. Recent analyses (Halpern et al., 2008) show that 40% of the oceans today are seriously affected by human activities; hardly a single region is still untouched. If the growing trend towards overexploiting the Earth's atmosphere, soils, water and resources continues, there is a real danger that the planetary guard rails will be breached, causing irreversible damage to humanity's natural life-support systems (WBGU, 1995b, 1999a, 2001, 2004, 2011; Rockström et al., 2009a).

Such risks to the global Earth system undermine the operational logic of existing nation-state institutions, because they can no longer be limited geographically to the latter's territory and jurisdiction. "Environmental globalization means that we all increasingly affect each other regardless of where we live" (Harris, 2010:141). Not all regions of the Earth are equally affected by the impact of global environmental changes; on the other hand, not all societies have the same infrastructural, technical and economic ability to adapt either. Nevertheless, in a 'global risk society' (Beck, 2007) – a constitutive element of which is a historically unique degree of connectivity between a large number of players – many critical phenomena are almost impossible to contain regionally, which increases the overall vulnerability of the social system (Homer-Dixon, 2006:112f.). Hence, a failed state like Somalia is not only a problem for its own population and neighbouring countries such as Ethiopia or Kenya: pirates operating from Somali shores also threaten important international shipping routes and have led to ongoing military operations in the region, e.g. by NATO, the EU and China.

The spatial expansion of social and economic interlinkages, and the absence of an adequate regulatory framework or functioning international institutions, have created a situation in which no nation state – however powerful it might be – is today able to solve the problems that mankind faces in a globalized world alone (Beck, 2007:356 ff.). The impotence of national policy measures is not limited to containing global environmental problems, it also affects the economic and social problem areas that result from a largely uncontrolled and accelerated globalization. As a result, regional and global challenges, which seemed to have been overcome at the national level by environmental and welfare-state measures, keep coming back (Messner, 2000:55). Global environmental problems like climate change or the threat to the oceans – to say nothing of the global financial and economic crisis – have a kind of 'macroscope' effect that brings home to people the globe-spanning network of their interdependencies and makes humanity aware of the emerging global society.

For a long time, the practice of tying the concept of society to the nation state ('methodological nationalism', as Michael Zürn calls it in *Regieren jenseits des Nationalstaats*, 1998) has prevented people from thinking of the world in its entirety as a social unit in its own right (Greve and Heintz, 2005:89). Yet as early as the early 16th century, Erasmus of Rotterdam described the world as a 'common fatherland of all people' (Erasmus 1521; Leggewie 2001). In the writings of the French Freemasons of 1740 the world was referred to as a great republic to which each nation belonged as a family and every individual as a child (Messner, 2000:45). Immanuel Kant introduced the concept of the 'global civil society' in 1784 and explained it in more detail in his essay *Perpetual Peace* (1795). The first half of the 20th century was marked by two World Wars and the Great Depression. The famous pictures of the 'blue planet' made possible by manned spaceflight in the late 1960s were translated into the concept of the One World (Messner, 2000:45). These images thus represent an 'objective' equivalent to subjective self-ascertainment on the oceans in the early modern period, which was described in chapter 2.1.1 as an awareness of global socialization and responsibility.

While such terms as 'global economy', 'world literature', 'citizen of the world' or 'world peace' are part of everyday language usage, the concept of 'global society' remains controversial (Messner, 2000: 46). In the early 1970s the theorem of the 'global society' (Greve and Heintz, 2005) was introduced into the scientific debates – almost simultaneously and yet independently – by a number of authors. They included John Burton (1972), Niklas Luhmann's systems-theory-based global society theory (1975[1971]), Peter Heintz's global society theory (1974), which arose in the context of development sociology, and John Meyer's world polity theory (1980). All global social theories share the idea that a comprehensive global context has emerged in the course of historical development which has its own form of social organization. The global society is characterized by non-reducible structural features, and all social processes and units should be regarded as a consequence of these emerging global structural features (Greve and Heintz, 2005).

This distinguishes global society theories from conventional globalization theories, most of which go no further than observing an increasingly networked world. 'Global society', by contrast, has a double meaning. First, the term means that a global cause-and-effect relationship has developed that crosses national borders (Greve and Heintz, 2005: 110) – and here it is consistent with the globalization theorem. However, it goes further than this and states that overarching structures have developed within this global interdependency network, which has an effect on events and processes on the lower levels of the system (Greve and Heintz, 2005: 110). This refers not only to supranational governmental organizations, but also to overarching regulatory structures and institutions such as an observable global macroeconomic convergence (market economy), transnational milieus and mentalities (an international business class, global diasporas of migrants) and international normative orders (such as human rights, democratization, the legal formula 'responsibility to protect', etc.). This second level of meaning of global society theory is controversial. Critics of the concept argue that a global society presupposes a minimum of consensus, i.e. an implicit or explicit social contract. They say that this is not the case at present, nor do the prerequisites of such a common shared understanding exist – such as comparable socio-economic living conditions or a shared sense of belonging (Messner, 2000: 46).

The main difference between the evolving global society on the one hand, and societies that are organized in nation states on the other, is the absence of effective executive power. However, a wide variety of corresponding regulations or institutions are forming in international law which are continuously increasing in importance (*lex mercatoria*, international trade law, the WTO and the World Bank, regional courts of human rights, the International Tribunal for the Law of the Sea, the permanent International Criminal Court, authorities supervising compliance with the universal human rights pacts, the 'Rio Conventions' on climate, biodiversity and desertification, and so on). This development is also reflected in the growing importance of global rating agencies or private arbitration tribunals for resolving disputes between transnational corporations, e.g. the International Centre for Settlement of Investment Disputes ICSID (Fischer-Lescano and Möller, 2012: 17ff.). The system of states still forms the basis of legitimacy and, in a sense, the skeleton of these supra- and transnational agreements and bodies, but the nation states have no primacy when it comes to their design: "The global society is a society without a top and without a centre. (...) This decentralization and differentiation (...) is Janus-faced. It offers new opportunities and changes the balance of power, but it also produces massive risk situations" (Fischer-Lescano and Möller, 2012: 16f., own translation).

Although few doubt the existence of the global society in the sense of a global network of interdependencies, the degrees to which overarching regulatory structures have been realized differ considerably to date.

Building global regulatory structures and institutions is made difficult by the comparatively large geographical, cultural and social distances between the players involved in the genesis and reproduction of global structures (Greve and Heintz, 2005: 111). The problem of geographical distance has declined in importance over the last decade, primarily due to significantly easier travel and the revolution in communications technologies. However, the mere existence of a technical infrastructure is not sufficient to generate globe-spanning interrelations: "A cultural infrastructure is also required to counter cultural and social heterogeneity" (Greve and Heintz, 2005: 112, own translation).

As a medium of globalization the oceans have made an essential contribution to the evolution of the global society and still represent its backbone. A reformed form of ocean governance could therefore also provide stimuli for a sustainable design for the global society. There has been an international regulatory framework for the conservation and sustainable use of the oceans for a long time (e.g. in fishing, shipping). Although it still needs to be developed further, it is already far more advanced than what we see in other areas of international relations or for the governance of other global public goods (Chapter 3). Despite the importance of the seas as an example of a comparatively well-developed international level of institutionalization, the oceans and ocean governance have so far been paid little attention in the various attempts to theorize the global community.

2.1.3
The cosmopolitan challenge

The development of the global society does not automatically promote peace, nor does it lead directly to more welfare. The political and institutional/legal containment of market-driven globalization is one of the future challenges of the 21st century (Messner, 2010: 53 and 71). One possible way to create the conditions needed to enlarge the scope for political decision-making is to establish 'cosmopolitan forms of statehood' (Beck 2007:128) like the ones that have evolved in processes like European integration, the development of international organizations and various forms of global governance (Beck, 2007:126ff.). The Europeanization and – at the global level – cosmopolitanization of the political regulatory framework and institutions would not only provide an opportunity to deal more effectively with such problems as the global financial and economic crisis, socio-economic inequality or the challenges we face as a result of global environmental changes (like damage to the marine ecosystems); it would also generate fundamentally new possibilities for participation and democracy. The global society must not inevitably lead to the kind of undemocratic world government feared by warning voices. For example, in many places of the world people already have no or only limited political participation rights today, because their nation-state affiliation is not identical to the state in which they live. However, at present it is too early to say what forms of 'cosmopolitan democracy' (Gilroy, 2004:7) might look like; Paul Gilroy therefore speaks of a 'cosmopolitan yet-to-come' (Gilroy, 2004:334).

As a rule such cosmopolitan prospects and discussions on the global society and a world government are dismissed as unrealistic wishful thinking. However, cosmopolitanism is no longer a utopian principle dreamed up in ivory-tower debates between social scientists and philosophers; rather, in the Anthropocene, it is an admission of constraints and interdependencies that already exist. From this perspective it is not the proponents of a cosmopolitan order who are quixotic and out of touch with reality, but all those who want to hold on to the primary organization framework of the nation-state in a globally interdependent world (Beck, 2007).

The inadequacy of international cooperation and institutions – which can be observed, for example, in the political processing of anthropogenic climate change or the global financial and economic crisis – should not obscure the fact that there are already a large number of global institutions, some of which work well, some less well – e.g. the World Bank, the World Health Organization, but also international NGOs like the Red Cross, Amnesty International and Greenpeace. Extensive international arrangements are already in place for the protection and use of the sea, such as the Convention on the Law of the Sea (UNCLOS) and transnational private initiatives such as the Marine Stewardship Council (MSC; Section 3.5.1).

Of course, the existence of such transnational institutions does not mean that the strong sources of resistance to the establishment of cosmopolitan forms of governance can be ignored. This resistance can come from national policy-makers who fear a loss of power or from players in the business sector, and organized global irresponsibility plays into the hands of their profit interests. Another factor not to be disregarded is the importance of people's acquired fixation on the nation state, which makes it difficult for people today to identify with the societal units and institutions that transcend nation states (Elias, 1987:301ff.). This can be observed, for example, in the European integration process. These forms of resistance are enormous and it is quite possible that all efforts to cosmopolitanize the institutional structure will fail. The difficulty lies in harmonizing people's thinking and feelings ('sense of belonging') with the social and political institutions and their de facto global interdependencies. In this sense, cosmopolitanism describes not simply the name of a solution, but a challenge (Appiah, 2007:11).

2.1.4
Global appreciation of the oceans

"We must take the oceans to our hearts," declared German Chancellor Angela Merkel at a conference of her party on marine conservation in 2011 (Merkel, 2011). On the one hand she surprised everyone with this, since the oceans and their condition are not a top issue in Germany; on the other hand she received widespread approval, since the population in Germany, too, regards the oceans as very important and gives a high priority to their conservation. This finding – which is based on comparative public opinion polls and a few clues from the World Value Survey (WVS, 2011) – is confirmed by detailed empirical studies conducted in the USA, New Zealand, Australia, the UK and other countries (Spruill, 1997; Arnold, 2004; Sesabo et al., 2006; Mee et al., 2008; Whitmarsh and Palmieri, 2009; Freeman et al., 2012; Halpern et al., 2012; Ressurreição et al., 2012; Ranger et al., no date). The issues covered included the establishment of marine protected areas, the need for ecosystem-based marine spatial planning and the implementation of European marine-conservation policies. These studies show that

- although the oceans do not take top priority among the ecological crises in the public's perception, there is a growing understanding of their central role in the environmental system and in environmental protection.
- the general public have strong positive associations and emotional bonds with the oceans. The example of the seas makes the subject of sustainability especially plausible; i.e. with a view to conserving marine quality there is a broad social consensus in favour of abandoning uses that are not sustainable.
- most people believe that the oceans are under threat and generally favour stricter regulation, more conservation efforts and an expansion of protected areas. People wrongly imagine that the level of conservation is higher than it actually is. A slightly higher preference is given to the protection of coastal areas compared to the deep sea; emissions from the land are regarded as more dangerous than, for example, the negative consequences of overfishing.
- public opinion is in favour of marine research and recreational activities at the seaside, but tends to be cautious to sceptical vis-à-vis commercial uses of the sea.

These findings raise action dilemmas and questions for research. *First,* people's general assessment of the oceans and their conservation should be queried repeatedly over time and in a more differentiated way than hitherto. In this context, a) the positions of key players (the fishing and aquaculture industries, nature-conservation and environmental organizations, the tourism industry) should be determined including their general attitudes and values, b) more distinctions should be made according to cultural traditions, incomes and geographical location, and c) sectoral projects and plans should be made more compatible with ecosystem considerations.

Second, in addition to general attitudes to the oceans and marine conservation, questions should also be asked about people's willingness to help improve the quality of the sea by paying higher taxes, changing their behaviour as consumers and actively participating in marine conservation themselves. Willingness to do so declines the lower the person's income, the further the person's residence is from the coast, and the more aware the person is of the specific consequences of a conservation strategy for each individual (e.g. restrictions on the choice of holiday destination, behaviour during a beach holiday, higher prices of certified fish products, etc.).

2.2 A social contract for the seas

2.2.1 A social contract as a basis for the Great Transformation

The following section is essentially based on, and partly taken verbatim from, the WBGU-report 'A Social Contract for Sustainability' (2011). In this report the WBGU explains the urgent need for – and the benefits of – a transformation towards sustainability and gives recommendations on how to achieve this goal. The WBGU defines the Great Transformation as the global remodelling of economy and society towards sustainability. The goal of the transformation towards sustainability is to safeguard humankind's natural life-support systems for the long term. This major transformation will require technological advances, new concepts of welfare, diverse social innovations, and an unprecedented level of international cooperation (WBGU, 2011).

The idea is for the global economy to operate within the limits of the Earth system (*planetary guard rails*) and thereby avoid irreversible damage. But the Great Transformation will not only avoid irreversible damage to the Earth system, it will also deliver valuable benefits for humankind. Overall, then, the transformation establishes patterns of production and consumption which maintain the freedoms, scope and opportunities of present and future generations (WBGU, 2011). This challenge can only be mastered through a broad social dialogue and a consensus on the core issues relating to sustainability. The WBGU calls the required global societal consensus a *new social contract*, combining responsibility for the future with democratic participation. In this consensus of global reach, individuals and civil-society groups, governments and the international community, businesses and science pledge to take on shared responsibility for maintaining natural life-support systems. For example, agreements would be concluded on the conservation of global common goods.

Modern philosophy justifies state order and political power with the idea of the social contract, which had precursors as early as Antiquity. In line with this model, individuals unite of their own free will in political communities, agreeing to uphold common rules and accept corresponding duties for mutual benefit (WBGU, 2011). Representatives of classical contract theory include Thomas Hobbes (1588–1679), John Locke (1632–1704), Jean-Jacques Rousseau (1712–1778) and Immanuel Kant (1724–1804). The social contract was a radical one because it no longer saw the individual as part of a God-given order but as an autonomous being with responsibility for shaping society. The new social contract for sustainability should have a global reach because of the international nature of the risks and natural hazards involved; it can no longer relate to the nation state alone.

A key element of this social contract is the 'proactive state' with greatly extended participation by citizens. While the liberal constitutional state is primarily focused on maintaining public order, the welfare state's main concern is the wellbeing of its citizens, while the enabling and guarantor state safeguards the fulfilment of public functions. The proactive state actively sets priorities for sustainability and flags them up by providing appropriate incentives and sanctions. The proactive state thus upholds the tradition of the liberal constitutional democracy but develops it further with a view to achieving a sustainable democratic polity and free civil society; in this context the proactive state takes into account the ecological borders within which an economy and society can develop (WBGU, 2011).

The great transformations the human race has so far experienced were, for the most part, the uncontrolled results of evolutionary change. Scientific knowledge is an indispensable element of modern governance and is becoming increasingly important in our ever-more-complex world. This applies in particular to the transformation towards a sustainable society because one of the latter's distinguishing features is the need to act in conditions of uncertainty. The task of the scientific community is therefore to identify policy options; it is a matter for the democratically elected decision-makers to decide on the appropriate course of action (WBGU, 2011).

2.2.2
Reform of ocean governance

The way the oceans are used today is still overwhelmingly characterized by exploitation. If this trend continues unchanged, and if no agreements are signed to protect the oceans, then irreversible damage is very likely (Chapter 1). This section shows how – in WBGU's view – the governance of the oceans should be reformed in order to permanently ensure the conservation and sustainable use of the seas. The WBGU's report 'A Social Contract for Sustainability' (WBGU, 2011), in which the Great Transformation is centrepiece, forms the basis of these thoughts.

The application of the Great Transformation to the oceans would change the way the oceans are used. In our interaction with the seas, humanity must act both as 'smart hunters and gatherers' and as 'sustainable gardeners'. In this way the currently precarious state of the oceans could be not only stabilized but also improved. A one-sided approach focusing on individual types of use would not do justice to the need to protect oceans.

The need for a reform of ocean governance comes on the one hand from the unsolved sectoral and regional problems in the areas of fishing, aquaculture and other marine ecosystem services. On the other hand, a systemic view of the seas reveals how these sectoral and regional problems can mutually influence and reinforce each other. It follows that certain rights of use must be subjected to critical revision, and local, regional and supranational instruments of governance need to be scrutinized. In this context not only the oceans, but also the interaction between the land and the sea should be taken into account.

The basis of such an overarching form of governance would be a consensus on the sustainable stewardship of the seas as a global common good in the form of a *social contract for the seas*. In this way humanity should take responsibility for the permanent conservation of the sea as a global common good. By assuming responsibility, the international community would commit itself to actively managing humanity's impact on the oceans and to counteracting negative developments. This *responsibility of global society for the future* should be combined with democratic participation. Conflicts of use (e.g. between coastal conservation and tourism) should be solved in a participatory way and be supported by change agents, who are to be found in (semi-)public and private organizations and movements. In this context the assumption of responsibility means not only protecting the natural environment, but also equitably sharing marine resources and preserving the oceans' functions for future generations – not only for coastal states, but for all countries.

Governance of Human Ocean Use 3

This chapter examines whether the existing governance of the oceans can cope with the challenges of the Anthropocene. A regulatory framework for human interaction with the oceans started developing as early as the 17th century. Yet the conflict between the *mare liberum* (the sea belongs to everyone) and the *mare clausum* (the sea belongs to the coastal states) has not been resolved to this day. Despite numerous international treaties and voluntary commitments, the seas are still being massively overfished, polluted and increasingly exploited as the Earth's last major source of resources (Chapter 1). It can therefore be assumed that the global governance regime in its present form cannot solve the problems facing the oceans. Building on this analysis, in this chapter the WBGU develops proposals for the further development of ocean governance with the aim of ensuring the conservation and sustainable use of the seas on a global scale.

3.1 Specifics of the seas

In order to assess the existing global and regional ocean-governance systems and to develop a future-oriented form of ocean governance, the WBGU formulates criteria based on findings of political and social science. Using these criteria, it begins by analysing and assessing present-day global and regional governance (Sections 3.2 to 3.7). In Chapter 7, proceeding on this basis it gives recommendations on how best to design a future system of ocean governance that can meet the challenges of the Anthropocene.

Three aspects are of particular importance to human interaction with the oceans (Section 1.4). These are (1) the oceans as part of the Earth system (Section 3.1.1), (2) uncertainties regarding future development (Section 3.1.2), and (3) the oceans as a global public and common good (Section 3.1.3).

3.1.1 Oceans as part of the Earth system

The oceans and the marine ecosystems are part of the Earth system and provide vital services for humanity. At the same time, human beings are an integral part of the ecosystems and influence their dynamics whenever they use them. Irreversible damage can be caused to marine ecosystems both by ocean pollution and by the overexploitation of individual biological resources such as fish species. Furthermore, the complex systemic interactions and feedback loops in the oceans do not follow the logic of national frontiers; in many cases they are linked across borders and globally– like the oceans themselves (Costanza et al., 1999; Posner and Sykes, 2010). Another impacting factor is land/sea interaction (e.g. the discharge of waste and pollutants produced on land into the sea via rivers), and the interaction between the atmosphere and the ocean (e.g. ocean acidification). The WBGU therefore considers it necessary to think systemically: i.e. not only to embrace the ecosystem approach (Section 1.4.2.1), but to go further. Up to now, ocean governance has been characterized by a sectoral approach depending on the respective use (Section 1.1). The motivation behind applying the systemic approach is to make it possible to gain an integrated view of the interactions between natural and social systems (Sections 1.4, 2, 7). The aim is to ensure that when interventions are planned, not only on their effects within the marine ecosystems are assessed, but broader systemic interrelations are also taken into account. Such a combined, integrated way of looking at things is required in order to develop a form of ocean stewardship that can solve problems. The systemic approach thus represents the first touchstone for the analysis and assessment of existing ocean governance (Section 3.1.4).

3.1.2
Demands on marine policy caused by knowledge gaps

Another important factor impacting on the design of marine policy is the scientific uncertainty and lack of knowledge regarding the future development of the oceans (Sections 1.2, 1.3). The complex interactions between the ecosystems and their use-related and external threats are often either not understood or impossible to predict. Similarly, the effects of future anthropogenic influences can only be predicted to a limited extent today. In the same way, there is no knowledge of possible future uses, or of the societal conditions under which decisions will be made in the future. However, these uncertainties should not be taken as a reason to refrain from taking action to protect and sustainably manage the oceans. Precautionary action is absolutely essential, because the oceans are in such a worrying state. The precautionary principle (Section 1.4.2.2), which has been established in environmental and development policy for a long time, should therefore play a role. The precautionary principle is the second touchstone for a future-oriented governance of the oceans.

Since the oceans and the Earth system are in the state of flux, a marine policy that is committed to the sustainable use of the oceans also needs to be continuously improving the knowledge base. Knowledge of the structures and dynamics of the ecosystems should be constantly expanded to improve the basis on which policy decisions are made. It is important in this context to be able to quickly apply the continuously expanding pool of knowledge to human interaction with the oceans; in other words adaptive management is needed. The WBGU regards adaptive management as a further touchstone to be met by ocean governance. Like a learning process, it should contribute to the iterative improvement of ocean conservation and management (Costanza et al., 1998).

The timely availability of new knowledge requires transparent information for all players, above all access to the relevant data. In the WBGU's view, therefore, ensuring transparent information is another touchstone that should be met by ocean governance. This touchstone is also of significance for other touchstones derived from the oceans' nature as a global public and common good, e.g. the need to ensure participatory decision-making structures (Section 3.1.4).

3.1.3
Oceans as a global public and common good

The WBGU regards the seas as a global public and common good which provides humanity with public goods, such as ecosystems and ecosystem services, and commons in the form of individual biological and non-biological resources (Chapters 1, 2; Box 3.1-1). By definition, no person or state may be excluded from the use of public and common goods for technical or societal reasons. At the same time, there can be non-rivalry in the consumption of public and common goods, in other words all users can use a good at the same time without restriction. This is why public and common goods are not offered via markets, but are produced collectively by means of cooperation (Kaul et al., 1999).

Commons, or common-pool resources, such as marine biological resources, are a subcategory of public and common goods. Marine biological resources, e.g. fish stocks, are limited and frequently non-stationary, so that free access or unregulated use can lead to the overexploitation or degradation of the resource (Hardin, 1968; Ostrom, 1990). In the case of common-pool resources there is rivalry in consumption, since the use of the resource by one person or one country has negative effects on all other possible users' chances of use (Ostrom, 1990; Posner and Sykes, 2010). Both overcoming the 'tragedy of the commons' (Hardin, 1968; Section 1.4.2.3) and the supply of global public and common goods, e.g. global ocean conservation, requires the cooperation of all stakeholders on the basis of collective rationality, and the development of rules for dealing with the global public and common good (North, 1992; Kaul et al., 1999; Vogler, 2012). However, it is individually rational *not* to participate in cooperation or pay the costs involved, but to take the so-called free-rider position (Weimann, 2010). This social-dilemma situation encourages the overuse of the seas and makes investments in the provision of marine ecosystem services economically unattractive for individuals (Posner and Sykes, 2010).

Because marine ecosystems, their services and threats to them do not respect national borders, regulations at the level of the nation state fail, because they cannot solve the problems of cross-border negative externalities or the international free-rider problem (Posner and Sykes, 2010). For global public and common goods, like the oceans or marine resources, this social-dilemma situation can only be resolved through the cooperation of all nation states and by agreeing rules on how to deal with the public and common goods. At the same time, it must be collectively agreed how international free-rider behaviour can be excluded or sanctioned (Sandler, 1998; Weimann, 2010).

Box 3.1-1

The oceans as a global public and common good – Non-sustainable business models as a consequence of false incentives

Up to now, most business models of the maritime industry, such as fishing, transport or mining, have been geared towards short-term benefit and are therefore not sustainable. The respective users ignore the long-term effects of individual uses such as fishing, oil and gas extraction or sewage discharge, as well as the interdependencies between the various forms of use. This leads to a constellation that is typical of negative externalities, in which there are no incentives for the individual players to think long-term. Apart from the fact that incentives either do not exist or point in the wrong direction, the short-term nature of entrepreneurial business models is also encouraged by the fact that many current users of the seas (be they producers or consumers) are benefiting from these business models and lobbying politicians accordingly (WBGU, 2011).

The fundamental conflict between short-term interests and profit maximization on the one hand, and long-term, sometimes irreversible damage and costs on the other, is also a determining factor for other global public and common goods; loss of biodiversity, loss of habitat and climate change are all caused by short-term-oriented business models and the short-termism of political systems. Both the corresponding long-term consequences (such as tipping points, creeping overuse) and the costs are passed on to future generations (WBGU, 2011). Climate change is a prominent example here: despite a scientific consensus, mankind looks likely to breach the 2 °C guard rail (WBGU, 2009).

Nicholas Stern, former chief economist at the World Bank, pointed out as early as 2006 that investment in preventing greenhouse-gas emissions is more cost-effective than measures to adapt to the adverse effects of climate change (Stern, 2006). However, investment in prevention would have to be made in the present, whereas necessary adjustment measures, especially in Western industrialized nations, are only expected in the future. We have to do with a similar contradiction between short-term costs and long-term yields in connection with the use and conservation of oceans (WBGU, 2009, 2011).

Especially thorny social dilemmas are involved when measures need to be taken which only pay off in the long term, but already incur costs today, e.g. sustainable fisheries (Chapter 4). Seen from an individual standpoint, sustainable fishing is not rational, but it would be rational from a collective perspective: the consequence is otherwise an over-exploitation of fish stocks and, over time, a loss of the potential uses of the commons (Chapter 4). A distorted incentive structure can lead to the development of unsustainable business models for the management of the global commons and make it impossible to overcome the social-dilemma situation (Section 3.1-1).

On the basis of numerous case studies, Elinor Ostrom has studied how local communities have overcome social dilemmas relating to local common-pool resources such as forests, water supplies, pastures, etc., by developing rules (Ostrom, 1990, 2009a; Ostrom et al., 1999; Cox et al., 2010). Various measures can be derived from these studies which are constitutive for designing rules on dealing with public and common goods:

- define clear-cut boundaries between users and non-users,
- secure coherence of local social and ecological conditions,
- assert the principle of community decision-making,
- make sure that uses are monitored,
- set up conflict-resolution mechanisms,
- establish a regime of sanctions,
- ensure that the rights of local users are recognized,
- establish nested, non-hierarchical levels of decision-making.

The sea, as a public and common good, is used by many actors with different interests (Chapter 2). This constellation, along with the global interlinkages that have expanded strongly in the last 20 years, undermines the logic of existing nation-state institutions, because these actor-constellations and interlinkages can no longer be limited geographically to the latter's territory and jurisdiction.

To internalize external effects in the use of the sea and in ocean conservation, it is critical that rights of use (in the economic sense) of the sea as a public and common good are defined and assigned (Kaul et al., 1999; Costanza et al., 1999; Gawel, 2011). Simultaneously, local, regional and national regulations on use should be embedded into the global regime on use, and free-rider behaviour should be suppressed at every level of governance. Kaul et al. (1999) write on this subject that divisions between national and international politics need to be overcome. In this context, rules for joint decisions should be developed to overcome the social dilemmas (Chapter 2). Global cooperation mechanisms are another criterion for assessing the governance of the ocean as a global public and common good (WBGU, 2011; Section 3.1.4).

Ostrom (2009b) speaks in this context of a polycentric form of governance, which she says is necessary in view of the challenges associated with global public and common goods such as the atmosphere or the oceans. This underlines the fact that the global governance architecture needs to be geared to a larger number of public and private players, from global to local. Global collective action requires systemic thinking (Sections

1.4.2.1, 3.3.1), adequate opportunities for the participation of societal players, and a division of labour according to the subsidiarity principle (Chapter 2). In the WBGU's understanding, the subsidiarity principle requires that the lower political level must initially be responsible for solving problems. The next-higher level is only legitimized to act if it can implement and finance strategies for a sustainable use of the oceans more efficiently (WBGU, 2004: 152). Global bodies of rules should leave enough room for manoeuvre in order to develop and implement regionally adapted solutions (WBGU, 2011). The WBGU sees subsidiary decision-making structures as another key criterion for the governance of the oceans, because they help improve acceptance and effectiveness (Section 3.1.4). All relevant stakeholders should be involved at an early stage in designing human interaction with the sea as a global public and common good. In this way it is possible to guarantee that rules will 'fit' and can be implemented. Participatory decision-making structures are therefore another important criterion for a successful governance of the oceans.

Since global public and common goods always run the risk of falling victim to market failure – e.g. in situations where a player seeks short-term profit maximization based on individually rational considerations, and the associated external costs are passed on to the general public (and in this case especially to future generations, Box 3.1-1) – ocean governance should create incentives to encourage the development of long-term, sustainable business models (WBGU, 2011). The WBGU therefore regards incentives to develop innovations for sustainable and low-risk ocean uses as another key criterion for a successful governance of the seas (Section 3.1.4).

The existence of an attractive and efficient incentive structure is also a fundamental prerequisite for overcoming nation-state vested interests and getting them involved in international cooperation (Chapter 2; WBGU, 2011). In other words, in addition to mechanisms for allocating rights of use, rules should also be established on distributing both the profits from the use of the oceans and the costs of conserving them. These distribution mechanisms should be based on principles of equity. In the WBGU's opinion, therefore, the governance of the oceans should have fair distribution mechanisms for cost and benefit sharing both between countries and between different levels of a country's government (WBGU, 2009).

In some cases, rules are more likely to be complied with if all players accept their material and procedural design as justified and sensible (Chapter 2; Mitchell, 1994; WBGU, 2011). The distribution of costs and benefits according to a mechanism whose internal design is regarded as fair and which involved as many stakeholders as possible in its development, is much more likely to be adhered to than one designed in the opposite manner. Ultimately, however, diverging interests can never be completely resolved by negotiations. Incentives for non-compliance will thus remain for certain, individual actors (Mitchell, 1994). Moreover, new conflicts not considered in previously negotiated agreements can crop up as a result of changing conditions (e.g. access to new resources in the Arctic made possible by the melting of the Arctic ice). Conflict-resolution mechanisms are therefore needed to ensure the coordination of dynamically evolving user interests. And last, but not least, sanction mechanisms are needed to ensure compliance with agreed rules and to exclude free-rider behaviour.

3.1.4
Touchstones for assessing the existing governance of the oceans

The touchstones for assessing the present governance of the oceans are based on the two fundamental perspectives or action-guiding principles outlined above: the 'systemic approach' and the 'precautionary principle' (Sections 1.4.2, 7.1). Furthermore, the WBGU includes the criteria described in Sections 3.1.1 to 3.1.3 in the assessment and recommends that they be used to analyse existing ocean governance at the various levels from local to global. These ten criteria take into account both the specifics of the oceans and general demands on governance.

- The sector-specific approaches that are commonplace today should be replaced by a *systemic approach* (Section 3.1.1) in which conservation, use, pollution and all interactions between these factors in human uses of the seas are integrated in a single 'big picture'. The approach comprises four levels. First, marine ecosystems are themselves complex systems which should be protected and used according to an 'ecosystem approach' (CBD, 2000, 2004c). Second, land/sea interactions should also be taken into account. Third, the linkages in the Earth system should be considered. Fourth, it should be taken into account that there are complex and dynamic interactions between society and nature on all these levels.
- According to the *precautionary principle* (Section 3.1.2), steps based on state-of-the-art science and technology should be taken to prevent possible environmental damage, even when there is no complete certainty as to the probability and magnitude of damage. The application of the precautionary principle is particularly important in complex sys-

tems – to which marine ecosystems and their land/sea interactions belong – because their reactions to influences or disturbances are difficult to predict.

- *Adaptive management* (Section 3.1.2) aims to continuously improve the knowledge base for governance and to promptly use it in the conservation and sustainable use of the oceans. Adaptive management aims to broaden our knowledge of the structure and dynamics of ecosystems via a learning process and thus iteratively improves the protection and management of the seas.
- *Transparent information* (Section 3.1.2) ensures that all stakeholders have access to the relevant data.
- A *clear assignment of user rights* (Section 3.1.3) is necessary to prevent the overexploitation of the sea as a public and common good. This makes it possible to exclude certain users and thus to coordinate use – either via markets or by negotiations. Furthermore, the societal costs of use can be charged to the users according to the 'polluter pays' principle, so that the external costs are internalized.
- Neither the conservation nor the sustainable use of the oceans as a global public and common good will be possible without an unprecedented level of global cooperation culture and *global cooperation mechanisms* (Section 3.1.3). Global cooperation forms the basis for the development of international treaties on marine conservation and use, as well as for the joint implementation of these treaties.
- *Subsidiary decision-making structures* (Section 3.1.3) – assigning decision-making powers primarily to decentralized decision-makers at the regional or local level, and secondarily to central international agencies – are crucial for the acceptance of global and national regulations. Moreover, such an interpretation of subsidiarity makes regulations easier to enforce efficiently.
- *Participatory decision-making structures* (Section 3.1.3) make it possible to reveal interests; they lead to decisions that all stakeholders can understand.
- *Incentives for innovation* (Section 3.1.3) encouraging a sustainable, low-risk use of the oceans should aim to reward stakeholders who develop long-term, sustainable business models on the use and conservation of the seas – instead of seeking short-term profit maximization.
- *Fair distribution mechanisms* (Section 3.1.3) should aim to ensure an equitable division both of the benefits of marine resource use and of the costs – e.g. of conservation, monitoring, surveillance and sanctions. This applies to costs and benefit sharing both between countries and between different levels of a country's government.
- *Conflict-resolution mechanisms* (Section 3.1.3) are necessary in order to coordinate the many and complex use interests of different stakeholders (e.g. governments and individuals).
- *Sanction mechanisms* (Section 3.1.3) at the different levels of governance are key instruments for ensuring that regulations on use are complied with.

3.1.5 Common heritage of mankind

The concept of the 'common heritage of mankind' was developed for global public and common goods in the 20th century and, in the *Zeitgeist* of the 1960s, enshrined as a concept in four international conventions (the 1967 UN Outer Space Treaty, the 1982 UN Convention on the Law of the Sea, the 1961 Antarctic Treaty, and the 1972 World Heritage Convention; Baslar, 1998; Taylor, 2012). As an ethical approach of legal theory, the concept of the 'common heritage of mankind' states that global public and common goods – such as outer space, the atmosphere, the ocean floor, or the Antarctic – belong to all human beings, today and in the future, so that national sovereignty rights cannot be claimed. What this means for international environmental policy is that the world's natural resources are to be preserved and protected so that they can also be used by future generations (Baslar, 1998).

Common ownership of public and common goods, which is linked with the approach of the common heritage of mankind, requires a steward, a regime for conservation and use that serves exclusively peaceful purposes, and regulations on sharing to ensure that the benefits and costs of the regime are fairly distributed (Wolfrum, 1983; Baslar, 1998; Taylor, 2012). The world community is responsible for the preservation and use of global environmental goods and, as a user of the global environmental goods, must therefore organize and design their protection in a cooperative way, and justly distribute the benefits of their use and their costs.

The age of the Anthropocene combined with the requirements of sustainable development (Section 1.4) also leads to a new form of responsibility of the international community to preserve humanity's natural life-support systems (WBGU, 2011). The Anthropocene requires a new ethic to enable humankind to meet its organizational responsibility. In relation to the oceans this means that the specific properties of the seas must be taken into account (Sections 3.1.1, 3.1.2). From the sustainable development approach follow the norms of intra- and intergenerational justice, which are key to the conservation and use of the sea (Section 3.2). Consequently, in the 21st century the sea as a global public and common good requires an extended regime of conservation and use in order to fully meet humanity's responsibility in the Anthropocene (Chapter 7).

The question is, therefore, to what extent the idea that the oceans, too, are part of the common heritage of mankind (Mann Borgese, 1999) is suitable and strong enough as a guiding principle for the conservation and use of the sea – an idea already developed in the 1960s by Arvid Pardo and Elisabeth Mann Borgese and introduced into the political genesis of UNCLOS (Chapter 2, Section 3.2.2, Box 3.2-2).

3.2 Ocean governance in international law: UNCLOS

The United Nations Convention on the Law of the Sea (UNCLOS) is the most important basis for the conservation and use of the seas in international law (Wolfrum and Fuchs, 2011). The treaty is also referred to as the 'constitution of the oceans' (UN, 2002). It establishes a comprehensive regulatory framework for the conservation and use of all the oceans and, as a framework convention, standardizes rights and obligations on a wide range of different uses of the ocean space and its resources (Czybulka and Kersandt, 2000). UNCLOS was adopted in 1982 and came into force in 1994, combining the previously existing laws that were codified in the Geneva Conventions on the Law of the Sea. 164 states and the European Union had ratified the Convention by January 2013. Although the USA contributed greatly to the formulation of UNCLOS, it has still not ratified the treaty (Borgerson, 2009). UNCLOS has to be specified in greater detail by national law or international conventions (Box 3.2-1).

By establishing different zones within the oceans, UNCLOS seeks to solve the fundamental conflict between the free use of the seas by all states and the claims to the sea made by individual coastal states (Box 3.2-2; Wolfrum and Fuchs, 2011). The principle that applies here is that the sovereign rights and jurisdiction of nation states (in particular their rights of use) decline, the further from the coastline of the respective state the use is located (Vidas, 2010; Maribus 2010).

The extraction and exploitation of resources on the seabed is an exception in this context. Since the seabed seaward of the continental shelf, including the non-living resources, has been declared part of the common heritage of mankind and is administered by the International Seabed Authority (ISA), a tax on profits from deep-sea mining and compulsory technology transfer has been agreed on the initiative of the developing countries.

In addition to the regulations on the status of the marine zones and the economic use of the oceans, UNCLOS also emphasizes the importance of marine environmental protection. However, it is the states parties themselves that decide whether they meet the protection requirements imposed on them by UNCLOS (Wolfrum and Fuchs, 2011).

Compared to the previously existing (use) regime, UNCLOS considerably extended the rights of coastal states and flag states, thus taking into account a 'nationalization' of the oceans (Shackelford, 2010). Only the high seas and the seabed beneath the high seas do not fall under national jurisdiction since they are territories beyond national sovereignty. UNCLOS emphasizes the sovereign rights of states to use their natural resources, and its primary aim was to solve the 19th and 20th century marine conflicts of use over the drawing of national frontiers and the appropriation of resources. Although these conflicts are still relevant, the law of the sea today faces new challenges: the state of the oceans, the unbroken trend towards further overuse and pollution (Chapter 1), and new opportunities for tapping marine resources created by new technologies (Chapter 1; UNGA, 2011; Wolfrum and Fuchs, 2011). The following analysis focuses on the extent to which the international law of the sea, as a multilateral treaty, can successfully regulate a 'responsibility for the seas' in the Anthropocene (Vidas, 2010; Gjerde, 2011) and provide a suitable framework for a sustainable use of the oceans within the framework of the planetary guard rails – or to what extent it perhaps needs to be further developed.

3.2.1 Zoning of the oceans by UNCLOS

UNCLOS divides the oceans into zones, defines the legal status of these zones, and standardizes the rights and jurisdictions of coastal and flag states that apply in each one (Wolfrum and Fuchs, 2011). The scope of UNCLOS extends over the entire ocean seaward of the coast line, also known as the *baseline*. According to Article 5 of UNCLOS this is usually the low-water line along the coast. Alternatively, in localities where the coastline is deeply indented and cut into, or if there is a fringe of islands along the coast, straight baselines can be laid down by joining appropriate points. The extent of the individual zones is determined on the basis of the baseline. The decisive factor when it comes to whether it is permissible to use the oceans and marine resources, and by whom, is the marine zone in which the use would occur. In principle, a state's jurisdiction decreases, the further a location is from the coast. However, the right of innocent passage (Article 17 ff. of UNCLOS) applies in all marine zones, regardless of whether state sover-

Box 3.2-1

Further specification of UNCLOS with implementing agreements

Due to its nature as a framework treaty, UNCLOS refers in numerous provisions to the need for further specification by national law or international conventions. However, the Convention does not offer a procedure of its own for international negotiations to define UNCLOS stipulations in greater detail. Implementing agreements are therefore the subject of negotiations as multilateral treaties under international law and become effective among the states parties through signature and ratification. Implementing agreements do not alter UNCLOS. Should UNCLOS and an implementing agreement contradict each other in wording or content, this contradiction must be resolved by interpretation. As a rule, implementation agreements contain interpretation guidelines which ensure the primacy of the underlying framework convention. Two international implementing agreements have been agreed on UNCLOS to date:

- the Agreement of 28 July 1994 relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982 (seabed regime; Section 3.2.3.2);
- the Convention of 4 August 1995 for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (Section 4.1.4.4).

eignty applies. The following rules apply to the individual marine zones (Figure 3.2-1).

3.2.1.1 Territorial sea

The *territorial sea* (Articles 2 to 32 of UNCLOS) extends up to 12 nautical miles (nm) seaward from the baseline. The sovereignty of the coastal state covers this territorial sea and includes territorial jurisdiction over the sea, the air space above it, the seabed and the subsoil. The coastal state is entitled to use the sea and to enact regulations in this area, e.g. on the exploitation of resources, the installation of offshore wind turbines, and conducting marine research. The coastal states can supplement internationally valid rules with stricter national rules on environmental protection, the prevention and reduction of marine pollution, discharges, etc., which must then be respected by transiting ships (Kimball, 2001). The coastal state's jurisdiction over the territory and its use is, however, limited by the right of innocent passage, which allows ships of all states to pass through the territorial sea without the coastal state's permission. To ensure the safety of shipping, the coastal state has the option of setting up shipping lanes. However, the use and protection of the territorial sea must not lead to any hindrance or restriction of the right of innocent passage (Proelß, 2004; cf. also Article 211, para. 4 of UNCLOS). In this respect the territorial sea differs from the *internal waters* located on the landward side of the baseline (Article 8 of UNCLOS), where there is no such restriction of national jurisdiction, since UNCLOS does not apply there.

3.2.1.2 Contiguous zone

The so-called *contiguous zone* is a border-control zone located seaward of the territorial sea. Its exclusive purpose is that of border control, i.e. to prevent or punish infringements of customs, fiscal or immigration laws, etc. As a control zone the contiguous zone does not have any territorial legal status of its own, so that it is located as a rule within the area of the EEZ (Graf Vitzthum, 2006). According to Article 33 of UNCLOS the maximum extent of the control zone is limited to 24 nm seaward of the baseline.

3.2.1.3 Exclusive economic zone

The *exclusive economic zone* (EEZ; Articles 55 to 75 of UNCLOS), which is adjacent to the territorial sea, extends up to 200 nm seaward of the baseline and does not belong to the coastal state's territory. Here, the coastal state may exercize functionally limited jurisdiction. If the dimensions of the EEZ do not collide with either an adjacent or an opposite EEZ, the coastal state may establish it by the unilateral act of laying claim to it. Otherwise, Article 74 of UNCLOS provides for the delimitation of adjacent EEZs by agreement between the coastal states concerned. If a coastal state waives its claim to an EEZ, it remains entitled to use its continental shelf regardless of this, if applicable. In this case the waters beyond the territorial sea are part of the high seas (Graf Vitzthum, 2006).

UNCLOS assigns the rights of use within the EEZ to the coastal state with final effect. They comprise, for example, the right to exploit the living and non-living resources (e.g. fish stocks, oil and gas resources) in the water column, on the seabed and in the subsoil, and to build installations or artificial islands (e.g. oil platforms, wind turbines). The powers of jurisdiction assigned by UNCLOS to the coastal states are of great economic importance. For example, 90% of all commercially relevant species of fish occur in the EEZs of coastal states (Maribus, 2010). For Germany, the special significance of the EEZ stems in particular from the planned offshore wind turbines which are to be built

Box 3.2-2

History of the law of the sea: who owns the sea?

The need to regulate the use of the oceans was recognized as early as the 17th century. The growing importance of the major seafaring nations' merchant shipping fleets, the expansion of fishing, and the nascent development of marine mineral resources led to conflicts of interest among the great seafaring nations and raised the question of who owned the sea. In response to the Portuguese policy of *'mare clausum'*, according to which individual states could make individual claims for the use of the seas (Portugal claimed a monopoly on maritime trade with the East Indies), Hugo de Groot (Grotius) wrote a body of rules in 1609 called *'mare liberum'*, which elevated the freedom of the seas to a basic principle and postulated the freedom of the seas for all seafaring nations (Stumpf, 2006; Mann Borgese, 1999; Aure, 2008). The aim was to secure the right of free global trade for the Dutch East India Company whose advisor Grotius was. In 1625, a time when Britain was competing with the Netherlands for dominance in maritime trade, the British lawyer John Selden developed a written form of the *'mare clausum'* concept, assigning individual claims to the use for the seas to individual states.

In the 20th century, there was a growing need for a new basis of the law of the sea under international law, according to which some coastal states no longer recognized the common-law rules dating from the 17th century, for example the right to claim a three-mile coastal strip as national territory. With the demand for energy and raw materials rising, the oceans increasingly became a valuable source of raw materials starting in the mid-20th century; at the same time the technical capabilities for recovering mineral and living resources improved. The coastal states tried to bring ever larger parts of the sea and seabed under their control and extended their coastal strips to as much as 200 nautical miles. A conference convened in the 1930s to regulate the width of the territorial sea failed to reach agreement. The decisive impulse for the expansion of the coastal states' rights after the end of the Second World War came from the USA, when President Harry S. Truman proclaimed a new policy on raw materials, coupled with an expansion of the coastal zone as far as the continental shelf. The background was the discovery of resource deposits off the American coast and improved drilling techniques. The American example was soon followed by other countries, so that the world's 200 nm zone (exclusive economic zone, EEZ) and the continental shelf became part of customary international law (UN, 2011). With the signing of UNCLOS in 1982, this practice was then codified under international law in the course of international negotiations on the contractual regulation of the international law of the sea.

During the long phase of negotiations on UNCLOS (1956–82), demands were made at the UN level that went far beyond the scale of regulation of UNCLOS adopted in 1982. For example, the then Ambassador of Malta, Arvid Pardo, called on the world to classify the oceans as the 'common heritage of mankind' in a much-publicized speech to the UN General Assembly in 1967 (Mann Borgese, 1999).

predominantly in the EEZ (KPMG, 2010).

In addition, under Article 56 of UNCLOS the coastal state has jurisdiction with respect to scientific marine research, so that any projects of third countries require its consent. The coastal state is furthermore obliged (Article 192 ff. of UNCLOS; Section 3.2.1.3) and entitled to protect and preserve the oceans. Equipped with corresponding powers of jurisdiction to preserve the marine environment by Article 56, para. 1, letter (b) of UNCLOS, the coastal state may, for example, declare protected areas. Since the freedoms of navigation and overflight, and the freedom to lay submarine cables and pipelines, apply in the EEZ, there are limitations on what regulations of ocean conservation can achieve. Here, only the internationally agreed standards of Article 211, para. 6 of UNCLOS apply (Section 3.6.4). Coastal states may not introduce stricter rules unless certain regions worthy of special protection require regulations on discharges, the designation of protected areas, or the like. Then, however, approval must be obtained from the International Maritime Organization (IMO) according to section 211, para. 6, letter (a) of UNCLOS (Kimball, 2001).

3.2.1.4 Continental shelf

The Commission on the Limits of the Continental Shelf (Article 76, para. 8 of UNCLOS), which was set up in 1997, makes recommendations on request by coastal states on demarcation in the case of extended continental shelves. UNCLOS states parties must obtain such a recommendation in order to be contractually allowed to use an extended continental shelf.

The *continental shelf* (Articles 76 to 85 of UNCLOS) comprises the seabed and its subsoil beyond the territorial sea. However, the continental shelf regime under UNCLOS does not relate to the water column, i.e. the waters above the seabed. With regard to the continental shelf, the coastal state has the sovereign right to exploit the natural resources, the right to engage in research on the seabed and subsoil, and the right to erect installations and buildings. Where areas of the continental shelf and the EEZ overlap, the rights of use relating to the continental shelf have no independent significance, since the rights within the EEZ are more extensive. In two situations, however, the rights of use on the continental shelf have an independent importance. First, this is the case in the event that a coastal state does not establish an EEZ. For, unlike in the EEZ, the rights to the continental shelf exist regardless of

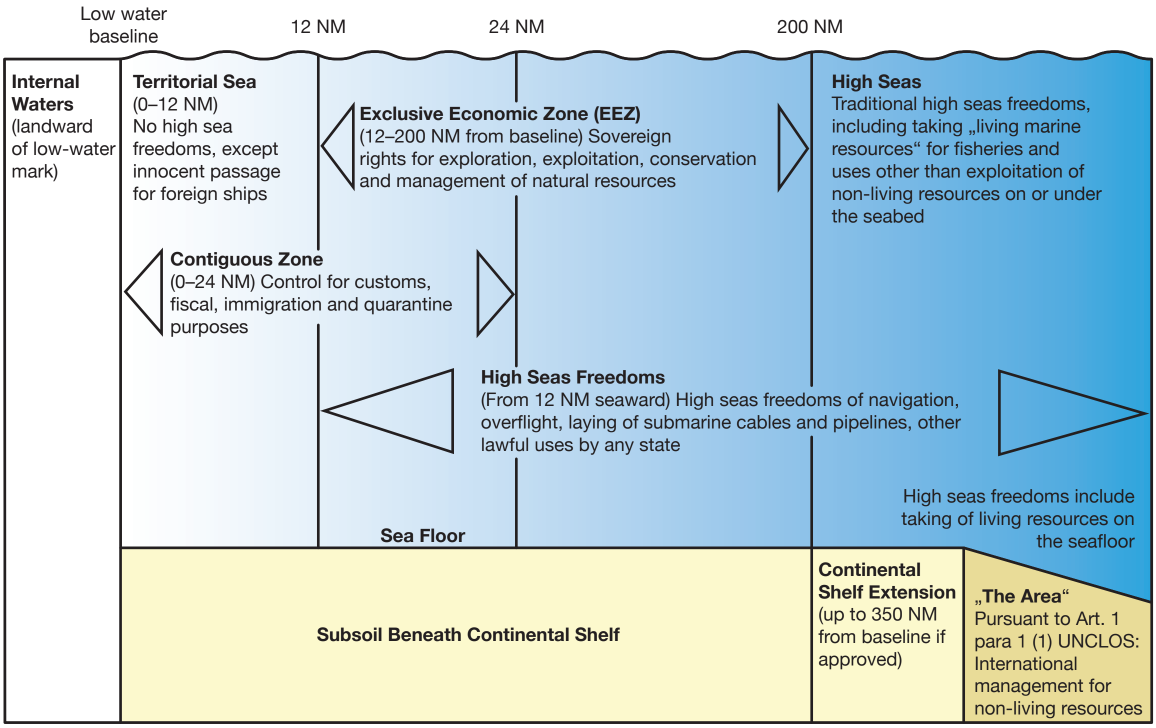


Figure 3.2-1
Sequence of marine zones under the UN Convention on the Law of the Sea (UNCLOS).
nm = nautical mile = 1.852 km.
Source: Gorina-Ysern et al., 2004

any state act of appropriation. Second, it is the case where the continental shelf extends seaward further than the 200-nm-wide EEZ due to geological conditions (e.g. off the coasts of Argentina, in the South China Sea and in the Arctic). UNCLOS provides for the following arrangement on the seaward limit of the continental shelf: if the course of the topographic outer edge of the continental margin runs at a distance of less than 200 nm, then according to UNCLOS Article 76, para. 1, the hydrographic boundary of the continental shelf is fixed at 200 nm measured from the baseline (Graf Vitzthum, 2006). If the outer edge of the continental margin lies beyond this limit, the coastal state concerned can file an application for recognition of an extended continental shelf to the Commission on the Limits of the Continental Shelf, which was established by UNCLOS (Section 3.2.1.2). If the application is successful – e.g. if corresponding geological evidence is submitted – the coastal state can define the outer limit of its continental shelf in accordance with the Commission's recommendation and claim the corresponding rights of use to the extended continental shelf. The maximum expansion of the extended continental shelf is 350 nm from the baseline, or alternatively no more than 100 nm from the 2,500-metre isobath (submarine elevations are excepted from this alternative delimitation according to Article 76, para. 6, sentence 1 of UNCLOS; Section 3.2.1.5; Box 3.2-3).

The reason why the Commission on the Limits of the Continental Shelf was set up was because UNCLOS's stipulations on the dimensions of the continental shelf were vague, and this often led to border disputes. Especially in cases where the geological continental shelf extends seaward beyond the 200-nm-wide EEZ (Section 3.2.1), the clarification of any territorial claims by individual states parties by the Commission is important (Section 3.2.5; Box 3.2-3). The Commission on the Limits of the Continental Shelf also decides on the funding of the International Tribunal for the Law of the Sea (ITLOS) and the remuneration of the judges. In order to settle border disputes between adjacent or opposite continental shelves, the Commission on the Limits of the Continental Shelf offers the coastal states in conflict the option of submitting joint applications in order to give the Commission a mandate for a recommendation on the delimitation in the disputed territory.

3.2.1.5
High seas

The *high seas* begin beyond the outer border of the EEZ and are limited to the water column; i.e. they do not include the ocean floor. Overall, the high seas cover about 202 million km², i.e. 64% of the total area of the oceans. In essence the use of the high seas (Articles 86 to 120 of UNCLOS) follows the principle of freedom of the seas (Box 3.2-2). No state is allowed to subject any part of the high seas to its sovereignty. Freedom of navigation, fishing and marine research applies in the area of the high seas. The designation of marine protected areas on the high seas by individual states is not regulated under UNCLOS, but could be required under Article 194, para. 5 of UNCLOS on ocean conservation. The freedom of the high seas – i.e. freedom of shipping, fishing, etc. – would have to be observed (Proelß, 2004).

3.2.1.6
The Area

The seabed located below the high seas, the so-called *Area* (Article 133 to 191 of UNCLOS, Annexes III and IV), is not subject to any national jurisdiction. The Area and its mineral resources are belong to the 'common heritage of mankind' pursuant to Article 136 of UNCLOS. UNCLOS provides for a steward and an international regime of management for the use of mineral resources in the Area, i.e. the mineral resources that are located "at or beneath the seabed" (Part XI of UNCLOS). This so-called *seabed regime* is presented in Section 3.2.3.2.

3.2.2
Regulations of UNCLOS on the conservation and sustainable use of the oceans

UNCLOS defines requirements (minimum standards) for the protection and preservation of the oceans and in this way places limits on their use (Wolfrum and Fuchs, 2011). These requirements apply to all marine zones. The states parties to UNCLOS are obliged to protect the marine environment "in accordance with their capabilities". No damage must be caused by pollution to other states or their environment (Article 194, para. 2 of UNCLOS), and no damage may be transferred (Article 195 of UNCLOS). As regards the use of technologies or the introduction of invasive species, UNCLOS stipulates that states shall take all necessary measures to prevent and reduce any resultant pollution of the marine environment (Article 196 of UNCLOS). In addition, UNCLOS contains certain obligations of states with regard to international and regional cooperation, technical assistance, monitoring and assessing pollution, enforcement, responsibility and liability (Articles 197 to 237 of UNCLOS). Furthermore, UNCLOS requires that states pass more detailed national legislation regulating their obligation to protect the oceans (Article 207 ff. of UNCLOS). UNCLOS provides that the states parties agree global and regional conventions on marine environmental protection, transfer these agreements into national law and monitor compliance with them (Lagoni, 2007). It only establishes a separate regime for the seabed (Section 3.2.3.2).

3.2.3
Institutions of UNCLOS

The UN Convention on the Law of the Sea (UNCLOS) led to the establishment of several international institutions:

- the Commission on the Limits of the Continental Shelf (New York; Section 3.2.1.4);
- the International Tribunal for the Law of the Sea (Hamburg);
- the International Seabed Authority (Kingston).

Fundamental decisions, particularly on amendments to UNCLOS, are taken by the Meeting of States Parties. The central task of the Meeting of States Parties is to hold negotiations on proposed amendments to UNCLOS (Box 3.2-4). Since no such an amendment procedure has been carried out to date, the Meeting concerns itself primarily with matters of the Commission on the Limits of the Continental Shelf and the International Tribunal for the Law of the Sea. The Meeting of States Parties is supposed to be convened only when needed, but it has been held annually since 1994. The Meeting is usually convened in the run-up to the General Assembly of the United Nations, taking the opportunity to prepare ocean-related resolutions of the General Assembly.

3.2.3.1
International Tribunal for the Law of the Sea

Article 279 of UNCLOS obliges the states parties to settle disputes by peaceful means. The International Tribunal for the Law of the Sea (ITLOS, Article 287 of UNCLOS in conjunction with Annex VI), which was established in 1996, serves to settle disputes concerning the interpretation or application of UNCLOS. However, according to Article 287, para. 1 of UNCLOS, the states can choose other means to settle disputes, so that cases relating to the Law of the Sea can also be brought before the International Court of Justice or to an arbitral tribunal. In practice, ITLOS has jurisdiction in matters relating to the prompt release of ships pursuant to Article 292 of UNCLOS – although here, too, the parties in the dispute have a limited choice (Wolfrum, 2006b: 481). Under certain conditions, ITLOS may furthermore have jurisdiction to order provisional measures, so that ITLOS can assumed to have a *de facto* 'monopoly' over handling

Box 3.2-3

Planned extensions of the continental shelf in the Arctic: who owns the Arctic?

The countries bordering the Arctic Ocean are the coastal states Canada, Denmark, Norway, the Russian Federation and the United States of America. With the ongoing retreat of the Arctic ice sheet the probability that the exploitation of resources in the Arctic Ocean would soon become technically feasible and economically attractive has been increasing for years. As a result, these countries are trying to lay territorial claims to the seabed and subsoil of the Arctic Ocean. The simmering conflict over the territorial division of the polar region came to the public's attention when, in August 2007, a Russian submarine anchored a Russian flag to the bottom of the Arctic Sea, thus underlining Russia's claims. Although the United States has not acceded to UNCLOS to date, the coastal states stated in the Ilulissat Declaration of 2008 that they intended to determine the outer limits of their respective continental shelves in particular according to the rules of the Convention on the Law of the Sea. The main point at stake about possible extensions to the continental shelf is the geological allocation of the Lomonosov and Mendeleev Ridge. In its application filed in December 2001, Russia claimed this mountain ridge in the polar region as submarine elevations which, due to their geological topography, were natural parts of the Russian continental margin within the meaning of Article 76, para. 6, sentence 2 of UNCLOS (Wolfrum, 2008). Denmark objected to this application by Russia in February 2002, stating that the borderline between the Danish and Russian continental shelf was disputed. As a result, Denmark invoked Article 83 of UNCLOS, thus challenging the jurisdiction of the Commission on the Limits of the Continental Shelf to decide on disputed territories. In the recent past, Russia in particular has sought to find a peaceful settlement to the Arctic conflict. A conflict with Norway that had been ongoing for decades relating to marine borders in the Arctic Ocean has been settled. Russia, Canada and Denmark/Greenland are currently jointly striving to find an amicable solution to the Arctic conflict. One of the options being considered is a joint application to the Commission on the Limits of the Continental Shelf for a recommendation on the delimitation of the border (Humrich, 2011).

these cases (Wolfrum, 2006b: 470). Regarding disputes concerning activities in the Area, moreover, there is a Seabed Disputes Chamber at ITLOS, which has exclusive and compulsory jurisdiction for these disputes. Furthermore, the Chamber supports the International Seabed Authority by preparing legal opinions. Disputes outside of UNCLOS can also be assigned to ITLOS, e.g. disputes under the Fish Stocks Agreement (Article 30 of the Fish Stocks Agreement). The International Tribunal has at least five permanently established chambers, first for the disputes that can be assigned to ITLOS under UNCLOS, but also for disputes relating to fisheries, the marine environment and boundary disputes over the marine zones. The possibilities of legal protection by the Court of Justice developed positively with the extension of the 'capacity to sue and be sued' to include natural and legal persons, since previously only states could go to court as a party. To date, only 21 cases have been brought before ITLOS (ITLOS, 2013). One reason for the rare use of ITLOS to settle disputes could lie in the numerous choices under Article 287 of UNCLOS, which offers settlement alternatives for most disputes under the Law of the Sea.

3.2.3.2 International Seabed Authority and the seabed regime

The International Seabed Authority (ISA; Article 156 ff. of UNCLOS) was founded in 1994 to manage the mineral resources of the Area according to the heritage of mankind principle (Article 136 of UNCLOS; Figure 3.2-2). According to the provisions of UNCLOS and the *Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea*, it has jurisdiction to authorize and monitor activities in the Area. Article 136 of UNCLOS declares the Area to be the common heritage of mankind. This framework principle is made up of four definitive basic statements:

First, "all rights in the resources of the Area are vested in mankind as a whole" (Article 137, para. 2 of UNCLOS). The states parties may not exercize individual national sovereignty. The legal regime does not, therefore, include the freedom of nation states to exploit resources as in the area of the high seas. Mining projects, especially to recover manganese nodules, are to be carried out on the basis of the system of use established under international law, because the extraction of mineral resources requires the mandatory assignment of rights of use by the provision of a regulatory framework in order to establish a secure investment framework (Wolfrum, 2006a: 334).

Second, "particular consideration" is to be given to "the interests and needs of developing states" (Article 140, 148 of UNCLOS), whose participation in deep-sea mining is to be promoted, "having due regard to their special interests and needs".

Third, the states parties have an obligation to realize equality among the states at the expense of states that are financially and technically capable of mining. In contrast to the use of the high seas, activities on the deep-sea floor have the advantage of being "carried out for the benefit of mankind as a whole" (Article 140 of UNCLOS).

Fourth, the creation of the International Seabed Authority (ISA) to ensure the monitoring and coop-

Box 3.2-4

Procedure for amending UNCLOS

The UN Convention on the Law of the Sea (UNCLOS) contains three different procedures for amendment:
- the general amendment procedure pursuant to Article 312 of UNCLOS;
- the simplified amendment procedure pursuant to Article 313 of UNCLOS; and
- the procedure for amendments to provisions relating to the Area according to Article 314 of UNCLOS.

The first prerequisite for an amendment of UNCLOS, regardless of the procedure, is that a proposal must be made by a state party (Article 312–314 of UNCLOS). If at least half of the states parties advocate the proposal in the course of the general amendment procedure within 12 months, a meeting is convened to amend UNCLOS. In principle, amendments to the text of the Convention should be made as far as possible by a unanimous decision of the convened Meeting of States Parties (Article 312, para. 2 of UNCLOS). Under the simplified amendment procedure (Article 313 of UNCLOS), the states parties are informed about the proposed amendment without a meeting. The states parties can raise objections both to the choice of the simplified procedure and to the proposed amendment. The amendment is adopted, however, if no state party objects within a year. If there is an objection, the proposed amendment is deemed to have been rejected. A separate amendment process is used for activities in the Area; here, the states parties are merely informed of the proposed amendment. In order for this proposed amendment to be adopted, it must first be approved by the Council of the International Seabed Authority and subsequently by the Assembly (Article 314, para. 1 of UNCLOS). The representatives of the states parties in these institutions are authorized to examine and approve the proposed amendment. All adopted amendments are displayed for 12 months for signature by the states parties pursuant to Article 315, para. 1 of UNCLOS, unless otherwise stated in the amendment.

eration of the states parties involved (Wolfrum, 2006a: 336) follows from the idea of the common heritage of mankind.

As regards the use of resources in the Area, the provisions of Article 133 of UNCLOS refer only to mineral resources that are located "at or beneath the seabed". According to the unequivocal wording of the seabed regime, therefore, living resources are not covered and are not allocated to the common heritage of mankind, but to the freedom of the high seas (Friedland, 2007). The marine environment must be protected from damage in the course of mining the mineral resources. To this end, the ISA is to adopt rules pursuant to Article 145 of UNCLOS to prevent and reduce pollution of the Area as a result of mining operations and to protect the natural resources. In addition, the general obligations to protect the marine environment under Article 194 ff. of UNCLOS apply, as do their more detailed description relating to activities in the Area in Article 209 of UNCLOS. To date, the Authority has accordingly adopted guidelines for monitoring possible environmental impacts in relation to the exploration of manganese nodules in the Area (UN, 2001). The designation of parts of the Area as protected areas is also possible as a protective measure (Jenisch, 2010).

The International Seabed Authority has jurisdiction over the deep-sea bed and its mineral resources (Box 3.2-5) on behalf of all states (Jenisch, 2010). Activities in the Area have to be approved by the International Seabed Authority (Friedland, 2007). The company filing the application must sign a contract with the International Seabed Authority on compliance with the requirements laid down in the work plan (Jessen, 2012). Certain unusual aspects for the applicant result from the earmarking of the Area as the common heritage of mankind (Jenisch, 2010).

The International Seabed Authority has adopted several 'Regulations' under the generic term *Mining Code* for the extraction of manganese nodules, polymetallic sulphides and cobalt-rich crusts. This Code lays down the preconditions for exploration dives and environmental-protection requirements, taking into account the precautionary principle and applying 'best environmental practice' (Regulation 31, subsection 2 of the Manganese Nodule Code; Regulation 33, subsection 2 of the Sulphide Code), which is defined in relation to the environment as the application of the most appropriate combination of control measures and strategies. Only environment-friendly processes may be approved which ensure the regeneration of the vulnerable deep-sea ecosystems. Regulation 31, subsection 3 of the Manganese Nodule Code also refers to the best available technologies. In cases of dispute, the International Seabed Authority can institute proceedings at the Seabed Disputes Chamber of the International Tribunal for the Law of the Sea.

3.2.4
Assessment of UNCLOS

In order to assess the effectiveness of UNCLOS, the WBGU uses a number of touchstones for gauging how suitable ocean governance is for tackling certain problems (Section 3.1.4). These touchstones can also reveal the shortcomings and weaknesses of UNCLOS and help develop ways of improving marine governance (Chapter 7).

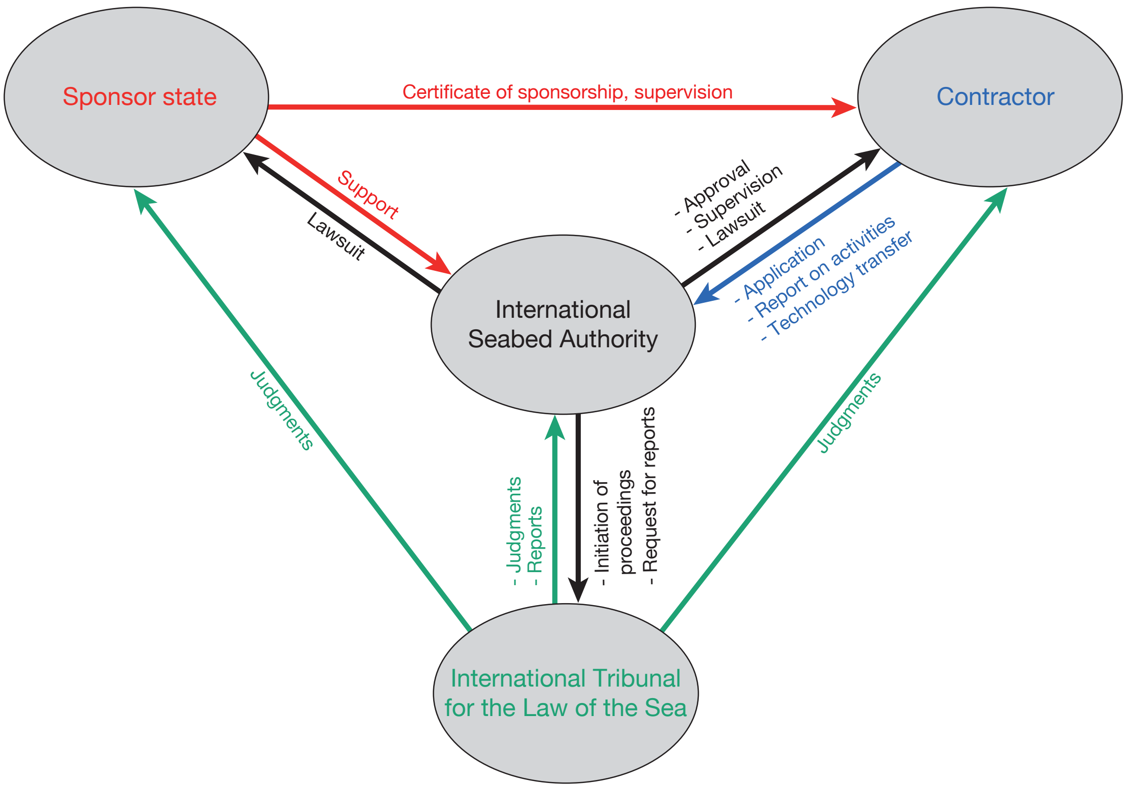


Figure 3.2-2
The International Seabed Authority approves, reviews and supervises the extraction of mineral resources in the Area. Applications to conduct mining operations can be filed by both state and private companies (contractors); private companies require the support of a state party (a so-called sponsor state). This sponsor state assumes responsibility under international law for the company's mining activity and is liable for errors of selection and monitoring.
Source: WBGU

3.2.4.1
Systemic perspective

In principle UNCLOS contains a systemic perspective in that it lays down an overarching framework for the conservation and use of the oceans. Its scope is not limited to certain marine areas, and its purpose is to create a basic order to govern human activities in the oceans. UNCLOS itself acknowledges that "the problems of ocean space are closely interrelated and need to be considered as a whole" (Preamble, recital 3). However, this is only reflected in individual stipulations. For example, when it comes to conservation of fish stocks the states parties have an obligation to take into account the interdependence of stocks (Article 61, para. 3 of UNCLOS) and the effects of fishing activities on associated and dependent species (Article 61, para. 4, and Article 119, para. 1, letters (a), (b) of UNCLOS). Moreover, fragile ecosystems and the habitats of rare or endangered species are to be protected (Article 194, para. 5 of UNCLOS). However, this systemic perspective is watered down by several contrary regulations. For example, the division of the oceans into zones with different legal regimes means that individual sections are considered in isolation, so that the sea is not looked at as a whole. Furthermore, the zoning does not correspond to the ecosystem boundaries, which can lead to problems in ecosystems that cross zone borders when the systemic approach is used (Tsamenyi et al., 2003). UNCLOS is also based on a pollution-related approach which considers different sources of pollution separately (Wolf, 2006). The orientation towards individual pollution sources appears useful on the one hand, because the causes of pollution can differ in importance and require different measures. On the other hand, the split means that, as a rule, even international or regional agreements only cover certain parts of the marine environment, such as fisheries, waste disposal, ships' emissions or similar issues, leading to a further fragmentation of the ocean-conservation regime – although this would be difficult to avoid, partly due to the high degree of specialization and technicity (Wolf, 2006). For example, the IMO is unable to effectively administer coordinated measures of marine environmental protection because of its orientation towards the technical reduction of ship emissions (Höfer and Mez, 2003). This fragmentation based on sectoral regulation is further

Box 3.2-5

Financial compensation for the use of the seabed

Region of the recognized continental shelf beyond the 200 nm

The coastal states are obliged to "make payments or contributions in kind in respect of the exploitation of the non-living resources of the continental shelf beyond 200 nm" (Article 82 para. 1 of UNCLOS). The size of these payments is to be staggered over time (from 1% to 7% of the value or volume of production; Article 82, para. 2 of UNCLOS). The obligation to pay begins with the sixth year of production and is assessed on the basis of annual output. The payments are made to the International Seabed Authority, which is subsequently responsible for their equitable distribution among the states parties of UNCLOS. The interests and needs of developing countries are to be given special consideration in the distribution.

Region of the Area

The issuing of exploration and mining licences is organized by the International Seabed Authority. Starting at the beginning of extraction, the licensee pays a charge that is staggered over time, but is not less than an annual fee of US$1 million. The International Seabed Authority must develop an equitable method for the distribution of profits in which the interests and needs of developing countries are given special consideration (Article 160, para. 2, letter (f)(i) of UNCLOS). Potential beneficiaries of this distribution method are all the states of the world.

encouraged by the provisions of UNCLOS relating to 'competent international organizations' and the 'generally accepted international rules and standards' (Proelß, 2004). There are hardly any dovetailing or overarching regulations affecting the entire system or interdependencies between individual objects and areas of regulation. Article 194, para. 3, letter (a), and Articles 207 and 212 of UNCLOS do take into account land/ocean and atmosphere/ocean interactions (Chapter 1). They stipulate that the states parties are to enact rules and take measures to reduce and prevent pollution of the sea from the land or the air. However, more complex interdependencies are not considered by UNCLOS.

Similarly, the preservation and management of living marine resources does not demand any consideration of the impact of fishing activities on other ecosystems or other objects of protection such as biodiversity, nor do nature-conservation or animal-welfare issues need to be considered (Article 61 of UNCLOS). Equally, UNCLOS does not contain specific provisions on particularly sensitive marine organisms such as deep-sea species. Precisely because of the intricate relationships between marine species and ecosystems, as well as their mutual dependencies, removing fish stocks can cause damage to other ecosystems (Tanaka, 2011). This narrow, sectoral approach is reinforced by the fact that, accordingly, the more detailed international or regional conventions also only regulate individual pollution sectors. Furthermore, UNCLOS's systemic component is restricted by the fact that not all areas have been processed in greater detail by treaties. For example, there is no treaty providing for the designation of marine protected areas at the global level. Similarly, novel – especially technological – developments such as CO_2 capture and storage, geoengineering, etc., have hardly been covered by UNCLOS implementing agreements up to now. UNCLOS also regulates the protection of the sea in isolation, without referring to any interaction with other conventions dealing with marine conservation, such as the CBD.

Overall, although UNCLOS contains systemic elements, a sectoral perspective dominates for the most part which is characterized by a limited focus on the respective use. The complex and dynamic interactions within the oceans and marine ecosystems, as well as within the Earth system (land/sea, sea/atmosphere, climate change) and the societal systems are not given sufficient consideration in UNCLOS.

3.2.4.2
Precautionary principle

The precautionary principle is not explicitly part of UNCLOS. In its definition of pollution (Article 1, para. 1, no. 4 of UNCLOS), it refers to "effects" which are "likely to result". Although this covers the time element of the precautionary concept, it does not require states parties to take precautions to avoid risks. In its report on sea-floor management, however, ITLOS requires the UNCLOS states to apply the precautionary principle – as part of its standard of care – in the context of resource exploitation in the 'Area'. Regarding the precautionary principle, ITLOS sees a clear trend towards the recognition of the precautionary principle under customary international law and derives from this the duty of states to make provisions for risks (ITLOS, 2011:131, 135). This principle is explicitly stated by implementation agreements such as the London Protocol (prevention of marine pollution, Section 3.3.2.6), the OSPAR Convention (ocean conservation in the Northeast Atlantic, Box 3.4-1; Article 2, para. 2, letters (a), (b), para. 3, letters (a), (b)), the Helsinki Convention (HELCOM, marine environmental protection in the Baltic Sea) and the regulations of the ISA Mining Code. Although the precautionary principle is already acknowledged in many regulations and decisions on ocean use (e.g. in the Third Conference on the Protection of the North Sea in 1990), it is rarely strictly applied in practice.

3.2.4.3
Adaptive management

Although UNCLOS can be amended and/or further developed by the states parties when required, thus enabling the treaty to be adapted to new findings and circumstances, the regulations on amending the treaty's text are inflexible, complex and take a long time. Since the amendment procedure is laborious (Box 3.2-4) and offers little promise of success, it has not been used to date. In addition, UNCLOS contains no arrangements providing for an adjustment, when necessary, in the light of new knowledge or technological developments. The seabed regime is more flexible, since its arrangements are supposed to be regularly reviewed. There are no other options for adjustment. In this way the framework agreement makes it difficult to practise the kind of adaptive management that allows governance to change when new knowledge comes to light.

3.2.4.4
Incentives for innovation

Up to now, UNCLOS does not provide for incentives for innovation that encourage a sustainable, low-risk use of the oceans, e.g. new, long-term and sustainable business models on the use and conservation of the oceans. The promotion of marine environmental protection is largely limited to the obligation of the states parties to enact more detailed laws to protect and preserve the marine environment (Article 192 ff. of UNCLOS). The regulations of UNCLOS on "technical assistance" relate to innovation indirectly at best (Article 202 f. of UNCLOS). In the context of development programmes, the aim is to promote science, education and technological development in the field of marine environmental protection. To this purpose UNCLOS provides for knowledge and technology transfer to the benefit of developing countries.

3.2.4.5
Assignment of rights of use

Under UNCLOS rights of use are assigned by the zoning of the oceans into territorial waters, EEZs, continental shelf limits and the high seas. Rights to use the resources of the Area are not directly assigned by UNCLOS. However, as a framework convention it legitimizes the International Seabed Authority to issue licence contracts to explore and/or recover these resources on application. There are allocation difficulties, particularly relating to the rights to use living resources, as these are not geographically determined. Accordingly, there is a lack of regulations from UNCLOS on the assignment of the living resources in the high seas.

In addition to this assignment of rights of use, UNCLOS also contains a model for allocating the costs of damage incurred: the 'polluter pays principle'. Under Article 195 of UNCLOS, damage may not be relocated to another zone, otherwise states could avoid their obligation to bear the costs by shifting the location of any damage (Proelß, 2004). This principle requires implementation by more specific treaties. The London, OSPAR and Helsinki Conventions already refer to the polluter pays principle.

3.2.4.6
Cooperation

The UNCLOS states parties are obliged to cooperate in the protection of marine resources, the preservation of the marine environment and the establishment of standards in the prevention and control of marine pollution from the land. A separate section of UNCLOS is devoted to global cooperation for the preservation of the marine environment (Article 197 ff.). In the context of the use of resources, states parties are expected to cooperate in the Review Conference of the Seabed Regime 15 years after the first commercial production and in the promotion of scientific marine research in the Area.

3.2.4.7
Subsidiary decision-making structures

Since UNCLOS has the structure of a framework convention in which many individual regulations are referred to the nation states, a subsidiary decision-making structure has in principle been created. In some cases, implementing agreements like the FSA also induce the creation of regional structures like the Regional Fisheries Management Organizations (RFMOs).

3.2.4.8
Transparent information

In the WBGU's view, the UNCLOS decision-making structures are not transparent enough, not least because of limited opportunities for participation by stakeholders in the marine sector. NGOs are excluded from decisions on exploration or mining licenses by the International Seabed Authority. Similarly, the decisions of the Commission on the Limits of the Continental Shelf on the exact course of the outer limits of the continental shelf are taken behind closed doors by a commission of experts. Accordingly, the decision-making structures of the Commission on the Limits of the Continental Shelf reveal transparency shortcomings (Jenisch, 2010).

The decision-making procedures of ITLOS, by contrast, are transparently structured. Its decisions are based on public hearings. The judgments made by majority decision must be substantiated and published and also take into account the opinions of judges with differing views.

3.2.4.9
Participative decision-making structures

Up to now, participation by the states parties has been provided for particularly in the further development of the Convention text. However, UNCLOS lacks other participation rights and participatory elements. Decisions by the International Seabed Authority on exploration and mining licences are made without the participation of NGOs. Although companies or states can be involved as applicants in the approval procedure when exploration or mining licences are awarded in the Area, environmental organizations or other third parties have no opportunities to put forward objections. Similarly, the International Seabed Authority is not involved in proceedings of the Commission on the Limits of the Continental Shelf relating to the outer limits of continental shelves, even though the decision directly affects its jurisdiction.

There is also no obligation to enable NGOs to participate in judicial proceedings before ITLOS's Seabed Disputes Chamber. Nevertheless, such representatives were recently given an opportunity to make a statement during the preparation of an ITLOS opinion (Jessen, 2012). Asking NGOs for statements (*amicus curiae*) is a possible course of action in the context of WTO dispute-settlement procedures (de Brabandere, 2011); it can therefore possibly be expected from ITLOS in future as a legal tradition of international courts.

3.2.4.10
Fair distribution mechanisms

The criterion of fairness and justice pervades UNCLOS as a guiding principle and is already mentioned three times in the Preamble alone. UNCLOS provides for an equitable use of marine resources, taking into account the capabilities and interests of developing countries. The developing countries are also given special consideration in ocean conservation in that they only have to prevent and reduce contamination in accordance with their capabilities. Similarly, a distinction is made between developing and industrialized countries in the quality of protection efforts, especially according to their different technological and scientific capacities. Aspects of intergenerational justice are taken into account by the seabed regime in that the resources of the seabed are declared as part of the common heritage of mankind, i.e. also for future generations. The requirements of fairness referred to in UNCLOS must be specified in more detail in implementing agreements.

3.2.4.11
Conflict-resolution mechanisms

The resolution of conflicts is clearly regulated in UNCLOS (Part XV). The states parties to UNCLOS can invoke ITCLOS or an arbitral tribunal formed under UNCLOS to settle disputes concerning the interpretation or application of the Convention (Article 287). If the parties cannot agree on the same procedure, then an arbitration procedure is provided for to make a decision.

3.2.4.12
Enforcement mechanisms

According to the provisions of international law the flag state is primarily responsible for monitoring its ships and enforcing the relevant national and international regulations (Graf Vitzthum, 2006: 399 ff.). However, flag-state control is often ineffective. On one hand, many flag states barely have the personnel or the financial means to monitor compliance with regulations; on the other, they have no interest in imposing the corresponding costs on the ships to ensure that as many ships as possible register with them (König, 1990). Corruption is another obstacle to the enforcement of the existing legal regulations. So-called 'classification societies', which are usually entrusted with the task of controlling the ships, apply very lax standards in some countries. This is precisely why many operators have their ships registered there. These so-called 'flags of convenience' increased in number rapidly in the past, and many of the ships wereoperated by holding companies, so that the owners' true identity remained in the dark (Behnam, 2003).

In addition to the flag states, UNCLOS also grants the port states the right to conduct inspections of ships sailing under foreign flags. Port states can lay down national standards as a prerequisite for entry into their ports, because the right of innocent passage does not apply here (König, 2002). If the ship's documents are not in order, or if there is cause for concern, port states have the authority to board and inspect the ship (Blanco-Bazán, 2003). However, it lies in the port state's sole discretion whether it intervenes in the case of statutory violations that might threaten the marine environment. UNCLOS does not lay down any obligation to take such action. Some port states fear that if they exercise strict controls they will be less attractive for ships and thus suffer a competitive disadvantage vis-à-vis other ports (König, 2002).

Coastal states also have powers of inspection and enforcement in their territorial seas based on their exclusive sovereignty. The possibility of controlling ships in the coastal area is reduced to checking the ship's documents. This restrictive way of handling the situation is a result of the regime on innocent passage through the territorial sea, in which the rights of the coastal state to protect the marine environment is an exception in the context of the right of passage (Graf Vitzthum, 2006: 401 ff.). So although environmental-protection standards may therefore be stricter in the territorial sea than the internationally agreed regulations, this only applies as long as the right of innocent passage is not obstructed as a result (König, 2002). A vessel may only be prevented from continuing its journey if it is found to have violated international regulations, causing a threat to the marine environment (Kimball, 2001). The coastal state is only allowed to exercise enforcement measures in the exclusive economic zone if serious damage to its interests is to be feared.

In order to exercise their powers of enforcement more effectively and efficiently, port states in various regions have signed agreements such as the Paris Memorandum of Understanding on Port State Control. These are not based on international treaties, but on administrative agreements between the regional authorities of affected states. They specify the applicable international rules, but do not introduce any additional requirements of vessel safety or environmental protection. However, they do lay down a percentage of incoming ships that must be controlled. The agreements not only lead to more effective enforcement, they also prevent distortions of competition in the region and prevent unilateral actions (Kimball, 2001). However, since they are not legally binding, in cases of non-compliance the parties are restricted to exercising political or economic pressure or introducing economic incentives (König, 2002).

In addition, UNCLOS obliges the states parties to take measures to protect the marine environment from land-based pollution. In principle, this also includes the respective state enforcing these measures vis-à-vis private actors (Hafner, 2006: 402). However, the states are not obliged by UNCLOS to enforce uniform (minimum) standards of protection (Birnie and Boyle, 2002: 408). Nor does any treaty apart from UNCLOS exist at the international level that deals with this source of pollution in a binding and comprehensive way (Graf Vitzthum, 2006: 384).

According to UNCLOS the coastal state is sovereign in its use of resources in relation to the continental shelf and the EEZ – for example by means of oil and gas platforms (Proelß, 2010). This also relates to operating mobile platforms under a foreign flag in its coastal waters. The coastal state enacts security and protection standards and has an obligation to enforce them (Article 214 of UNCLOS). There are no uniform, international regulations in this regard either (Proelß, 2010).

3.2.5
Core problems and challenges of future ocean governance

The age of the Anthropocene brings with it new threats on a global scale for the oceans as part of the Earth system, inter alia as a result of the ongoing physical destruction of marine habitats (e.g. by destructive fishing methods), by overfishing, the massive pollution of the seas (e.g. with plastic waste), as well as warming and acidification (Section 1.2). The present pressure of use on the oceans is also expected to intensify further in the coming years: overall, many new uses of the oceans have become possible for which UNCLOS in its present form does not provide sufficient regulatory tools. These new uses of the oceans include, for example, new shipping routes as the Arctic ice melts, prospecting for (and extracting) energy and mineral resources, deep-sea fishing, the generation of renewable energy on and in the sea, and offshore aquaculture. On the other hand, there is no legal framework that protects the marine ecosystems and thus guarantees that the seas are used in an environmentally sustainable way. Exploration in search of fossil fuels is penetrating into ever deeper areas of the ocean, and the extraction of marine methane hydrates is becoming more attractive with the advancement of technology and a rising demand for energy. In particular there is no international liability regime for operators of offshore oil and gas installations or for marine mining.

There are a number of global treaties that fill in details within the framework created by UNCLOS for many uses of the oceans (Section 3.2). These 'implementation agreements' are differently equipped in terms of their substantive provisions (e.g. consideration of the systemic approach or the precautionary principle, Section 3.1) and their powers to control and sanction. The number of states parties that have signed up to these implementation agreements vary. For example, the London Protocol (marine pollution prevention), which explicitly follows the precautionary principle and the polluter pays principle, only has 42 states parties. Reasons for the comparatively low level of participation might include the very precisely formulated bans (e.g. lists of prohibited substances); furthermore, the effective set of instruments for verifying compliance with the rules, and sanctions for states who do not comply, might be further reasons why some states are still holding back from acceding to the treaty.

The current zoning of the seas by international law under UNCLOS does not reflect the effect of marine pollution, which does not stop at zonal borders. By dividing the sea into zones with different legal regimes, individual sections are considered in isolation and the ocean is not seen as a whole. Furthermore, the zoning does not correspond to the ecosystem boundaries, and this can lead to problems in border-crossing ecosystems when the systemic approach is applied. There is therefore a lack of an integrated regime of conservation and use across the marine zones. Freedom of navigation, fishing and marine research applies on the high seas. The rights of use in the EEZ comprise primarily the exploitation of the fish stocks (90% of all economically important species of fish occur here), the use of oil and gas resources, and the erection of oil platforms and wind turbines. The sustainability of the management of the EEZ is neither checked nor sanctioned under UNCLOS.

Finally, the UNCLOS decision-making structures are not sufficiently transparent, particularly because of limited opportunities for the participation of stakeholders in the marine environment. A reform of UNCLOS should therefore also allow for greater involvement of civil society.

3.3 Global ocean governance: UN institutions and activities

The United Nations Convention on the Law of the Sea, or UNCLOS (Section 3.2), often referred to as the 'constitution of the seas', lays down the international governance framework for the use and conservation of the oceans. Various other institutions exist within the UN system parallel to, but independent of, UNCLOS which have helped shape this framework at a global level in the past, and will continue to do so in the future. The large number of different institutions involved, most of which pursue a sector-based approach focusing on specific uses (e.g. shipping) or environmental assets (e.g. marine biodiversity), has led to a marked fragmentation of ocean governance within the UN system: "Nevertheless, UNCLOS III leaves many of the details of marine resource management to further treaties and to domestic law, and these subordinate regimes perpetuate the fragmentation of ocean governance. One example of this fragmentation is the number and specificity of treaties currently in force that address different living marine resources" (Craig, 2012:91).

3.3.1 Actors: UN bodies and specialized organizations

Where they have a corresponding mandate and sufficient capacity, actors at the UN level make an important contribution to a sustainable stewardship of the oceans. For instance, they pool and continuously enhance knowledge, and on this basis drive forward the dynamic development of agreed goals. The following sections therefore examine the UN actors currently involved in the governance of the oceans and briefly outline their key activities.

3.3.1.1 UN General Assembly and UN Secretary-General

The annual General Assembly of the United Nations (UNGA) is the most important cross-sector forum for international marine policy. It identifies areas where action needs to be taken, evaluates ongoing processes, and takes decisions on behalf of the international community on the oceans and the law of the sea in the form of resolutions (for example Resolution 61/105 in 2007 on sustainable fisheries). The current items on the agenda of the UNGA relating to the oceans are as follows (UN, 2012c, 2013b):

- the reports of the Secretary-General on topical issues of ocean governance;
- the reports of the Ad Hoc Working Group of the Whole on the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects ('the Regular Process');
- the recommendations of the Ad Hoc Open-ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction ('the Ad Hoc Open-ended Informal Working Group');
- the reports on the meetings of the United Nations Open-Ended Informal Consultative Process on Oceans and Law of the Sea (UNICPOLOS);
- the reports of the Marine Environment Protection Committee of the IMO.

These reports and consultation processes form an important basis for the further development of international marine conservation. Most ocean-related reports to the UNGA are prepared by the Division for Ocean Affairs and the Law of the Sea (DOALOS) of the UN General Secretariat. In the light of the pressing need for action to protect the oceans, in 2012 UN Secretary-General Ban Ki-moon launched an initiative entitled The Oceans Compact – Healthy Oceans for Prosperity (Box 3.3-1). The implementation of the Oceans Compact is to be driven forward by an action plan to be drawn up with the support of a temporary, high-ranking Oceans Advisory Group.

3.3.1.2 Rio Process

The 'Rio Process' began in 1992 with the United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit, in Rio de Janeiro. To date, three sustainability summits have take place following decisions by the UNGA (1992, 2002, 2012). The primary goals of international environmental and development policy in Chapter 17 of Agenda 21, which was agreed at the 1992 Earth Summit, include the conservation of the oceans, seas and coastal areas and the protection and rational, precaution-oriented use and development of their living resources. Building on this, at the 2002 World Summit on Sustainable Development (WSSD), the international community decided to create networks of marine protected areas (MPAs) by 2012, also on the high seas (Section 3.6.2). The outcome document of the 'Rio+20 Conference' in 2012 deals extensively with the oceans. Particularly worthy of note are its comments on the urgent need for action to avoid land-based marine pollution with plastic waste, persistent organic pollutants (POPs), heavy metals and nitrogen, on avoiding ocean acidification and overfishing, and on the need to phase out harmful subsidies (UNCSD, 2012). No agreement was reached on negotiating a new agreement on the conservation and sustainable use of marine biodiversity on the high seas in general, and the creation of protected areas in particular (Section 3.6.2). However, this topic remains on the international agenda (Section 3.3.2.2).

3.3.1.3 International Maritime Organization

The International Maritime Organization (IMO), set up in 1948, aims to reduce – and, where possible, completely prevent – marine pollution by ships and to improve the overall safety and security of ships and shipping. The IMO is a specialized agency of the UN with 170 member states and 3 associate members (2013) representing more than 97 % of the world's merchant tonnage (IMO, 2011). Its motto is 'safe, secure and efficient shipping on clean oceans' (IMO, 2013a). 40 international conventions have been developed up to now under the aegis of the IMO, including MARPOL and the SOLAS convention. The IMO is primarily engaged in updating the existing law of the sea and ensuring that applicable laws really are enforced by member states. The IMO has an important communication and monitoring function in international marine policy.

3.3.1.4 UNESCO Intergovernmental Oceanic Commission

The UNESCO Intergovernmental Oceanic Commission (IOC), founded in 1960, has 145 member states (as per January 2013). Within the United Nations system it is the body responsible for ocean research, ocean observation, ocean data, early warning of marine dangers (e.g. tsunamis) and promoting ocean-research capacity (UNESCO, 2012a). Its aim is to improve the conservation of the marine environment given the growing influence of humanity on the oceans, and to develop the required decision-making processes and ocean-governance structures. The IOC organizes the Global Ocean Observing System (GOOS) and also acts as the interface for all ocean-related activities conducted by different UN institutions and under UN conventions (UNGA, UNEP, UNFCCC, CBD, etc.). The IOC supports the 'regular process' for observing the state of the marine environment and campaigns for a form of marine spatial planning that has been adjusted to meet today's challenges. With this in mind it has drawn up a forward-looking guide to implementing marine spatial planning (IOC, 2009). Through GOOS the IOC directly supports the Global Climate Observation System and studies the influence of climate change on the oceans (acidification, warming) and the role of the oceans in the climate system. The IOC has initiated a number of further programmes, including Capacity Development, Tsunami, Ocean Carbon, the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), the International Oceanographic Data and Information Exchange (IODE), IOC Law of the Sea, Marine Management, and Marine Assessments.

3.3.1.5 UN Environmental Programme (UNEP)

UNEP promotes the application of marine ecosystem management for the conservation and sustainable use of marine ecosystems. The Marine and Coastal Ecosystems Branch (MCEB) is responsible for ocean-related matters at UNEP. The MCEB provides a platform of institutional and programmatic cooperation on protecting the regional and global marine environment. Through its Regional Seas Programme (RSP), UNEP is a key actor in international marine conservation (Section 3.4.1). UNEP has developed its Marine and Coastal Strategy to give it a compass to guide its work. This strategy contains a vision for improving the marine and coastal-zone environment and for reducing human influence of on the seas. It describes land/sea interactions, the state of the marine environment and human wellbeing, the relationship between conservation and sustainable use, and the vulnerability of coastal zones and human populations (UNEP, 2012a).

3.3.1.6
UN-Oceans

UN-Oceans, established in 2003, is a coordination mechanism for all ocean and coastal issues within the United Nations system (UN-Oceans, 2013). The goals of UN-Oceans are, among other things,

- to strengthen coordination and cooperation of United Nations activities related to oceans and coastal areas;
- to review the relevant programmes and activities of the United Nations system;
- to identify emerging issues that are of relevance for the oceans; and
- to promote the integrated management of oceans at the international level.

UN-Oceans maintains a number of task forces – on marine conservation; on global partnership for climate change; on fisheries and aquaculture; on the reporting and evaluation process; on the state of the marine environment (the 'regular process'); and on the protection of the marine environment from land-based discharges. For example, UN-Oceans provided the joint platform for all UN bodies organizing events on ocean-related topics during the 2012 'Rio+20 Conference'.

3.3.1.7
Global Environment Facility (GEF)

The Global Environment Facility (GEF) has 183 member states (2013). Its International Waters Focal Area finances environmental-protection projects in trans-boundary waters, especially in developing countries, and uses its projects to highlight particular topics (e.g. the high seas, fisheries). The International Waters Focal Area is currently promoting the following ocean-related topics: international cooperation to reduce the threats to international waters; reducing land-based nutrient inputs and other types of land-based marine pollution; and protecting marine and coastal ecosystems (GEF, 2013). The GEF also supports collective management of trans-boundary surface water basins, groundwater basins and coastal and marine ecosystems, and corresponding political, legal and institutional reforms, plus the necessary investments in maintaining ecosystem services. The GEF is the largest financier of trans-boundary cooperation in international waters, including 21 of the world's biggest marine ecosystems (World Bank, 2013: 10).

3.3.1.8
World Bank Group

The World Bank Group's remit is to promote the economic development of less-developed nations through financial and technical support and advisory services. The World Bank publishes a regular World Development Report and carries out projects in partner countries, for example on oceans and coastal management. In 2012 it created the Global Partnership for Oceans, a global initiative whose purpose is to promote or restore the health and productivity of the oceans (Global Partnership for Oceans, 2013). Up to now more than 100 governments, international organizations, NGOs and representatives of private-sector interests have lent their support to this initiative. The goal is to achieve significant development progress in three areas by 2022: sustainable fisheries and aquaculture, the conservation of marine biodiversity and habitats (including coastal areas), and the reduction of marine pollution (Box 3.6-1).

3.3.2
UN conventions relating to the oceans

A variety of conventions dealing with the conservation and sustainable use of the oceans have been established under the aegis of the UN. These treaties vary widely both in terms of their goals (e.g. conserving biodiversity, protecting the world's natural heritage, preventing marine pollution) and in terms of their cooperation mechanisms: for example whether they include sanctions and, if so, how these sanctions are enforced. The most important treaties are described below.

3.3.2.1
Convention on Biological Diversity (CBD)

The objectives of the *Convention on Biological Diversity* (CBD) are to conserve biological diversity and to ensure the fair and equitable sharing of the benefits arising from the use of genetic resources. 192 states and the European Union are currently contracting parties to the CBD. With regard to the conservation of marine biodiversity, the scope of the CBD covers not only areas within the limits of a contracting party's national jurisdiction, but also actions carried out under a contracting party's jurisdiction or control beyond the limits of national jurisdiction. The provisions of the CBD do not, however, relate directly to the components of biological diversity, but only to processes and activities carried out on the high seas (Article 4, letter (b) of CBD). Article 5 of CBD states that contracting parties shall cooperate with each other, also with respect to the high seas. Overall, therefore, the high seas and the 'Area' are only subject to the CBD's protection to a limited extent (Glowka, 1994: 26f.), and the obligations on the contracting parties do not go further than those of UNCLOS (Friedland, 2007: 161).

The CBD has no effective sanction mechanisms. However, as a framework agreement it can have legally binding protocols added to it. Thanks to its almost universal membership, the CBD has made a substantial contribution to consensus building with regard to the oceans. This can be seen, for instance, in the implementation of the CBD's Programme of Work on Marine and Coastal Biological Diversity (CBD, 2004a), the elaboration of the ecosystem approach (Sections 4.1.3.1 and 7.1.2), the political objectives in the field of marine conservation (Section 3.6.2.1), and the governance of international fisheries (Section 4.1.4.1).

3.3.2.2
Negotiations on a new implementing agreement on marine biodiversity on the high seas

In 2004 the UN General Assembly convened the informal BBNJ working group (BBNJ stands for Biological Diversity Beyond Areas of National Jurisdiction), which has since dealt with the conservation and sustainable use of biological diversity on the high seas. Its aim is to find ways of closing loopholes in the existing legislation in this field, including those identified by the World Summit on Sustainable Development (Section 3.3.1.2; WSSD, 2002) and the Convention on Biological Diversity (Section 3.3.2.1; CBD, 2004a). The objective is to lay the foundation for negotiating an implementing agreement under UNCLOS. This implementing agreement would address three issues: (1) the sustainable use of marine genetic resources (including access and benefit sharing); (2) nature conservation (primarily by means of marine protected areas on the high seas); and (3) environmental impact assessments (Section 7.3.4.2). Overarching topics such as technology transfer and capacity building are also on the agenda. However, it remains an open question when formal negotiations might begin. Through its work and its studies, the CBD is doing important scientific and technical preparatory work that will make it easier to designate marine protected areas on the high seas at a later date. In particular, the CBD has already proposed selection criteria and made initial suggestions for a list of ecologically or biologically significant marine areas (EBSAs) that are suitable candidates for marine protected areas on the high seas (CBD, 2012).

A prerequisite for successfully negotiating a new, ambitious implementing agreement is a strong mandate – a resolution by the UN General Assembly, say, including guidelines on a sustainable form of stewardship of biological diversity on the high seas (Druel et al., 2011). This would strengthen people's awareness of the problem, demonstrate political will on the part of the international community, and encourage swifter action by states (Cole et al., 2012: 42). However, the prospects of success also depend on the behaviour of key actors: for example, whether the USA ratifies UNCLOS, which would send out a positive signal. The interests of major emerging economies must also be taken into account in sufficient measure, so that the designation of new marine protected areas is not blocked. As the agreement affects areas beyond national jurisdictions, achieving as broad and universal a consensus as possible within the international community is a key precondition for successful implementation. If possible, all countries that are important actors on the high seas should ratify the new implementing agreement (Druel et al., 2011).

Given the urgent need for action and the fact that negotiating and ratifying a new multilateral agreement usually takes many years, parallel measures – such as the designation of further marine protected areas – should be agreed to stem the ongoing damage being done to the marine environment on the high seas (Section 3.6.2.1).

3.3.2.3
UN Framework Convention on Climate Change (UNFCCC)

The goal of the UNFCCC is (1) "To stabilize the greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system – such a level to be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change;" (2) "To ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (Article 2 of UNFCCC). The diverse effects of climate change on the marine ecosystems, food from the sea, and the economic use of the ocean are therefore also within the focus of the UNFCCC's goal; marine conservation is thus one of the arguments used to justify climate protection.

In its 2006 special report 'The Future Oceans', the WBGU argued that preventing a "dangerous acidification" of the oceans was also covered by the mandate of the UNFCCC (WBGU, 2006). This is disputed by some people, however (Kim, 2012). Even so, an approach to climate protection that would be ambitious enough to prevent a global increase in temperature of more than 2 °C would most likely also limit the acidification of the oceans (Section 1.2.5; WBGU, 2006).

Another area where the UNFCCC applies to the oceans is the obligation it places on its parties to protect their sinks and stores, explicitly including marine and coastal ecosystems (Article 4 of UNFCCC). Under the overall heading of 'blue carbon' the UNFCCC is currently discussing the recognition of measures aimed at preserving coastal ecosystems as a climate-protection measure. However, in view of the multitude of functions performed by coastal ecosystems, and their comparatively moderate potential for climate protection, the WBGU considers it unhelpful to focus one-sidedly on the aspect of CO_2 storage when discussing the protection of these ecosystems (Box 1.2-1).

Furthermore, the UNFCCC framework creates incentives to invest in renewable energy, e.g. by means of the flexible mechanisms of the Kyoto Protocol or via various funds. This could be important for the development of renewable energy from the sea, especially in developing and newly industrializing countries.

3.3.2.4
UNESCO World Heritage Convention and World Heritage Marine Programme

The Convention Concerning the Protection of the World Cultural and Natural Heritage (or World Heritage Convention) was adopted under the aegis of UNESCO in 1972. Its aim is to protect the cultural and natural heritage of humanity. As per 2012, 190 countries have signed up to the Convention. Proposals for new additions to the World Heritage List are evaluated every year. By submitting supporting studies and guidance, UNESCO's World Heritage Marine Programme plays a key role here by ensuring the selection of a "representative, balanced and credible" marine World Heritage List (UNESCO, 2013a). There are currently 745 cultural properties, 188 natural properties and 29 'mixed' properties (UNESCO, 2013b). The following coastal and marine areas feature on the list of Natural Heritage Sites:

- The Wadden Sea (2009; extended in 2011)
- Galápagos Islands national park and marine protected area (1978; extended in 2001)
- Phoenix Islands Protected Area (2010)
- The Ningaloo Coast (2011)
- High Coast/Kvarken Archipelago (2000; extended in 2006)
- Giant's Causeway and Causeway Coast (1986)
- Dorset and East Devon Coast ('Jurassic Coast') (2001)

3.3.2.5
MARPOL and SOLAS

The International *Convention for the Prevention of Pollution from Ships* (MARPOL, 152 member states as per February 2013), which was developed under the aegis of the IMO in 1973, primarily targets ship owners in order to stop operational discharges into the ocean by shipping (BSH, 2011).

Areas of the ocean that are highly frequented as transport routes and therefore require protection measures to prevent marine pollution from oil, noxious substances and garbage can be designated 'special areas' (Annex I, II and V of MARPOL), thereby placing them under protection. For example, discharging oil from the area of the cargo tank is prohibited in 'special areas', with the exception of clean or segregated ballast (Annex I). Other substances that are harmful for the marine environment are classified and can also be subject to a ban on discharges (Annex II). Annex V regulates the conditions for – and on certain conditions the ban on – discharging or dumping garbage into the marine environment in 'special areas'. In addition, member states can apply to the IMO to have an area designated a Particularly Sensitive Sea Area (PSSA). This can be substantiated on grounds of the ecological condition of the area or its importance for tourism (IMO, 2013c). In these areas, specific routes can be made mandatory for vessels, for example (Proelß, 2004), or the regulations of Annex I, II, V or VI of the MARPOL Convention can be applied (IMO, 2005). In the meantime, designation as a PSSA and or as a 'special area' is not exclusive; rather, an area can meet the requirements for being designated as both a 'special area' and a PSSA at the same time (IMO, 2013c).

Annex VI of the MARPOL Convention regulating exhaust emissions by ships came into force in 2005. This Annex sets a limit on the sulphur and nitrogen content of fuel used on board ships, which must now not exceed 4.5%. Emissions are limited to 1.5% in designated SO_x Emission Control Areas (SECAs) such as the North Sea and the Baltic Sea (Blanco-Bazán, 2003). Article 211 of UNCLOS also stipulates that allowing the right of innocent passage must not come at the expense of the environment.

Also under the aegis of the IMO, the fourth version of the Safety of Life at Sea Convention (SOLAS; 162 member states as per February 2013) was drawn up in 1974 to ensure the safety of shipping. It includes mandatory technical requirements for ships, such as double hulls for vessels that do not exclusively transport liquid substances. These standards aim to prevent marine pollution caused by container ships or oil tankers that sink or lose their freight.

3.3.2.6
London Convention and London Protocol

The global Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (or London Convention, BGBl. II. 1977, p. 165) was agreed in 1972 (87 member states as per May 2013). In 1996 it was extended with the adoption of the London Protocol (BGBl. II 1998, p. 1,345; 42 member states as per May 2013).

The London Convention (1972) bans the dumping of certain substances contained on a blacklist. By contrast, the London Protocol declares a general ban on dumping with certain exceptions (UBA, 2010). Exceptions can be granted *inter alia* for dredged material, sewage sludge, fish waste, vessels, platforms and other man-made structures at sea, CO_2 in geological formations under the sea, organic material of natural origin, and bulky items. Prior to dumping these materials in the ocean, the possibility of disposing of them on land must first be examined. The Protocol extends the subject matter and geographic scope of application to all vessels that have been authorized to fly the flag of a member states or have been loaded in that state's territory (Erbguth and Schlacke, 2012).

3.4 Regional ocean governance

The regional level plays a key role in the governance of the oceans because it often proves to be the most suitable level for tackling problems (Backer et al., 2010). Global, universalistic standards and regulations such as UNCLOS (Section 3.2) have the advantage of being supraregional in their reach and having binding force. However, they often lack 'grounding' – i.e. spontaneous acceptance by local communities and relevance to their everyday lives. Such local communities contribute local knowledge, but sometimes also an ethnocentric or excessively provincial perspective on global challenges. Regional integration and alliances are therefore needed to 'localize' and concretize universalistic standards such as those of UNCLOS and similar approaches of the United Nations and its subsidiary organizations (Section 3.3). Regional structures give the tasks of global marine policy a greater degree of collective identity without furthering nationalistic approaches or attempts by certain countries to go it alone. A regional narrative is able to 'earth' real-life aspirations of a 'good life' and at the same time provide a vital starting-point for cross-border cooperation, especially since many regional relations transcend borders either by tradition or through innovative networks.

While the world's oceans represent universalistic matter *per se* and were the basis of economic globalization, their cultural and political perception is more strongly connected with historical experience. It is not surprising, therefore, that many different cooperative approaches already exist in the field of marine policy dealing with challenges that are regionally specific, or at least perceived as such.

3.4.1 UNEP Regional Seas Programme

The UNEP Regional Seas Programme (RSP), which was set up in 1974, is a central component of ecological ocean governance. It aims to counteract the growing degradation of the world's oceans and coastal areas. The UNEP-RSP does this by promoting cooperation between neighbouring countries and encouraging them to take comprehensive and specific measures to protect their shared marine environment (UNEP, 2013b). The main elements of the programme include maintaining biodiversity, reducing pollution from the land, building governance and management capacity, and promoting education and awareness (Sherman and Hempel, 2008). To date, 13 regional programmes have been developed under the umbrella of UNEP-RSP covering significant areas of the world's oceans. 143 countries are participating in the meantime. Furthermore, five partner programmes exist (Arctic Region, Antarctic Region, North-East Atlantic Region, Baltic Sea, Caspian Sea) which were developed independently of UNEP-RSP. There is cooperation and an exchange of knowledge between the UNEP-RSP and these partner programmes, some of which are comparatively well developed, to support especially the less well developed regional programmes. Section 3.4.3 discusses one example of this: cooperation between the North-East Atlantic Region (1982 Convention for the Protection of the Marine Environment of the North-East Atlantic, OSPAR) and the West and Central Africa Region (WACAF, Abidjan Convention).

A core component of each programme is its regional action plan. In most cases this is supported by a legal framework in the form of a regional convention, as well as corresponding protocols dealing with specific issues (Rochette and Billé, 2012; Section 3.4.2).

The UNEP-RSP itself functions as a central platform for strengthening the institutional capacity of the individual regional programmes. At the same time it aims to promote their scientific components and the application of the ecosystem approach in regional ocean governance, aw well as to raise the political profile of the individual programmes (UNEP, 2013b). To this end UNEP, through UNEP-RSP, develops guidelines and recommendations and identifies best practices, which serve as an orientation framework for specific regions. For instance, it has developed manuals on the cooperative management of regional seas (e.g. on practical ecosystem management or financing the implementation of conventions and action plans). It also agrees 'Global Strategic Directions' (UNEP, 2007) which are regularly updated. Their aim is to adjust the management of marine areas to bring them in line with changing conditions ('adaptive management') and to improve coordination and coherence between the individual regions. For example, the Global Strategic Directions 2008-2012 underline the need to address the conservation of marine biodiversity in areas beyond national jurisdic-

Box 3.3-1

The Oceans Compact – Healthy Oceans for Prosperity

UN Secretary-General Ban Ki-moon launched an initiative called The Oceans Compact – Healthy Oceans for Prosperity in 2012 (UN, 2012a). The aim of the Oceans Compact is to "strengthen UN system-wide coherence in delivering on its oceans-related mandates" and to develop a strategic vision for the sustainable future of the oceans. The main issues to be addressed by the Oceans Compact are the worrying condition of the oceans, diminishing ocean productivity and ineffective ocean governance. The initiative is to be supported by corresponding strategies aimed at strengthening cross-sector cooperation and coordination at a national, regional and global level, including within the UN system. In so doing, it aims to focus attention on the cumulative impact on the marine environment of activities in different sectors and to promote the application of the precautionary principle and the ecosystem approach in international marine policy. It also implicitly mentions the idea of world heritage by referring to the need for a fair distribution of the yields and benefits of the oceans: "We need (...) to develop ways of sharing the wealth of the oceans to benefit all" (UN, 2012a: 2).

"To attain the goal of Healthy Oceans for Prosperity, we need to discover new and innovative ways to protect ocean resources" and to use marine resources more efficiently. "Three inter-related objectives advance this goal":

- *Protecting people and improving the health of the oceans*: This objective involves adapting to sea-level rise, promoting more sustainable management of coastal areas, reducing marine pollution and overfishing, and using a green economy approach to achieve sustainable development and poverty eradication. Finally, another aim is to strengthen the implementation of existing agreements.
- *Protecting, recovering and sustaining the oceans' environment and natural resources and restoring their full food production and livelihoods services*: Priorities here include restoring overexploited fish stocks, avoiding destructive fishing techniques, combating illegal fishing, conserving marine biodiversity and halting the spread of invasive alien species. In these areas, too, the aims is also to strengthen the implementation of existing agreements.
- *Strengthening ocean knowledge and the management of oceans*: This objective involves promoting marine scientific research (e.g. on acidification and overfertilization) and ocean monitoring to strengthen science-based marine policy, promoting suitable capacities and infrastructures, supporting the development of the regular 'global integrated assessment of the state of the marine environment including socio-economic aspects' (or 'Regular Process') planned for 2014 (UN, 2012a: 6), and promoting the sustainable use of ocean resources. If this process results in a scientifically robust report, this could represent the start of scientific reporting modelled on that of the Intergovernmental Panel on Climate Change (Section 7.3.1.2).

Implementation

The implementation of the Oceans Compact is to be driven by a results-orientated action plan – the Oceans Compact Action Plan – to be elaborated with the help of a time-bound, high-ranking Oceans Advisory Group. This group will be composed of representatives of the UN system, policy-makers, scientists, ocean experts and representatives of business and civil society. The aim is to develop a new orientation framework for international marine policy in this way. Finally, the Oceans Advisory Group is also to present proposals for financing the implementation of the Action Plan by mid-2013.

tion (ABNJ) within the framework of the regional programmes (Druel et al., 2013). Not least, the UNEP-RSP also provides an informal forum for the exchange of knowledge between the different regional programmes.

To a large extent the success of the UNEP-RSP and the regional programmes is a result of UNEP's approach of making cooperation within the UNEP-RSP itself non-binding under international law (Rochette and Billé, 2012). Countries are expected to comply with the measures they have agreed to without any threat of legal sanctions, the aim being to promote regional cooperation. UNEP explicitly supports cementing cooperation in the individual regions by agreeing additional internationally binding conventions and protocols (Rochette and Billé, 2012). With the exception of the North-West Pacific Region, the South Asian and the East Asian Seas Programmes, all regional programmes are now backed by internationally binding regional conventions (Section 3.4.2).

The UNEP-RSP is thus first and foremost a cooperation forum that is complementary to the internationally binding regional conventions. The UNEP-RSP's orientation towards UNEP's Marine and Coastal Strategy and globally agreed goals (e.g. WSSD, CBD), and its integration in the UNEP Marine and Coastal Ecosystems Branch (MCEB; Section 3.3), aims to ensure the coherence of ocean-related activities and the consistent application of an ecosystem-based management approach (Sherman and Hempel, 2008). Particularly noteworthy in this context is the cooperation between the UNEP-RSP and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, which is also run under the MCEB umbrella. This again highlights UNEP's particular emphasis on the regulation of land/sea interaction. This interface, which is important in relation to the systemic approach (Section 3.1.3), is insufficiently regulated under UNCLOS (Section 3.2). UNEP's approaches to closing these regulatory gaps therefore deserve a positive overall assessment.

Due to the general lack of empirical studies, it has not been possible up to now to make a final evaluation of the UNEP-RSP's performance in practice (UNEP, 2010a). However, it does contain approaches for a more systemically oriented, cooperative and adaptive system of ocean governance. In particular, the programme helps to intensify interregional cooperation. It has also been successful with respect to intra-regional cooperation, for instance in establishing regional conventions (Section 3.4.2) – which are to a large extent the result of prior cooperation within the respective regional programmes. Nevertheless, some of UNEP's activities do not interact sufficiently with those of other UN actors (IOC et al., 2011). This is particularly true of cooperation with the RFMOs, which are responsible for the regional management of fisheries (Section 4.1.4.4).

3.4.2
Regional seas agreements

The *Convention for the Protection of the Mediterranean Sea Against Pollution* (Barcelona Convention) was adopted in 1976 and came into force in 1978. This was the first time a framework for regional cooperation that was binding under international law was created to protect the marine environment, in this case the Mediterranean. Many such conventions exist in the meantime. They differ – in some cases widely – in terms of their geographical reach and regulatory scope, their agreed targets and the instruments used to implement them. Major differences also exist with regard to their financial and organizational/institutional capacity. What they share, however, is a focus on protecting the marine environment, and this is the reason why they play such an important role in the sustainable stewardship of the oceans. They facilitate a collaborative approach to addressing cross-border environmental problems.

In most regions, the framework for the cooperation is provided by a regional convention in which the general objectives and principles are established. This is also in line with the UNEP-RSP's approach. However, as a rule these objectives and principles are vague, so that the member states agree additional protocols on specific topics and develop action plans to drive forward the implementation of the objectives (Rochette and Billé, 2012).

3.4.2.1
Task areas

The range of topics addressed by regional protocols and actions has developed largely along the lines of global environmental-protection standards (Bodansky, 2009). First, legal instruments were agreed for regional cooperation on avoiding pollution by oil and other contaminants by shipping (Mediterranean, 1976; West Africa, 1981; Red Sea and Gulf of Aden, 1982; Caribbean, 1983; Western Indian Ocean, 1985, etc.) and on avoiding land-based pollution (Mediterranean, 1980; Black Sea, 1982; South-East Pacific, 1983, etc.). Gradually the spectrum was extended to include conserving biodiversity, mainly through by creating protected areas (Western Indian Ocean, 1985; South-East Pacific, 1989; Caribbean, 1990, etc.). More recently, goals that go beyond the protection of the marine environment have been pursued, albeit still to a limited extent. For example, the protocol on Integrated Coastal Zone Management (ICZM; Section 3.6.3) in the Mediterranean, adopted in 2008, also addresses factors of socio-economic development.

The states bordering on the Western Indian Ocean are also now working on the development of such an ICZM protocol under the Nairobi Convention (Rochette and Billé, 2012). There is currently a trend towards extending the conservation of marine biodiversity to areas beyond national jurisdiction (ABNJ). For instance, negotiations are currently underway on a new implementing agreement on marine biodiversity on the high seas (Section 3.3.2.2), and marine protected areas on the high seas have been designated under the OSPAR Convention (OSPAR, 2010c).

Marine spatial planning – a forward-looking instrument that offers ways of balancing different interests in a collaborative fashion – is also gaining importance in regional cooperation in the light of growing cross-border competition over use. For example, two projects have already been carried out within the framework of the Baltic Sea Action Plan, which was developed under the Helsinki Convention: BaltSeaPlan and PlanBothnia. These are simultaneously serving as pilot projects for the development of EU-wide marine spatial planning (Section 3.6.2). However, fishery governance is generally excluded here; the Regional Fisheries Management Organizations (RFMOs) established at the regional level by the member states of the Fish Stocks Agreement (FSA) are responsible for this (Section 4.1.4). Not infrequently, this division of responsibilities leads to a lack of coordination and coherence in governance within individual ocean regions, even where approaches for cooperation exist, e.g. in the case of the North-East Atlantic between the OSPAR Commission and the North East Atlantic Fisheries Council.

3.4.2.2
Institutionalization: governance mechanisms and capacity

Equally as important as the regulatory content of the regional seas agreements is establishing viable cooperation mechanisms and organizational/institutional and financial capacities. In order to cement cooperation and dynamically adjust governance to meet changing challenges, it is essential that regional actors are strengthened and supplied with the necessary skills, e.g. to pool regional knowledge and develop action plans and protocols.

Some regional conventions have comparatively well developed commissions, such as the OSPAR Commission and the Helsinki Commission, which are well equipped and staffed in areas such as environmental monitoring, evaluation, and assessing risks and impacts. Cooperation between member states is also supported by regular exchanges in the respective working groups that have been established within these two commissions (Backer et al., 2010; OSPAR, 2010c). These working groups develop options for enhancing the cooperation, which then have to be approved at the meetings of ministers that are held about every three years. One example is the decision made under OSPAR to designate marine protected areas in areas beyond national jurisdiction.

In all the commissions and secretariats created up to now under regional marine environmental conventions, legally binding decisions or regulations have to be agreed unanimously by the member states. The EU, by contrast, has forms of marine cooperation that are based on both majority and unanimous decisions (Section 3.4.3).

The work of the commissions focuses in most cases on administrative and financial questions. They often lack the resources to provide members states with the technical and legal support they need to implement regionally agreed targets and measures (Rochette and Billé, 2012). Under some conventions, e.g. the Barcelona Convention, 'Regional Activity Centres' have been set up alongside the commissions to carry out these tasks for specific subregions (Rochette and Billé, 2012).

3.4.2.3
Cooperation, coordination, coherence and complementarity

The coordination of regional activities and a skilful division of labour ('complementarity') are also essential to meet the demands of the systemic approach. Moreover, it must be ensured that regulations agreed and activities planned in one region do not lead to negative external effects in others. Regional cooperation can also help to avoid 'free-rider' behaviour in other regions. Such forms of cooperation currently exist only in the areas of environmental monitoring and evaluation, as well as in capacity-building. For example, OSPAR (protection of the North Sea and the North-East Atlantic) and HELCOM (marine conservation in the Baltic Sea area) are working together to harmonize indicators (OSPAR, 2010c). OSPAR and the Abidjan Convention are also collaborating on capacity-building in ecosystem management (OSPAR, 2010c).

In some cases, coordination within the individual ocean regions is problematic. Because competencies overlap in some cases – e.g. between the EU Marine Strategy Framework Directive and the conventions responsible for European regional oceans (OSPAR, HELCOM, the Barcelona Convention, Bucharest Convention) – improved coordination is needed to ensure the necessary degree of coherence, i.e. the coordination of political and institutional measures (Backer et al., 2010). Interaction between EU marine policy and these conventions is discussed in Section 3.4.3. Not least, it is also necessary to integrate relevant regulations from global agreements (e.g. FSA, CBD, CITES) into regional conventions. The extent to which this has been done in the past has varied greatly.

3.4.3
EU marine policy

The EU is an important actor in regional ocean governance. The exclusive economic zones (EEZs) of its member states together cover an area of approximately 25 million km^2. In a way they might be described as by far the biggest EEZ in the world. According to UNCLOS, however, the EEZs are controlled by the individual states parties to the Convention, not by the EU. Nevertheless, the EU has ways of influencing the governance of European regional seas through its skills in many political areas (e.g. environment, competition). However, large stretches of some member states' EEZs in overseas territories have hitherto been outside the EU's sphere of influence. The French overseas territories, for instance, which have extensive EEZs, have a large degree of autonomy from the French central government and hence also from the EU.

The EU has issued a number of strategies, action plans, guidelines and directives relating to European marine regions. These often have a sectoral basis, that is to say they apply to a specific use (e.g. the Common Fisheries Policy; Section 4.2.3) or relate to specific environmental protection goods (e.g. the FFH Directive). In addition, the EU has recently made efforts towards developing an integrated marine policy (EU Commission, 2008). The most important elements are currently the 2008 Marine Strategy Framework Directive (MSFD) and the 2007 Action Plan (known as the 'Blue Book on Maritime Policy'). Furthermore, regulations on land-based activities have already been created with the adoption of the Water Framework Directive (Heiskanen et al., 2011). The same applies to the NATURA 2000 system of protected areas set up under the Flora-Fauna-Habitat and Birds Directives, which covers both terrestrial and marine protected areas (SRU, 2012a).

For this report it is the external impact of EU marine policy that is most important. The central question is the extent to which EU policies are intermeshed in the sense of the systemic approach, and the extent to which there is a balance between conservation and sustainable use, taking the precautionary principle and other considerations into account. The EU has ratified the four regional marine environment conventions affecting European regional oceans: the Helsinki Convention (HELCOM) for the Baltic Sea, the OSPAR Convention for the North Sea and the North-East Atlantic, the Barcelona Convention for the Mediterranean, and the Bucharest Convention for the Black Sea (Section 3.3.2). It has also signed up to the Antarctic Treaty and has observer status in the Arctic Council (Box 3.4-1).

Thanks to its political and economic weight, due in no small part to the comparatively well-developed capacity of certain member states in the field of marine research, the EU plays a key role particularly in the European marine-environment conventions. This is especially true of HELCOM, where Russia is the only member state out of the nine countries bordering on the Baltic Sea that is not an EU member. This is one of the chief reasons why the EU views the Baltic Sea Action Plan (BSAP) as a pilot project for implementing the goals of the Marine Strategy Framework Directive (MSFD). To achieve the overarching goal of a 'good environmental status' formulated there, various pilot projects have been – and are still being – developed under the Baltic Sea Action Plan and given financial support from the Structural and Cohesion Fund and the Regional Fund (Schultz-Zehden et al., 2008). Particularly important are the projects aimed at developing marine spatial planning for the EU: PlanBothnia and BaltSeaPlan (Schultz-Zehden and Gee, 2013). These projects are attempting to reach a cooperation-based balance of interests between conservation and use, applying the instrument of anticipatory planning (Schultz-Zehden et al., 2008; Backer, 2011). The standards developed here are to be made available later for use in EU-wide marine spatial planning.

The development of 'spatial protection measures' by member states prescribed by the Marine Strategy Framework Directive (recital 21, Article 13, para. 4 of the MSFD) creates a framework for coordinating sector-based concepts of marine conservation and use. The EU's 2008 Roadmap for Maritime Spatial Planning calls for the creation of a single body to achieve better coordination (EU Commission, 2008). The Roadmap also includes ten shared principles, according to which, among other things, spatial planning should be based on an ecosystem approach and developed in a manner that is transparent for the public (Section 3.6.2.2).

The EU's marine policy contains elements of a systemically oriented form of governance, inasmuch as it develops an integrated marine policy including marine spatial planning, takes into account land-based pollution through the Water Framework Directive, and cooperates with other states under regional marine environment conventions. However, a number of questions remain unanswered. For example, the 2012 Limassol Declaration ('A Marine and Maritime Agenda for Growth and Jobs') gives the impression of giving preference to use over conservation (EU, 2012). Furthermore, it is problematic that competencies for fisheries, harbours, transport, energy generation and the extraction of raw materials still remain fragmented, which may well run counter to the goal of achieving an integrated approach as formulated in the Blue Book on Maritime Policy. In many cases, cooperation with neighbouring states could be stepped up; this is discussed in Box 3.4-2 with reference to the example of the Mediterranean region. Another question is the extent to which the EU can bring its land-based policy more into line with the criteria formulated in Section 3.1.3 and in so doing take a further step in the direction of systemic governance.

3.5 Private ocean governance

3.5.1 Options and limitations

The conservation and sustainable use of the oceans is a public task – one that must be addressed first and foremost by the international community and for which countries must create a framework in the field of marine policy (Chapter 2). At the same time, recent decades have seen the emergence of an array of non-state governance regimes in a wide variety of policy fields, including marine policy, in which private and semi-governmental actors work together. These activities can be described as private governance or – where private actors collaborate with state bodies – private-public governance (Falkner, 2003). In this context 'governance' means that the actions of private actors acquire public significance – by establishing standards, regulations and institutions which affect the actions and options of third parties (Cutler et al., 1999:4). Private governance is functionally significant in areas where states' effective capacity to control and regulate is inadequate. Moreover, it can and should create indirect legitimacy precisely in the supra- and transnational sphere where parliamentary or federative representation is lacking (Pattberg, 2004b).

One drawback of privatizing (global) policy-making is the risk of certain players unilaterally and unlawfully asserting their own interests. Other dangers include corruption and the systematic neglect of poorly organized public interests. The legitimacy and effectiveness of private governance and private-public partnerships should be judged on the basis of whether they are consistent with higher interests of sustainable policy and enable them to be implemented better. For this reason, networks of private and semi-private governance must be subject to strict control measures.

In recent decades, private actors have also gained considerable influence in the field of trans- and supranational environmental governance (e.g. forest management). On the one hand, they have offset the withdrawal of the state; on the other they have facilitated it. The democratic legitimacy of global environmental policy has been indirectly strengthened in this way. However, private-public partnerships usually lack institutional accountability (Leggewie, 2003; Scholte, 2011). Not every concern raised or expertise honed in civil society leads to appropriate action by government, but without local initiatives government action often remains just a paper exercise, inspiring neither enough acceptance nor resonance (Przeworski et al., 2009; Nanz and Fritsche, 2012).

Self-regulation, especially by companies, cannot replace government action in the traditional sense. But in many cases businesspeople are more advanced than their industrial associations – with which politicians consult and collaborate. The influence of private governance thus remains limited, and its ambiguity is probably irresolvable; for its effect in offsetting for the regulatory weaknesses of policy-makers is as contentious as its potential for legitimacy.

Co-regulation is a form of private governance (Pattberg, 2007: 3) in which private actors, usually companies, cooperate with non-profit organizations such as non-governmental organizations (NGOs). Private-private partnerships (Pattberg, 2004a) or 'private co-regulation' (Pattberg, 2007: 3) should be distinguished from unilateral initiatives by businesses where the corporate actors impose standards on themselves, monitor compliance and then, for example, put specially created labels on their products. This form of self-regulation is often problematic, since the self-imposed obligations are frequently insufficient to offer sufficiently effective protection for such endangered environmental goods as biodiversity (Lewis et al., 2010).

In private-private partnerships, by contrast, an independent body such as an NGO is in charge of both certification and monitoring compliance. The NGOs involved generally have the necessary expertise and an additional 'moral authority', lending such initiatives more legitimacy and greater credibility (Risse and Börzel, 2005).

3.5.2
Example: eco-labels and sustainability labels

Interest in sustainability labels has grown in recent years. They provide information about the ecological and social conditions where products or services originate (Lewis et al., 2010). They are awarded through a certification process in which a producer, an association of producers, or an official body responsible for the producers has to prove that certain products comply with the environmental standards connected with the eco-label. Awarding seals of quality and regular monitoring of compliance with the respective environmental standards can encourage the spread and implementation of certain environmental standards.

Consumers can make informed consumer decisions with the help of eco-labels, since they indicate ecological advantages over another product that is functionally just as good. However, it is essential that consumers have at least a rudimentary knowledge of the standards espoused by the label, and actually taken these into account when making their purchase decision.

Where there is sufficient demand, introducing eco-labels can trigger sustainable production processes and changes in the value chain. Apart from consumers actually basing their purchase decisions on labels, if they are to be successful it is also essential that the companies are convinced of the advantages of participating in certification and labelling processes, since quality labels cannot be established without the cooperation of companies (Auld and Gulbrandsen, 2010).

Fishery eco-labels

Sustainability labels have been developed for fisheries and aquaculture in recent years. Most of these labels were born of the realization that state action was insufficient to ensure the sustainable management of marine resources (FAO, 2011f). The following discussion refers only to eco-labels; it does not consider the private labels for fish and seafood used by individual supermarket chains. In principle, a distinction can be made between labels that relate to the conservation of a single species, and labels relating to all species of wild-caught or farmed fish and seafood. The most common labels aiming to protect a single species focus on dolphins. They are supposed to show, for example, that tuna are caught using methods that reduce the number of dolphins killed as bycatch. Since no independent certification body exists, there is a lack of clarity about

Box 3.4-1

Regional governance of the Arctic

The Arctic Council – central regional cooperation forum

The Arctic Council was formed in 1996 out of the Arctic Environmental Protection Strategy (AEPS), which had been adopted in 1991. It is the central regional cooperation forum for the governance of the Arctic. Its members are the five coastal states bordering on Arctic Ocean – Denmark, Canada, Norway, Russia and the USA – plus Finland, Iceland and Sweden. Originally, cooperation focused on the protection of the Arctic's marine and terrestrial environment, but today attempts are also made within the framework of the Arctic Council to deal in a cooperative manner with its member states' sometimes conflicting interests with regard to the commercial exploitation of the Arctic, as well as security issues.

As a cross-national forum, all decisions in all bodies of the Arctic Council are made by consensus (Rules of Procedure, 1998). Important decisions are taken at the ministerial meetings held twice yearly. Up to now member states have not been able to agree on sanction mechanisms. Within the Arctic Council, cooperation relevant to the conservation and sustainable use of the Arctic Ocean takes place primarily through programmes carried out by working groups and task forces, which are assigned tasks agreed by unanimous resolutions – e.g. the development of action plans. Significant capacity for jointly overcoming shared challenges has been developed in this way: in areas such as monitoring and assessing biodiversity and the consequences of climate change, conserving Arctic flora and fauna and the marine environment of the Arctic, disaster prevention and crisis response. Further positive steps include the possibilities created by the member states allowing participation by other states, indigenous peoples and NGOs, who have been granted observer status.

However, in the Ilulissat Declaration (2008), which deals among other things with the conflict over mineral resources in the Arctic, the five coastal states bordering on the Arctic Ocean underlined their exclusive claim to the Arctic. In so doing they allowed a divide to appear, symbolically at least, between themselves and the other members of the Arctic Council and the indigenous peoples (Winkelmann, 2008; Humrich, 2011). Given the emerging shift of interests towards increased commercial exploitation of the Arctic by the coastal states, which is in part diametrically opposed to the interests of conservation, any institutional strengthening of the cooperation mechanisms appears unlikely. Yet in order for governance to be able to meet the challenges of protecting the Arctic, a further institutionalization of the Arctic Council is required in addition to increasing the above-mentioned capacities for monitoring, prevention, protection and crisis response.

Significance of regional cooperation in the Arctic – opportunities and limitations

The importance of the regional level of governance for the sustainable stewardship of the Arctic Ocean (Section 3.4) stems from the distribution of powers – which is regulated under UNCLOS but has not yet been finally clarified – between the different coastal states, as well as between these states and the international community, relating to different areas of the Arctic.

The national sovereignty claims in the Arctic made by coastal states stand in the way of a comprehensive conservation and use regime under international administration along the lines of the 1959 Antarctic Treaty. Therefore, if the danger of limiting (or even revoking) coastal states' rights of jurisdiction over their Arctic territories is to be avoided, such an administration by the international community would only be admissible for the part of the Arctic defined by UNCLOS under international law as the high seas. Should the extensions of the continental shelf by coastal states under UNCLOS be successful, this would further limit the possibilities for action on the level of global governance (Box 3.2-3). Moreover, there is a potential for conflict between coastal states as a result of unresolved border issues. Establishing solid mechanisms for regional cooperation between the coastal states to ensure the conservation and sustainable use of the Arctic is therefore highly important.

Since coastal states in marine areas with ice cover also have the right to adopt and enforce national laws and regulations on environmental protection beyond their territorial waters (Article 234 UNCLOS), the coastal states bordering on the Arctic have an extended scope for action, which also requires reliable regional cooperation before it can be exploited.

OSPAR Convention

The jurisdiction of the OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic also includes large sections of the Arctic waters. Steps taken under OSPAR towards a sustainable stewardship of the oceans – such as establishing high standards of conservation in some areas of regulation – therefore also have relevance for the Arctic (Section 3.4.2). However, given the territorial limitation of the OSPAR Convention, its ratification by Canada, Russia and the USA is not possible (Proelß and Müller, 2008). This limits the contribution of OSPAR to regional governance of the Arctic to the areas of jurisdiction of the Arctic coastal states Denmark and Norway (both are OSPAR member states) and to parts of the Arctic high seas. For the high seas, enforcement of the rights of use and conservation standards agreed under OSPAR is considerably limited, as they are not binding on countries that are not member states. For this reason, up to now the OSPAR Convention has played only a minor role in the governance of the Arctic compared to the Arctic Council.

Furthermore, no use has yet been made in Arctic waters of the special possibility under OSPAR of designating marine protected areas in regions outside national jurisdictions (Section 3.4.2). However, OSPAR may become more important in future, especially if the current negotiations on a new implementing agreement relating to marine biodiversity on the high seas under UNCLOS are successful (Section 3.3.2.2). In this case the jurisdiction of OSPAR would extend over roughly a quarter of the Arctic high seas that would remain after the maximum possible extensions of the continental shelf. Given its comparatively well developed capacities, OSPAR would appear to be a suitable regional forum for designating marine protected areas in the region, as well as monitoring and checking them.

the demands and effects of the different labels – for example what precise amount of bycatch is tolerated. Although the amount of bycatch during tuna fishing is on the decline, the role of eco-labels in this development has not been sufficiently researched (Ward, 2008).

Fishery eco-labels that cover several species can be divided into national and transnational labels. National eco-labels include the following:

- state labels like those of the Alaska Seafood Marketing Institute or Responsible Fisheries Iceland;
- eco-labels from industry associations such as Sweden's KRAV, Germany's Naturland, the Marine Eco-label Japan, or Britain's Responsible Fishing Scheme; and
- eco-labels from NGOs such as the Swiss Fair Fish label or the Californian Fishwise label (Accenture and WWF International, 2009).

As far as transnational eco-labels are concerned, the Marine Stewardship Council (MSC) label currently has by far the biggest reach, followed by Friend of the Sea (FOS). Substantial research findings on environmental impacts are only available for the MSC label and, to a very limited extent, for FOS. A study by Froese and Proelß (2012) discussed in detail below, claims that 19% of the stocks certified by FOS are actually overfished. The following section discusses the MSC label. It is the oldest, financially strongest and largest transnational eco-label in terms of the number of fisheries certified.

The Marine Stewardship Council eco-label

The MSC is a private-private partnership (Pattberg, 2004a) set up in 1997 by the food company Unilever and the World Wide Fund for Nature (WWF) to combat global overfishing. It is a certification programme for fisheries covering wild-caught fish. Companies, too, can be awarded an MSC label – confirming that their fish products come from MSC-certified fisheries. The certification of fisheries is discussed in detail in the following subsection. The MSC has operated independently of WWF and Unilever as an international non-profit organization since 1998. The first fishery was certified by MSC in 2000 (Gulbrandsen, 2009; Christian et al., 2013). According to information provided by MSC itself, some 147 fisheries and about 8% of the global catch volume of fish and seafood were certified by the MSC in April 2012 (MSC, 2012a). 160 fisheries are currently certified according to the MSC standard (MSC, 2013). Certification is carried out by an independent certification organization selected by the fishery to be certified. The certification standards are not a fixed constant. The MSC environmental standard is based on three principles: protection of fish stocks, minimal impact on the ecosystem, and effective management. The MSC has developed 23 criteria for operationalizing these principles. However, these are only points of orientation for the certifier and are adapted to each fishery (MSC, 2012b). The certification process is divided into a confidential, non-public preliminary assessment and the certification process itself. In the preliminary assessment, the chosen certification body determines whether the fishery meets the prerequisites for certification. During the certification process itself, the certifiers check whether the fishery meets the MSC standards. The result is accessible to the public.

The awarding of the MSC eco-label identifies and publicizes fisheries that are run in a comparatively environment-friendly way. Given sufficient customer demand, this creates an incentive for comparatively less environment-friendly fisheries to become more environmentally compatible and to also seek certification. Independent monitoring bodies check compliance with the MSC standards on an annual basis. A new main assessment process must be carried out after five years (Gulbrandsen, 2009). Thanks to international cooperation with stakeholders from the entire value chain (fisheries, processing companies, suppliers, retailers, restaurants), the MSC not only has an impact on the certified fisheries, but also strives to create a market for sustainably caught fish that also integrates customer behaviour on land. The costs of certification – estimated by the MSC to be between US$ 15,000 and 120,000 – are met by the fisheries. All relevant stakeholders can lodge comments during the certification process and file objections after the results have been published (Christian et al., 2013).

Effectiveness and controls by the MSC

The MSC eco-label has achieved considerable market penetration and is viewed by various authors as the most important global regulator in ocean fishing (Oosterveer, 2008; Hale, 2011). The certification process documents at least a relative degree of environmental sustainability. The majority of certified fisheries are in industrialized nations; they are subject to an integrated management plan and have access to sufficient data on fish stocks (Gutierrez et al., 2011; Wolfrum and Fuchs, 2011).

A number of studies criticize the MSC eco-label for indirectly favouring certain fisheries. One of the prerequisites for MSC certification is coordinated action by everyone involved in the fishery and the availability of the required historical data on catches and stocks. However, fisheries that meet these conditions are not automatically among the ones whose fish stocks are most at risk. Since fisheries that are in a comparatively good state have a better prospects of being certified, they are more likely to make the effort to go through the certification process (Kaiser and Edward-Jones, 2006; Oosterveer, 2008; Gulbrandsen, 2009). A study involving MSC representatives suggests that most MSC-certified fisheries were comparatively well managed even before they received the MSC eco-label (Gutierrez et al., 2012).

Fisheries that meet most of the prerequisites for certification will be excluded from certification if they share the fished stocks ('open access stocks') with other, non-sustainable fisheries. Most certified fisheries are therefore ones that specialize in specific species whose stocks move within known areas, that have limited access and a regulatory framework that is enforced, often in cooperation with state authorities and scientists. Furthermore, relatively few fisheries in developing countries are certified, e.g. because of the large number of 'data-poor' stocks – a criticism to which the MSC has responded by taking special measures (Kaiser and Edward-Jones, 2006; Oosterveer, 2008; Gulbrandsen, 2009).

There has also been criticism both of the absolute MSC standards and in relation to the scope for interpretation of the criteria in the certification process. During the certification process, the MSC principles and assessment criteria must be interpreted and adjusted to the fishery in question by the external examiner. Ultimately this means that every fishery is assessed according to a different set of criteria and reference values. Ward (2008) notes that certain criteria leave excessive room for interpretation. Jacquet et al. (2010) point out that professional certifiers have a strong economic interest in successful certification. To this extent there is an incentive to use relatively weak criteria in order to receive more certification contracts: a successful certification usually leads to follow-up contracts (for monitoring or re-assessment). It is suspected in various quarters that this happens in practice, but it has not been proven by systematic investigation. There is also criticism that in individual cases fish stocks have been certified that are in rapid decline. This is possible, since the MSC allows certification in cases where there is a prospect of stocks recovering (Jacquet et al., 2010; Christian et al., 2013).

The MSC has also been criticized for not generally excluding bottom-trawl fisheries or fisheries that produce fish meal, and for having on occasion certified fisheries with high bycatch (Jacquet et al., 2010; Christian et al., 2013). In one case it has also been demonstrated that MSC-certified fish were not of the species stated in the certificate (Marko et al., 2011). The most serious scientifically supported criticism of the MSC, however, is of its certification of overfished stocks. In their study, Froese and Proelß (2013) concluded that 31% of MSC-certified stocks were overfished and continue to be overfished. For 11% of stocks, insufficient data was available for an evaluation to be made (Froese and Proelß, 2013). However, in their evaluation the authors used different definitions of overfishing from those of the MSC. The MSC has criticized the assumptions underlying the study and its findings. Both the MSC and Froese and Proelß (2013) stress that their respective evaluation methods are in line with the current Law of the Sea and international guidelines (Agnew et al., 2013).

In addition to the above-mentioned criticism, Froese and Proelß (2012) also come to the conclusion that the majority of MSC-certified fisheries are in a better condition than the statistical average of all fisheries. Likewise, Gulbrandsen (2009) believes that the effects on the environment are positive. Oosterveer (2008) concludes that the MSC has contributed more to the protection of fish stocks than the WTO negotiations on the abolition of fishery subsidies.

Eco-labels and the World Trade Organization

The goal of the World Trade Organization (WTO) is to create international rules to facilitate and promote free trade worldwide. From the WTO's point of view, eco-labels must not lead to discrimination as defined by the WTO principles. This means that the introduction of such labels must not lead to certain trade partners being given preferential treatment (principle of most-favoured-nation treatment) or to domestic products being favoured over foreign products (the principle of national treatment). Like many other forms of product labelling, the WTO treats eco-labels are as a form of standard-setting, as they can represent non-tariff barriers to trade. The agreement on technical barriers to trade defines standards as rules, guidelines or characteristics for products or related processes and production methods. A distinction is drawn between voluntary and mandatory standards, the latter being termed technical regulation. Further distinctions in standards are made between state and private, and between product-based and production- or process-based labels or marks (Stein, 2009). Non-tariff barriers to trade are defined as all barriers to trade that do not fall under monetary trade barriers, such as subsidies and customs duties.

In general, WTO law becomes relevant and applicable when a standard is initiated by a state or can be attributed to a state. Voluntary-obligatory state standards – where use of the label is voluntary but, if it is used, certain prescribed standards must be met (e.g. the EU organic farming logo) – conform to WTO rules if they relate to products, i.e. to certain product characteristics. However, it is not yet clear whether voluntary state process-based standards – standards relating to the production process for a product (e.g. fishing methods) – conform to WTO rules. Transnational voluntary eco-labels like the MSC label refer to the

Box 3.4-2

The Méditerranée – basis for stronger cooperation in the Mediterranean region?

Shared cultural and political areas of experience, which have developed in the course of history, form an important basis for regional cooperation. One excellent example is the 'Méditerranée', which is of great importance for cooperation between the EU and neighbouring coastal states bordering on the Mediterranean Sea. Since ancient times, the Mediterranean has formed a highly distinctive cultural entity, assuming many different forms. It only took on political form temporarily (as the 'mare nostrum' of the Roman Empire), but as a region of trade and culture it has left its mark on all the countries bordering it in Europe, Asia and Africa across the centuries, and continues to do so today (Leggewie, 2012). The political centre of globalization moved away from the Mediterranean region to the North Atlantic sphere from the 16th century onwards, and the dynamic of political conflict in the East-West divide and the Arab-Israeli conflict marginalized the Méditerranée in the 20th century, dividing it into spheres of influence of the superpowers (Abulafia, 2011). However, since the 1990s new approaches have emerged for a Euro-Mediterranean partnership between the EU countries and the states bordering on the Mediterranean Sea in the Middle East and North Africa (Jünemann, 2012).

This reconstruction is significant for the conservation and use of the Mediterranean Sea. The European Commission has recognized that marine conservation leaves much to be desired, mainly due to the lack of cooperation between Mediterranean countries and the EU's lack of influence over third countries. Many conferences, plans and conventions were held under the Barcelona Process and European Neighbourhood Policy between 1995 and 2010, including the 'Plan Bleu' organization in six regional hotspots (France, Italy, Tunisia, Croatia, Spain and Malta). A Communication by the EU Commission (2009b) and a research report on the needs of maritime spatial planning published in 2011 also point in the right direction – of comprehensive conservation based on the principles of sustainability. The Commission recognizes that one basic problem is that "a large part of the Mediterranean marine space is made up of High Seas. Approximately 16% of the marine space is made up of Territorial Sea and 31% is made up of diverse maritime zones, often contested by other coastal States due either to the extent of the claim or its validity. This set up means that a large part of the waters of the Mediterranean Sea is outside the areas under the jurisdiction or sovereign rights of coastal States. Consequently these States do not have prescriptive and enforcement powers to regulate comprehensively human activities beyond such areas, including for the protection of the marine environment and how fishing and the development of energy sources is carried out. Beyond these areas, States can only adopt measures with regard to their own nationals and vessels" (EU Commission, 2009b).

Furthermore, the Commission recognizes two major weaknesses:

"First: in most Mediterranean States, each sectoral policy is pursued by its own administration, just as each international agreement is performed within its own set of rules, rendering an overview of the cumulative impact of maritime activities, including at basin level, a difficult objective to attain. Second: the large proportion of marine space made up of high seas makes it difficult for coastal States to plan, organize and regulate activities that directly affect their territorial seas and coasts. The combination of these two elements gives rise to a situation where policies and activities tend to develop in isolation from each other and without proper co-ordination among all areas of activity impacting on the sea as well as all local, national, regional and international actors" (EU Commission, 2009b).

As ocean-related activities are fundamentally border-crossing activities, the Commission sees a need for "increased co-operation with non-EU Mediterranean partners" (EU Commission, 2009b). After all, the International Convention on the Law of the Sea, which has been ratified by all EU countries and all Mediterranean countries with the exception of Turkey, Syria, Israel and Libya, also offers good starting points. However, there are major gaps with regard to enforcement; there is also a lack of effective controls, especially with regard to fisheries. The obligation on EU member states to achieve a good environmental status of the Mediterranean waters by 2020 (target of the Marine Strategy Framework Directive) by means of 'integrated marine strategies' and an 'ecosystem-based approach' has not had enough effect up to now. Too little attention has been paid to all of the Commission's suggestions and decisions since 2009.

Marine conservation is a strikingly obvious priority activity of any Euro-Mediterranean cooperation – and, here too, it is not just a state or supranational task. The civil-society stakeholders concerned about the condition and conservation of the world's oceans can also become active in the Mediterranean – an area where they have been relatively inactive in the past. Just in the area of food, for example, these stakeholders include the International Union for Conservation of Nature (IUCN), the Marine Stewardship Council (MSC), the 'Followfish' organization, the fish guides produced by Greenpeace and the World Wildlife Fund, and specialized institutions like the Global Aquaculture Alliance (GAA). This is an NGO promoting environmentally and socially responsible aquaculture which issues 'Best Aquaculture Practices Certification Standards' for plants, shrimp, tilapia, pangasius and salmon. OCEAN2012 is an alliance of 185 predominantly European organizations which put the EU's Common Fisheries Policy under scrutiny. Finally, there is HEPCA, an environmental association sponsored mainly by Egyptian diving centres and hotels which thus represents another pillar of a new form of Mediterranean policy-making: sustainable tourism, whose development is essential for conserving the oceans. Another important area of action is Euro-Mediterranean energy cooperation, which involves not only large-scale projects like Desertec and the construction of a European supergrid from the North Cape to the Sahara, but also local projects on primary-energy generation using renewable energy; after all, this sun-blessed region offers excellent (but hitherto utterly neglected) prospects in this field.

If an ambitious historical analogy and a bold vision may be allowed in the context of Euro-Mediterranean cooperation, then such a cooperation could have the same degree of significance for the European Union and its neighbours as the European Coal and Steel Community (ECSC) had for 'core Europe' in the early 1950s. Successful cooperation between these nations grouped around the Mediterranean could potentially serve as a blueprint for regional integration processes in other marine regions.

production process, but are private in nature. They, too, are not explicitly regulated by the WTO and it is unclear whether they conform to existing WTO rules. Rulings by WTO Dispute Settlement Bodies on this matter have been ambiguous up to now (Stein, 2009). A number of authors believe that voluntary private transnational eco-labels cannot be contested under WTO law as long as they apply purely to niche markets and do not distinguish between domestic and imported products (Potts and Haward, 2006; Stein, 2009, Bernstein and Hannah, 2012).

However, since there has been no conclusive clarification by WTO bodies, the existing assessments with regard to the WTO conformity of voluntary private transnational eco-labels are hypothetical in nature. They are based on conclusions drawn from existing WTO agreements on environmental standards and existing rulings by the WTO's Dispute Settlement Body.

The latest round of international negotiations on the WTO began in Doha (Qatar) in 2001. They are still ongoing. The Committee on Trade and Environment was assigned under the Doha Declaration to investigate the effects of environmental measures on market access and the demands made on eco-labels. Eco-labels are also being discussed in the Technical Barriers to Trade Committee and the Committee on the Application of Sanitary and Phytosanitary Measures. Up to now it has not been finally clarified in these three forums how state and private production- and process-related labels are to be treated.

One of the most important points at issue is the distinction between product-related and process-related state standards. There is disagreement as to how the agreement on technical barriers to trade should regulate process- and production-related standards. A number of developing countries fear that adopting such standards would allow industrialized nations to force them to adopt the national policies of the industrialized nations on fishing methods or working standards, or allow industrialized nations to discriminate more strongly against products from developing countries. A number of other countries are in favour of adopting process- and production-related standards because they help achieve environmental targets. There is also basic disagreement between the negotiating countries over whether eco-labels promote international trade or restrict it through discrimination (FAO, 2011f). Furthermore, developing countries have expressed general displeasure within the WTO negotiations about the spread of eco-labels. They are afraid they will be unable to meet the expense needed to reach the standards on which the labels are based or afford the costs of certification, and will therefore be excluded from certain markets (UNEP, 2005).

The impact of private labels, including eco-labels such as the MSC label, on global trade was discussed at the WTO for the first time in 2005 by the Committee on the Application of Sanitary and Phytosanitary Measures. Here, too, developing nations expressed reservations about the costs of certification. It was also pointed out that private standards do not conform to the agreement on the application of sanitary and phytosanitary measures, as they generally lack a scientific basis. Disagreement remains as to whether (and how) private standards, including eco-labels, should be treated under the Agreement on the Application of Sanitary and Phytosanitary Measures. Nor is there agreement on how private standards should be treated under the Agreement on Technical Barriers to Trade. Likewise there are differing views on whether private standards tend to promote or hinder trade (FAO, 2011f).

The MSC itself is a member of the International Social and Environmental Accreditation and Labelling Alliance, an association of various non-governmental organizations like Fairtrade International, which award transnational sustainability labels. One of this alliance's aims is to achieve recognition as a legitimate standard-setting organization under WTO rules (Bernstein and Hannah, 2012).

Pros and cons of eco-labels and sustainability labels

Private eco-labels have both advantages and disadvantages as regards their potential contribution to the sustainable use of marine ecosystems. The MSC eco-label analysed above already has considerable reach, and this reach continues to grow. The greatest potential of the MSC lies in its non-public preliminary assessment phase, in which fisheries try to obtain the eco-label and restructure their activities so as to bring them more into line with the principles of sustainability. Since the incentive for fisheries to seek certification is driven by demand, the success of eco-labels depends very much on changing consumers' purchasing behaviour. The large Asian fish markets, for instance, show few signs of developing a comprehensive demand for certified fish, and voluntary certification programmes are no substitute for sustainable public management of fisheries. The discussion on a suitable definition of overfishing in the context of the MSC cannot be brought to a conclusion here. Given the increase in the number of different eco-labels and certified fisheries, it would appear to be a good idea to introduce minimum requirements for private eco-labels in fisheries at the EU level. Furthermore, the WTO should clarify as soon as possible how private voluntary eco-labels should be classified in terms of trade law.

3.6 Selected instruments

There is a broad range of instruments available to help humanity organize a sustainable way of interacting with the oceans. Three factors determine whether a given instrument is suitable to remedy the identified shortcomings of present-day ocean governance (Sections 3.2-3.5):

First, an instrument's structural design is crucial – for instance whether the associated sanctions are sufficiently effective or whether spatial planning has been designed in a systemic and cross-sectoral way.

A *second* critical success factor is the degree to which an instrument can be applied at, and integrated into, the various levels of governance in ways that properly address the issues at stake. Depending on the context in which the problem exists, instruments that are applied on a small scale can be just as important as cross-border and intergovernmental collaboration.

Third, it is vital that an instrument is designed to interact with other instruments. Environmental standards presuppose a monitoring system, for example, and marine protected areas can only be effective if they are supported by measures such as accompanying spatial planning, adaptive management and standard setting.

The WBGU believes that the following instruments are particularly well suited to remedying the identified shortcomings in ocean governance, as they satisfy many of the criteria discussed in Section 3.1.3 and can have an effect on every conceivable level of ocean governance.

3.6.1 Environmental monitoring

Monitoring the state of the oceans is fundamental to overseeing marine uses and conservation obligations. In turn actors must also be monitored if sanctions are to be applied or cases of liability exposed. Monitoring is thus the basis on which effective governance must be built. At the same time, the transparent recording and open accessibility of gathered data allows administrative decisions to be more easily understood and retraced. Without monitoring, adaptive ocean governance would not be feasible, as the latter requires the critical scrutiny and evaluation of existing governance practices. Without monitoring, there would be no indicators on the basis of which conclusions could be drawn about the quality of existing governance.

When collecting and analysing data about the state of the oceans, it is vital that monitoring and controlling activities dovetail perfectly. Only then can the impact of the different forms of use on marine ecosystems – and wider, systemic effects – be assessed. One must also bear in mind that the states parties are responsible for monitoring, controlling and enforcing the provisions of UNCLOS.

At the UN level, the most important monitoring processes in present-day ocean governance are the activities of the Global Ocean Observing System (Section 3.3.1.4), the UNEP World Conservation Monitoring Centre (Section 3.3.1.5), the Intergovernmental Oceanographic Commission (Section 3.3.1.4) and the FAO (Section 4.1.4.2). The EU's monitoring activities are grouped together under its Marine Strategy Framework Directive (MSFD) and the Common Fisheries Policy (CFP). Passed in 2008, the MSFD is an EU directive which places Member States under an obligation to "take the necessary measures to achieve or maintain Good Environmental Status in the marine environment by the year 2020 at the latest" (Article 1 para. 1 MSFD; EU, 2008). One current project in Germany is the Oceans Observation research programme pursued by The Future Ocean, a Kiel-based cluster of excellence.

The aim with regard to the high seas is to achieve improvements by means of a better exchange of information between the national authorities of the coastal and flag states (HSTF, 2005, 2006). To this end, the International Network for the Cooperation and Coordination of Fisheries-related Monitoring, Control and Surveillance Activities (MCS Network) was set up in 2001 as a voluntary (informal) association of national authorities committed to curbing illegal, unreported and unregulated (IUU) fishing activities. To date, authorities from more than 40 countries – including Japan, the USA, Australia, New Zealand, Norway, Spain, Mexico and Canada – have signed up. The network seeks to speed up the flow of data when IUU fishing activities are being tracked (MCS Network, 2012; Section 4.1.4.5).

Central to a future system of ocean governance is the rapid development of a dynamic monitoring system based on a set of targets for the state of the oceans. The transparent capture of data and open access to these data are key requirements if this system is to be realized. In the EEZs, practically complete surveillance is possible using patrol boats, patrol aircraft and GPS-based vessel monitoring systems. However, providing the same kind of surveillance on the high seas requires above all modern remote-sensing technologies such as echo location, radiolocation and satellite positioning. The latest developments in such technologies include unmanned aerial vehicles, over-the-horizon radar, modern satellite-imaging systems and synthetic aperture radar. Since these technologies are relatively expensive, the cost of an effective system to physically monitor and control the high seas can quickly reach an estimated magnitude of several hundred million (or even billions of) US dollars a year (estimate based on the HSTF, 2005, 2006).

3.6.2 Marine protected areas and marine spatial planning

3.6.2.1 Marine protected areas

Marine protected areas (MPAs) are one of the most important instruments to preserve marine ecosystems, increase their resilience and adaptive capacity, and help contain or avoid human interventions in the marine environment (such as overfishing or the destruction of habitats) by means of rules and bans (WBGU, 2006). MPAs also serve to conserve and replenish overfished stocks and to protect important habitats and life stages (Section 4.1.3.4).

Worldwide, marine protected areas currently cover an area of around 6 million km^2, equivalent to about 1.6% of the world's oceans (Bertzky, et al., 2012:6). By comparison, Australia has an area of 7.6 million km^2. These MPAs are concentrated mainly in coastal waters, where 7.2% of the sea's area is protected. Relative to all marine areas under national sovereignty (i.e. coastal waters and EEZs), the proportion of protected areas shrinks to 4%. Coverage of the high seas is significantly lower. In 2010 an estimate by Toropova et al. (2010:28) put the figure at less than 1%. And fully protected zones (known as no-take zones or marine reserves, where fishing and other activities are prohibited) account for only a tiny fraction of these MPAs (Toropova et al., 2010; Gaines et al., 2010). The international community is thus well short of its target of placing 10% of the world's seas and oceans under protection by 2020 (Aichi target 11: CBD, 2010a). Yet even this target is not ambitious enough in the WBGU's view. As early as 2006 the WBGU recommended that "at least 20-30% of the area of marine ecosystems should be designated for inclusion in an ecologically representative and effectively managed system of protected areas" (WBGU, 2006:22; Section 7.3.9.1).

The system of protected areas is far from reaching these targets – not only quantitatively, but also qualitatively. Ecoregions (large areas of the Earth with characteristic communities of flora and fauna; the World Wildlife Fund, for example, has designated 232 ecoregions in the oceans) and habitats are not properly reflected in the existing system of marine protected areas (Spalding et al., 2013). In 2010, 44 coastal ecoregions had more than 10% of their total area designated as protected areas, while less than 1% was set aside for protection in 102 other coastal ecoregions (Toropova et al., 2010). The recently observable trend towards growth is due to the designation of a few very large MPAs: eleven of the marine protected areas designated since 2003 are larger than 100,000 km^2 and therefore account for 60% of all MPAs (Toropova et al., 2010). Merging marine protected areas to form supraregional networks is crucial to their effectiveness. Given that many of the species in need of protection are spread across extensive geographical areas, the impact of isolated individual protected areas is very limited (Gaines et al., 2010).

Experience with the world's biggest marine no-take zone, a network of protected areas set up at the Great Barrier Reef off the east coast of Australia in 2004 and covering more than 115,000 km^2 (roughly the size of Bulgaria), has been extremely positive. Stocks of many species of fish had recovered after only two years (Russ et al., 2008; McCook et al., 2010). Although creating this network of protected areas impaired fishing activities, it also led to economic benefits, especially for tourism (McCook et al., 2010). Nevertheless, the effective management of protected areas also necessitates regular monitoring to ensure compliance with the rules, since no-take zones, too, can be affected by illegal fishing (McCook et al., 2010). A meta-analysis of the many studies that have been conducted on the impact of marine protected areas in different ocean regions confirms their positive impact, e.g. on biomass, stock density and biodiversity (Lester et al., 2009).

Marine conservation on the high seas is a special case, because there is currently no central authority responsible for establishing and managing marine protected areas (Sections 3.3.2.2 and 4.1.4.4). Thanks to international collaboration, however, it has nevertheless been possible to create a number of protected areas on the high seas (Bertzky et al., 2012). One significant step forward was taken in 2010, when a network of protected areas was set up in the north-east Atlantic pursuant to the OSPAR Convention (Matz-Lück and Fuchs, 2012; Box 3.4-1). As a result, a total area of 286,00 km^2 – more than 3% of the area covered by the OSPAR Convention – is now designated as a protected area. Even so, it appears that further protected areas are needed in the north-east Atlantic (O'Leary et al., 2011). By contrast, negotiations at the Commission for the Conservation of Antarctic Marine Living Resources to establish marine protected areas in the Antarctic region are currently making only slow progress due to the resistance of individual countries (the CCAMLR is the regional fishery-management organization for Antarctic waters; Section 4.1.4.4).

The fact that large swathes of the deep sea can be regarded as *terra incognita* makes it difficult to designate protected areas on the basis of scientific criteria, but it certainly does not hinder the non-sustainable use of the stocks that live there (Davies et al., 2007; Villasante et al., 2012; Section 4.1.2.3). The FAO's concept on vulnerable marine ecosystems (VMEs) and the FAO guidelines on deep-sea fishing (FAO, 2009b) offer valuable information on designating MPAs in the deep sea.

There are efforts to achieve a substantial improvement in the protection of biological diversity on the high seas – partly with marine protected areas – by negotiating a special UNCLOS implementation agreement. This process is discussed in Section 3.3.2.2.

Marine protected areas are key elements of ocean conservation, but they can hardly achieve their goals as stand-alone measures. Effective marine protected areas and networks should be reinforced and expanded in general. Given the existing regulatory loopholes the need for action is particularly urgent on the high seas and on behalf of endangered deep-sea habitats. It is also important to integrate the MPAs into a more comprehensive management system for marine areas – a system that also includes socioeconomic development goals (Spalding et al., 2013). Wherever possible, marine protected areas should therefore be seen in the context of marine spatial planning, which divides the oceans up into zones with varying intensities of use (Section 3.6.2.2).

Marine spatial planning can also help to avoid use conflicts between regions (Gaines et al., 2010). In particular, it can help reduce fishery yield losses, or even increase fisheries' yields. A clear allocation and validation of user rights can reduce fishermen's resistance to the creation of protected areas or even succeed in eliciting their support (Smith et al., 2010a). For this reason, MPAs should also be integrated into sustainable fishery-management strategies (Section 4.1.3).

3.6.2.2
Marine spatial planning

Spatial planning is the public-sector practice of dividing up space by assigning legally binding uses or functions to each space or planning area (Weiland and Wohlleber-Feller, 2007). In the course of the spatial planning process, due account is given to economic, social and ecological concerns, each of which is weighed against the others. In marine spatial planning, the idea is to allocate human activities at sea, in the sea, on and in the seabed in such a way that these activities further the realization of the ecological, social and economic aspects of political and legal planning goals.

As a cross-sectoral instrument, marine spatial planning aims to reduce conflicts over space between sector-specific uses and marine conservation efforts. In addition, it helps estimate the cumulative effects of different human uses in the same ocean region. This elevates marine spatial planning to a systemic instrument that transcends the sector-specific management of uses. Marine spatial planning can also be designed in an adaptive way – so that it can be refined and improved as new knowledge is gained about marine ecological interrelationships. It follows that spatial planning concepts should be regularly updated and adapted in line with changing conditions. Ideally, marine spatial planning should be kept free of preconceived expectations, and that presupposes the political will to relocate existing uses, where necessary, based on the outcomes of the spatial planning process.

Numerous coastal states – especially those in Europe, but also Canada, the USA, Australia, New Zealand and China – already operate cross-sectoral marine spatial planning in their coastal waters and/or EEZs (UNESCO, 2012b). The vast majority of countries have designed their spatial planning concepts merely as expert recommendations for the relevant decision-makers. These *soft laws* are not binding for administrations or courts and can therefore give no legal certainty to the actors concerned. Only Belgium, China, Germany, the USA and the United Kingdom have integrated marine spatial planning into national law, making it compulsory and legally enforceable.

With few exceptions, there is no spatial planning for the high seas. These exceptions are confined to a few marine protected areas on the high seas (in the Mediterranean, for example), and their primary objective is species protection (meaning that they have a purely sectoral focus). To date, there is no cross-sectoral spatial planning on the high seas (Ardron et al., 2008).

Marine spatial planning is a forward-looking planning instrument which anticipates future actions and future ocean uses and, in so doing, applies the precautionary principle to identify potential conflicts at an early stage. In this way, marine spatial planning can make provision for the potential risks of zoning. Because it weighs up the potential for conflict and integration between different uses and across different sectors, marine spatial planning promotes a systemic approach to ocean governance. If spatial planning is evaluated as outlined above, and if it is also designed to be adaptable to changes in the environment and the level of knowledge, it will further the goal of dynamic, adaptive ocean governance. Backed by the force of law, spatial planning furthermore creates the legal certainty needed to underpin long-term investment. To this end, both the avoidance of conflicts by adopting a cross-sectoral approach to planning and the binding allocation of specific uses to marine spaces create greater legal certainty for uses that are in line with plans.

3.6.3
Integrated coastal-zone management

Shaped by the definition used by the European Commission, integrated coastal-zone management (ICZM) is an informal process which coordinates all developments in coastal areas within the limits set by their natural dynamics and capacity (EU Commission, 1999). This process is designed to be dynamic, continuous and iterative. It is also to be guided by the principle of sustainability. The aim of ICZM is to strike a balance between the development and use of coastal regions on the one hand and the conservation and restoration of coastal ecosystems on the other (EU Commission, 1999).

Worldwide, the ICZM programmes under national law are as many and varied as the interests and conflicts inherent in regional coastal development. The concept of coastal-zone management was pioneered by the USA, where cross-cutting planning focusing specifically on coastal regions was already under discussion as long ago as the 1960s. In 2002 a study identified more than 700 ICZM projects worldwide with the involvement of 145 coastal states (Sorensen, 2002).

The ICZM concept was mentioned in international law for the first time in the Agenda 21 (UNCED, 1992b). Internationally, specific concepts for coastal-zone management have been developed and implemented, in particular under the aegis of the UNEP's Regional Seas Programme (Section 3.4). In regional international law, recommendations for the establishment of coastal-zone management can be found in both the Helsinki Convention and the OSPAR Convention (Wille, 2009).

There is deep disagreement within the scientific community on how the terms 'integration' and 'management' should be defined and interpreted (Wille, 2009). In the context of integration as defined in ICZM, a distinction is usually drawn between the horizontal and vertical dimensions. Horizontal integration embraces on the one hand ICZM's cross-sectoral function, and on the other a cross-cutting spatial view of onshore and offshore issues and how they interact with each other (Cicin-Sain and Knecht, 1998). Vertical integration takes into account the comprehensive incorporation of all administrative levels (Clark, 1996).

However broad the understanding of the scope of the management concept, ICZM is first and foremost an informal instrument whose aim is to forge networks between (private and public-sector) players in the relevant coastal areas in order to initiate a process of dialogue. This process serves to identify long-term development opportunities and, by accommodating the interests of all stakeholder groups, seeks to develop optimal overall solutions (BMU, 2006). In practice, this debate focuses mostly on aspects of economic development and coastal protection (SRU, 2004). Unlike marine spatial planning, ICZM is a highly procedure-oriented instrument which, although limited to coastal zones, goes beyond spatial concerns and can thus be used to manage the interests of competing user groups. While ICZM can submit suggestions for formal planning instruments, unlike spatial planning it is not a formal, binding instrument of planning and decision-making (BMU, 2006).

Localized at the land-sea interface, ICZM is the ideal instrument with which to explore and, where appropriate, find solutions to numerous conflicts in land/sea interaction. Problems like the discharge of pollutants and nutrients into the sea can be addressed and solution approaches or countermeasures developed in the course of the ICZM process. ICZM can thus lead to a systemic expansion of ocean governance to include land-based issues and consider land/sea interactions. The fact that ICZM is usually effected on a small scale ensures that local actors who are directly affected can broach specific regional problems and, ideally, contribute to finding balanced solutions. The highly specific nature of such solution strategies improves their acceptance among regional players, and with it the likelihood that they will indeed be implemented.

However, its informal nature means that ICZM is no substitute for formal planning instruments. Since ICZM lacks transparency and regulatory force and is non-binding, the ideas it generates must be complemented by legally binding marine spatial planning (SRU, 2004).

3.6.4
Environmental standards

As a rule, environmental laws do not cast their conservation goals in stone. Rather, they prescribe an environmental status – an environmental quality objective – that is worth maintaining or targeting (Salzwedel, 1987). One example is the maximum sustainable yield (MSY) enshrined in fishing legislation (e.g. FSAs). Environmental standards then flesh out the bare bones of this vague environmental status. On the one hand, they do this by defining thresholds and guidelines for the resources requiring protection. This makes the quality of the defined environmental status quantifiable. In fisheries policy, for example, MSYs are further specified by the introduction of quotas and by defining total allowable catches (TACs; Section 4.1.4). On the other hand, they define technical ground rules and measurement methods to ensure that efforts to verify compliance with these thresholds are standardized. Environmental standards simplify the enforcement of environmental law by limiting discretionary leeway and expressing environmental statuses in hard numbers (Schulze-Fielitz, 2011). Depending on their binding force, environmental standards can be classified as (strictly binding) thresholds or as guidelines (whose binding nature is graded according to a scale; Vogt-Beheim, 2004). As technical norms or material thresholds, environmental standards initially reflect a non-binding scientific consensus about the environmental issues at stake. They become legally binding when they are regularly incorporated into national regulatory law (e.g. through references to technical norms in specific bodies of law) or by being enacted as positive law.

The UN Convention on the Law of the Sea (UNCLOS, specifically Article 192) places signatory states under an obligation to protect and conserve the marine environment. Furthermore, the obligations listed in Articles 192 ff. of UNCLOS demand that states use resources sustainably and in an environment-friendly manner, and that they reduce the pollution of the seas from explicitly named sources. However, since it is a regulatory framework, UNCLOS does not specify these stipulations in greater detail. It does not define quotas either for catches of fish or for the extraction of resources, nor does it define quantitative limits on marine pollution. Instead, the task of specifying environmental protection is left to the states parties, so that the level of conservation, for example, is at the discretion of these states. Under the currently valid marine international law, environmental standards are reflected in particular in the fields of maritime shipping (e.g. annexes I-VI of the MARPOL Convention) and fishing (e.g. quotas for individual species of fish as prescribed by regional fisheries management organizations). Moreover, the environmental stipulations under UNCLOS already feature mechanisms for incorporating international environmental standards. For example, Article 210, paragraph 6 of UNCLOS states that national environmental regulations must not be less effective than the global rules and standards.

Establishing international environmental standards in UNCLOS could harmonize the level of protection afforded – to the benefit of the marine environment worldwide. Harmonized environmental standards would make it easier to verify compliance with treaty obligations, allowing states parties and, where appropriate, environmental associations to exercise more effective mutual control.

3.6.5
Environmental liability

To be liable is to be legally accountable for damage caused by oneself or third parties. A distinction is drawn between fault-based liability, which presupposes intent or negligence on the part of the author of the damage, and liability without fault, which is rooted in the dangerous nature of an otherwise permitted action. Environmental liability in particular seeks to compel parties that cause damage to the environment to pay the cost of remedying that damage (EU Commission, 1999). Here, a further distinction is made between the liable party's obligation under civil law to compensate other legal entities for damage done to them, and the regulatory requirement that the liable party remedy damage done to the environment (Ehlers, 2006). Liability for damages under civil law is regulated by the respective national tort law – where appropriate in conjunction with private international law. However, a separate public legal basis is needed in order to establish remediation obligations. The aim of this regulatory remediation obligation is to prevent damage to the environment happening in the first place. By insisting that any damage caused must be remedied at the polluter's own cost, the aim is to create an incentive for parties with the potential to cause environmental damage to act with extreme caution when engaging in hazardous activities (UBA, 2007).

In international marine environmental law, the key regulations governing liability for pollution of the sea are enshrined in Articles 192 and 235 of UNCLOS. These articles stipulate that states have the obligation to protect and preserve the marine environment and are liable in accordance with international law. Pursuant to Article 235, paragraph 2 of UNCLOS, states are obliged to ensure that legal recourse is available for compensation in respect of damage caused by pollution of the marine environment. In international law, the states parties have fulfilled this obligation, in particular in the shipping sector. The International Convention on Civil Liability for Oil Pollution Damage (1992), for example, establishes liability without fault for the owners of tanker vessels if oil pollution is caused by their ship. Other similar conventions exist for hazardous and noxious substances (the HNS Convention), for bunker oil (the Bunker Oil Convention) and for the transportation of hazardous waste (the Basle Protocol). However, these additional liability conventions have yet to come into force because they have not been ratified (Ehlers, 2006).

At present, there are no international liability regulations governing pollution caused by offshore activities. However, what is known as the OPOL Agreement does create a voluntary obligation under civil law under which offshore industries assume liability without fault up to US$ 120 million for pollution of the marine environment.

On the high seas there are no valid rules governing liability for polluting the environment. The conventions cited above apply only in territorial waters and/or in coastal states' EEZs. The 1993 Lugano Convention sought to apply a cross-sectoral approach to liability for damage resulting from activities dangerous to the environment. However, since it, too, has not been ratified, it is highly unlikely that this convention will come into force.

In regional international law, the most important regulation on the remediation of environmental damage is the EU Directive on 'environmental liability with regard to the prevention and remedying of environmental damage' (EU, 2004). This directive harmonizes environmental-liability law across the EU Member States. However, it governs only the regulatory aspects of environmental liability, targeting the avoidance and remediation of environmental damage without establishing claims for compensation under private law. The application of the Directive for the marine environment is also subject to geographic constraints: it covers water pollution only up to the seaward boundary of the territorial sea, so that within European EEZs only damage to biological diversity is covered (Ehlers, 2006).

Liability regulations that make the polluter pay the cost of remedying environmental damage could improve ocean governance in two ways. On the one hand, they would make the actors concerned more cautious and prudent, as the threat of potential liability gives them a financial incentive to avoid polluting the environment. This effectively reinforces the importance of the precautionary principle to the actors involved. On the other hand, the cost of remedying pollution of the marine environment would be assigned to the polluter instead of being shared by the community. Assigning costs according to the 'polluter pays principle' constitutes an equitable form of cost distribution and is thus also in line with the common heritage of mankind principle. If the polluter is unable to foot the bill, the state that approved the harmful action or the responsible flag state could face residual liability.

3.6.6 Sanctions

Sanctions are coercive measures used to enforce compliance with legal obligations. Sanctions play a role above all in associations of nation states when one member state fails to meet its obligations. In the supranational context of the EU, financial penalties are a common sanction (e.g. within the framework of EU infringement proceedings; Article 258 ff. of TFEU). Under international law, suspensions are an option and can lead to the exclusion of the infringing state from the association of states or the international treaty. Under the WTO regime, financial sanctions can also be imposed in the form of penal tariffs, once a court of arbitration has established violations of international trade law. Sanctions are likewise applied to secure peace and ensure compliance with humanitarian law. In accordance with Article 39 ff. of the UN Charter, further possible forms of sanction include economic embargos and the use of armed force.

Coercive measures of international treaty law are agreed separately in the respective treaties. Where no such agreement has been reached, Article 60 of VCLT can be applied as a general provision of international treaty law. Under this provision, serious treaty violations can lead to the state that is in breach having its participation in an international treaty suspended or terminated.

In international environmental law, the termination of a treaty is an undesirable outcome. On the contrary, sanctions should be agreed which increase the likelihood of compliance with the treaty. The types of sanction described above are alien to existing international treaties on the conservation of the marine environment (UNCLOS, FSAs, etc.). One possible model might be to adapt the European Union's infringement proceedings (pursuant to Article 258 ff. of TFEU) to the international context. In international law, sanctions are coercive measures to enforce treaties whose sole purpose is to achieve compliance with treaty provisions. They are thus a key instrument for improving the effectiveness of international treaties.

3.6.7 Class actions

Class actions enable non-governmental organizations to take legal action against the violation of objective legal norms in order to help protect or enforce the public interest (Kloepfer, 2004). In their capacity as a collective legal remedy, class actions have a special status in the European culture of protecting the rights of the individual. This is because they allow access to the courts (or out-of-court mediation bodies) in cases where it would normally only be possible to assert the violation of rights *in personam* (Erbguth and Schlacke, 2012). In the context of environmental law, class actions have so far risen to greatest prominence in countries where lawsuits are traditionally filed by damaged parties and where non-governmental organizations had little access to legal protection until the Aarhus Convention came into force in 2001. Class actions also serve to improve the enforcement of environmental law, because the organizations represented use them to check the legality of administrative actions (Kloepfer, 2004).

With the signing of the Aarhus Convention, the EU and its Member States undertook to offer the public concerned and associations recognized by Member States recourse to court or out-of-court proceedings in order to prosecute violations of environmental legislation. To translate this obligation into reality, the EU ratified the Public Participation Directive (EU, 2003) which places the EU Member States under an obligation to give environmental-protection organizations access to judicial proceedings. As a result, the conservation of the marine environment can already be realized through class actions within the EU. Outside the EU, class actions exist in isolated cases depending on national legislation. To date, class actions are not permissible as a way of enforcing international environmental-protection treaties.

Class actions can be used as an instrument to improve contractual fidelity in the protection of the marine environment. However, this applies only if environmental associations are recognized as international legal subjects, or if they are at least granted commensurate procedural and material rights. Since signatory states regularly fail to impose sanctions to punish violations of environmental-protection treaties, enforcement of these treaties is lacking (e.g. FSAs; Section 4.1.4). Class actions could enable environmental-protection organizations to take breaches of treaties to court, thereby improving the effectiveness of marine protection treaties.

3.6.8 International financial transfers

Agreements to share burdens and arrange international funding are another element of an effective ocean governance regime. The protection and sustainable use of the oceans generates costs, e.g. for human resources and technical equipment in the fields of administration, monitoring, control and enforcement. Beyond this, individual countries and actors also incur costs, at least temporarily, in the form of loss of revenue (e.g. from fishery or the extraction of raw materials). On the other hand, the benefits of the sustainable use and conservation of the oceans are enjoyed by the entire global community. International cooperation on ocean governance will therefore only come about if the burdens of ocean conservation are shared as fairly as possible between all states.

Various ethical principles can be applied when considering how to share these burdens (WBGU, 2002, 2010). The *polluter pays principle* charges the costs to those countries that make the greatest use of the seas and therefore necessitate protective measures in the first place. In accordance with the *precautionary principle* and the *principle of equality*, however, all countries alike must share responsibility for the future of the oceans, i.e. even those that make less intensive use of the sea – not least because most countries contribute indirectly (e.g. via trade, consumption, tourism and other land-based activities) to the destruction and degradation of marine ecosystems. According to the *ability to pay principle*, a larger share of the financial burden should be borne by those countries whose economic performance puts them in the best position to do so. Lastly, the *principle of equivalence* can be cited, according to which countries should participate in funding to the extent that they will later benefit from the services financed.

Based on these principles, international financing instruments (in the form of international funds, for instance) would need to be negotiated along the lines of other international environmental treaties (such as UNFCCC and CBD) in the interests of sustainable global ocean governance. International financial transfers can boost the willingness of countries to cooperate in an international regime (Barrett, 2001, 2007). For example, transfers from economically strong nations to countries with smaller income levels can make it possible for the latter countries to comply with ocean-conservation regulations. This arrangement indirectly makes less-well-off countries more willing to agree to an ambitious governance regime for the conservation and sustainable use of the oceans. Up to now, the conservation and sustainable use of the oceans has received financial support from international financing mechanisms such as the World Bank and the Global Environment Facility (GEF), in cooperation with other UN organizations such as the FAO and the UNDP (Box 3.6-1; Section 3.3.1). In principle, the funds thus supplied are a suitable way to leverage additional funds from private investors. On the whole, however, the roughly US$ 200–400 million made available each year (Box 3.6-1) is not enough to finance a global and sustainable form of ocean governance (Table 7.3-1).

3.7 Conclusions

Existing governance protects the oceans inadequately

The state of the oceans is deteriorating, despite the existence of numerous international treaties (Chapter 1). Incomplete implementation, an ocean governance that is too fragmented and a lack of viable options for imposing sanctions are the main reasons. Yet most of the problems associated with the subject of the oceans lack neither political attention nor focused activities in the form of programmes, projects, plans of action or treaties within the UN system. The WBGU has identified three key reasons why existing ocean governance is not effective enough.

First, there is an implementation problem in many areas of international marine policy. Progress has been made in developing ocean governance: for example, there are now two implementation agreements translating the overall UNCLOS framework into more concrete terms (Section 3.2). Many other *soft law* instruments have also been fashioned. Overall, however, their degree of implementation varies very considerably and in most cases is unsatisfactory. The example of fishery, which is discussed in detail in Chapter 4, makes this point especially clear.

There is also a lack of consistent implementation in the designation and establishment of marine protected areas. The aim of the Convention on Biological Diversity – to provide effective protection for 10% of the world's marine areas by 2020 – appears scarcely reachable. Very few of the marine areas already under conservation enjoy a sophisticated level of protection. Nonetheless, efforts are being made to step up the implementation of marine conservation. For example, it is hoped that a plan of action will drive forward implementation of UN Secretary-General Ban Ki-moon's 'Oceans Compact' initiative.

Second, the WBGU notes that ocean governance is excessively fragmented. As a result of the profusion of international treaties and organizations on the use and conservation of the oceans, responsibility and authority in international marine policy are spread far and wide. In the majority of cases, the individual treaties and organizations only have a mandate for specific sectors. The framework convention UNCLOS, for example, delegates many details of marine-resource management to implementation agreements and applicable national-state law. This fragmentation becomes especially apparent in the handling of marine bioresources. Integrated, cross-sectoral approaches (which take account of the ecosystem approach, for example) are often completely lacking, and those that do exist are not rigorously implemented by the institutions of ocean governance. While it is desirable to have marine issues anchored in as many institutions as possible in the sense of 'ocean mainstreaming', a prominent institutional figurehead is also needed to safeguard the 'interests' of the oceans. There is a need for action here.

In some cases, steps have already been taken towards the necessary coordination and bundling of measures to conserve the oceans and ensure their sustainable use. The UN Oceans coordination mechanism, for instance, does this on a global scale, while UNESCO's Intergovernmental Oceanographic Commission (IOC) adopts the same approach in research. On the whole, however, this form of bundling does not seem to be succeeding to the necessary extent. Even within the EU there is a need for coordination due to overlapping areas of competency between the Marine Strategy Framework Directive and the various conventions responsible for Europe's regional seas (OSPAR, HELCOM, the Barcelona Convention and the Bucharest Convention).

The conservation and sustainable use of the oceans is enshrined in many parts of the UN system, e.g. using a large number of consultation processes and reports. In its capacity as the most important cross-sectoral forum for international marine policy, the General Assembly of the United Nations places this issue high on its agenda. At present, the oceans are also one of the core topics in the Rio Process, which has been ongoing since 1992. In 2012 the UN Secretary-General then sent a clear message that the international community must concern itself with the state of the oceans by launching the Oceans Compact.

There is a lack of coordination, coherence and complementarity both between the individual UN organizations (despite efforts such as those undertaken since 2003 within the framework of UN Oceans) and between players at the lower levels of governance. Equally, there is a lack of systematic dovetailing and, in particular, of coherent and complementary coordination between the individual levels of governance. The only visible manifestations – such as efforts to apply globally agreed principles and goals at the regional level – are still at an embryonic stage.

Third, ocean governance lacks reporting obligations and effective enforcement and sanctioning mechanisms. For a variety of reasons, states parties fail to implement international regulations. In many cases, the latter are translated into national law either inadequately or only after long delays. In other cases, implementation fails due to a lack of political will or a lack of resources.

Similarly, existing conflict-solving mechanisms such as the International Tribunal for the Law of the Sea and courts of arbitration are inadequately dimensioned, given the manifold problems facing the world's oceans. There are, for example, hardly any strategies defining what to do when rules are violated in areas of the high seas that are beyond the scope of national sovereignty. At this level, there is no superordinate steward with the right to take legal action.

UNCLOS is in need of reform

UNCLOS offers room for the further elaboration of sustainable ocean governance – and the regulatory gap on the high seas is particularly wide. An analysis of international marine policy in its present form shows that UNCLOS has created a 'constitution for the oceans' which in many ways offers a platform for the reform of ocean governance in the direction of sustainability. For this to happen, some of the weaknesses of UNCLOS must be remedied. While UNCLOS sees the oceans as an ecosystem, it falls short of a strictly systemic approach, making no provision for land-sea interactions, for example.

The zoning of the oceans into coastal waters, EEZs and the high seas runs counter to the ecosystem approach enshrined in UNCLOS. Such zoning does allocate rights of use and conservation obligations, but it provides an inadequate basis for monitoring and enforcing environmental standards outside of coastal waters. Two exceptions are the London Convention (1972) and the London Protocol (1996) on the prevention of marine pollution, both of which have worldwide scope. The Convention on Biological Diversity likewise tackles marine-conservation issues from a systemic perspective. Since it is a framework convention, however, it has no sanctioning mechanisms at its disposal.

The biggest shortcoming in governance concerns the high seas, parts of which are unregulated, and where regulations do exist they are not implemented with sufficient rigour. For example, the UN Fish Stocks Agreement (FAS), one of the UNCLOS implementation agreements, covers only a part of fish stocks on the high seas (Section 4.1.4.4). Since participation is weak and implementation only partial, a regime of open access – which is conducive to overfishing – continues to prevail in many areas of the high seas in practice.

Rights of disposal over the oceans as a public and common good are too vague

The rights of disposal over the oceans, a public and common good, are insufficiently defined and allocated. As a result, there are not enough incentives for a sustainable interaction with the blue continent. The respective users often ignore the long-term environmental effects of individual uses such as fishing, oil and gas extraction or sewage discharge, as well as the interdependencies between the various forms of use. Individual players have few incentives to act in a long-term-oriented way that is in the interests of sustainable use. In order for external effects to be internalized in the use of the oceans and marine conservation, it is crucial that countries or the international community find regulations which clearly define and allocate rights of disposal. Simultaneously local, regional and national regulations on use should be embedded into the global regime on use, and free-rider behaviour should be minimized at every level of governance. One example of this kind of regime is the FSA, which, together with the RFMOs, is responsible for the conservation and management of straddling and highly migratory fish stocks (Section 4.1.4.4). At the same time, this regime illustrates the magnitude of the challenge of effectively preventing free-rider behaviour in the marine environment (Section 4.1.4.5).

Insufficient use is made of available instruments

Many instruments of ocean governance, such as marine spatial planning, the designation of marine protected areas, coastal-zone management and environmental liability, are not yet being used by all countries, and some are not sufficiently integrated into international treaties.

When it comes to conserving and managing the high seas, one problem is that there is no superordinate steward like the International Seabed Authority that is able, for example, to apply marine spatial planning or designate protected areas. At this level, regional treaties offer opportunities to apply both instruments and thereby avoid conflicts over usage.

Marine spatial planning also opens up the possibility of organizing marine conservation on a systemic and cross-cutting basis: from the management of individual fish stocks to the management of entire ecosystems; from due provision for individual drivers of overexploitation of the oceans to the integration of all forms of human influence on the sea; from the management of individual marine protected areas to the regional and supraregional networking of protected areas. This point constitutes another platform for the further development of ocean governance in the direction of sustainability.

Links between marine science and marine policy are too weak

As things stand, marine research is not systematically integrated into the decision-making processes of an international marine policy focused on sustainability. For this reason, the UN's plans to publish a regular global report on the status of the marine environment as of 2014 ('Regular Process': Section 3.3.1; Box 3.3-2) are especially promising. This could be the beginning of a kind of scientific reporting like that carried out by the IPCC on the problem of climate change.

Ideas for future ocean governance

If a regime of sustainable use and conservation is to take shape for the oceans in general and the high seas in particular, it is important *first* to extend the idea that the oceans are the common heritage of mankind to include all areas of the sea and all marine resources. UNCLOS

Box 3.6-1

Existing international funds and programmes to finance the conservation and sustainable use of the oceans

In the past, the World Bank and the GEF have collaborated with other UN organisations such as the FAO and the UNDP to support a number of programmes and projects in sustainable fishery management, sustainable aquaculture, marine protected areas, coastal protected areas and integrated coastal-zone management (ICZM).

Funding from the World Bank, PROFISH and ALLFISH

According to former World Bank President Robert Zoellick, the World Bank invested a total of about US$1.6 billion in the fields of coastal-zone management, fisheries management and marine protected areas in 2012 (World Bank, 2012b). One important element of the funding provided by the World Bank is the PROFISH programme (The Global Programme for Fisheries), a multi-donor trust fund whose mandate is to promote sustainable fisheries management in Africa, Asia and Latin America. PROFISH was founded in 2005 and is administered by the World Bank. In addition, ALLFISH (The Alliance for Responsible Fisheries), a public-private partnership between the fish- and seafood-processing industry and the World Bank, FAO, GEF and International Coalition of Fisheries Associations set up in 2009, aims to advance the cause of sustainable fisheries and aquaculture, especially in developing countries. There is also the Strategic Partnership for a Sustainable Fisheries Investment Fund in the Large Marine Ecosystems of Sub-Saharan Africa (endowed with US$60 million, financed by the GEF; World Bank, 2009) and the Capturing Coral Reef and Related Ecosystem Services Partnership (World Bank, 2012a).

GEF funding priorities: 'international waters' and 'biodiversity'

In line with its focus on international waters and biodiversity, the GEF currently supports several projects relating to the oceans, including the establishment and running of marine protected areas. However, the total funding made available for GEF grants relating to the oceans over the past two decades (1991-2012) totalled only about US$ 700 million (Sherman and McGovern, 2012; UNDP and GEF, 2012b, c). In this period, the GEF's 'international waters' funding priority accounted for around US$450 million, although US$176 million of this amount was earmarked for inland waterways (i.e. rivers, lakes and aquifers), so that only grants totalling US$274 million were channelled into marine and coastal conservation (UNDP and GEF, 2012c). If these grants are combined with further investment support provided by the World Bank and other project co-financing arrangements, a total of US$4.1 billion has been made available by the GEF since 1991 for the conservation of marine ecosystems, including measures to reduce land-based discharges into the oceans (UNDP and GEF, 2012a; Sherman and McGovern, 2012). This figure is equivalent to roughly US$200 million per annum.

In collaboration with the FAO, the World Bank, UNEP, CBD, UNCLOS and a number of regional fisheries management organizations, the GEF has launched the 'Programme on Global Sustainable Fisheries Management and Biodiversity Conservation in Areas Beyond National Jurisdiction' to support management of the oceans outside of national territorial waters. This programme is endowed with US$ 50 million, plus co-financing amounting to US$223 million. It comprises four subprojects focusing on tuna fishing and deep-sea organisms. What is known as the GEF's 'Oceans Partnership Fund' is also part of the programme (GEF, 2012).

The leverage effects connected with GEF grants are estimated by the UNDP at between 57:1 and 2,500:1 (UNDP and GEF, 2012a). In other words, experience shows that for every dollar the GEF has made available as a grant for marine and coastal conservation, at least US$57, and perhaps as much as US$2,500, has been invested in addition by private players. A leverage effect of 8:1 is assumed in the case of public-sector investment in the creation and running of marine protected areas (UNDP and GEF, 2012a).

Global Partnership for Oceans

The World Bank launched the Global Partnership for Oceans in early 2012 (Section 3.3). The aim of this partnership is to bundle and selectively deploy knowledge and funds to improve the state of the oceans. Over a five-year period, a total of at least US$300 million in public funds is to be bundled to mobilize leverage totalling US$1.2 billion in private funding. According to the World Bank, the focus should be on sustainable fisheries management, sustainable aquaculture, the conservation of coastal ecosystems and the reduction of land-based discharges into the oceans (World Bank, 2012a). The aim is for the moneys generated in the course of this partnership to trigger governance reforms in individual countries, maintain marine protected areas, and support the exchange of information and experience between countries (World Bank, 2012b).

already establishes this concept for the seabed on the high seas. *Second*, the precautionary principle, which is already taken into account in regional marine conservation treaties and the FSA, for example, should be anchored within UNCLOS. Building on the precautionary principle, a *third* step could be to tackle other important elements of forward-looking ocean governance and create the appropriate instruments. Examples include adaptive management, a systemic approach and programmes to promote innovation. Although there are binding marine treaties under international law with effective sanctioning mechanisms which are also monitored and enforced (by the International Maritime Organization [IMO], for example), these treaties are limited to certain individual areas of use. Examples include the MARPOL Convention and the London Protocol. Many international marine-policy agreements, especially UNCLOS and its implementation agreements, are binding under international law, but most have no sanctioning mechanisms to deal with non-compliance or violations. Nor is regular reporting compulsory in most cases.

Food from the Sea

4

Fishing is one of the oldest uses to which the oceans have been put. To this day, fish and seafood play an important role in providing many people with nutrition and protein. Aquaculture – the cultivation of fish on land or in coastal areas – also has a tradition that dates back thousands of years and today supplies nearly half of the fish products consumed by humankind. Both branches of industry have caused damage – severe damage in some cases – to marine ecosystems. This chapter explores how changes in governance can help place fishing and aquaculture on a sustainable footing in future, thus enabling both to contribute to the transformation towards sustainability.

To this end, this chapter not only investigates fishing (Section 4.1) and aquaculture (Section 4.2) in isolation, but also examines how each interacts with the other (Section 4.3). For example, the most important fish-farming methods used in marine aquaculture are dependent on marine fish caught in the wild, which indirectly increases the pressure on marine ecosystems. Section 4.4 examines the systemic effects of global environmental changes on fishing and aquaculture. For both sectors, these effects will gain in importance in the future. The focus here is on the anthropogenic effects on the oceans of other branches of industry: emissions of greenhouse gases and CO_2 leading to climate change and ocean acidification, and inputs of other harmful substances causing eutrophication, dead zones and the pollution of marine ecosystems.

Fish is not the only product of fisheries and aquaculture. They also deliver other marine animals (seafoods such as crustaceans, molluscs, snails and squids) and, in aquaculture, algae. The topic of whales is not dealt with here, as they have been scarcely relevant to human nutrition since the moratorium declared by the International Whaling Commission in 1986. Both fishing and aquaculture should always be seen in the context of other uses (such as energy generation, tourism and nature conservation).

4.1 Marine fishery

4.1.1 Status and trends of fisheries

From a global perspective, marine fisheries are in a very worrying state (Froese et al., 2012; Beddington et al., 2007; FAO, 2012b: 13; Maribus, 2013). There is broad scientific and political consensus that the global limits of use have already been reached or even exceeded. Urgent action is therefore needed to conserve or replenish fish stocks (WSSD, 2002: para. 30a; Worm et al., 2009; Mora et al., 2009; FAO, 2010b; Costello et al., 2012b). So far, few countries are making real progress towards sustainable management of their fish stocks. The EU has slowly begun to move in the direction of sustainability (Section 7.4.1.7).

Marine fisheries experienced a tremendous upswing in the latter half of the 20th century (FAO, 2011a). Annual landings of fish rose from 16.8 million tonnes in 1950 to 86.4 million tonnes in 1996. Since then, catches have stagnated at around 80 million tonnes a year, with a slight downwards trend (Figure 4.1-1; FAO, 2012b: 11). However, stagnating yields certainly do not mean that a stable, sustainable state has been reached in which stocks and catches are in equilibrium. On the contrary, catching the same amount of fish requires a greater global fishing effort, and this has indeed increased by 54% since the 1950s (Anticamara et al., 2011). The more readily accessible natural stocks are increasingly being depleted by fishing. Fisheries are compensating by switching to other stocks ('serial depletion'; Srinivasan et al., 2012). The limits of what is technically possible in the fishing industry are being pushed back further and further by ever-more-advanced methods for locating and catching fish (Berkes et al., 2006). Today, industrial fishing fleets can sail to very remote regions of the high seas (such as the South Pacific) in search of new fish stocks. They are increasingly fishing the eco-

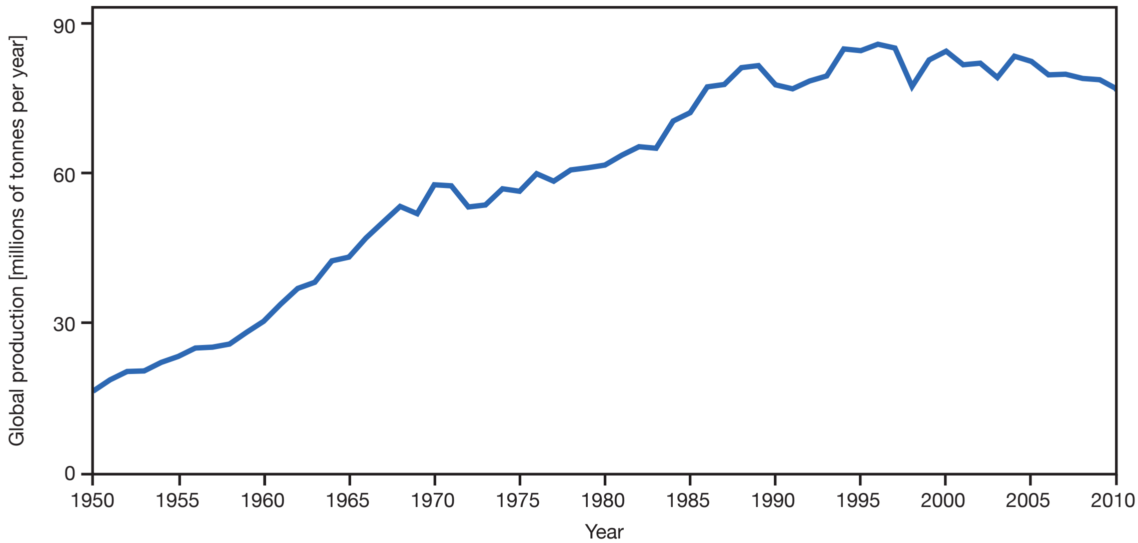


Figure 4.1-1
World marine fisheries production.
Source: FAO, 2012b: 5

logically fragile stocks that populate the deep sea with all the signs pointing towards overexploitation, even though a precautionary approach would be especially important for these stocks (Davies et al., 2007; Norse et al., 2012; Villasante et al., 2012). In future, the fishing industry will find it increasingly difficult to reach current catch volumes, as there are hardly any remote or unused regions of the ocean left (Swartz et al., 2010; see Box 4.1-1 on the Arctic). There is little room to expand the scope of fishing activities (Jackson, 2008; FAO, 2011a; Worm and Branch, 2012) – all the more so since fishery is limited by the available amount of global marine primary production, and these limits already becoming clearly noticeable (Chassot et al., 2010).

Using the FAO's official figures as the basis (FAO, 2012b: 11), 30% of global stocks are overfished. 57% of stocks are already fully exploited (in terms of the maximum sustainable yield, or MSY; Box 4.1-5). Only 12.7% of global stocks theoretically still have the capacity to cope with higher catch volumes, and the proportion of overused stocks has increased continually (Figure 4.1-2). This observation is corroborated by a global survey of experts which concludes that the overall effectiveness of stock management is lagging a long way behind international targets (Mora et al., 2009; Figure 4.1-3).

Accordingly, Worm et al. (2009) come to the conclusion that nearly two thirds of well-studied stocks are in need of replenishment. However, the study also shows that, in some regions, improved management – leading to lower rates of use – have enabled stocks in these regions to recover. The FAO (2011a; 2012b: 13) likewise reports positive case studies in a number of industrialized countries (USA, New Zealand, Australia: the California Current and several shelf areas; Box 4.1-6). Costello et al. (2012b) have added an estimate on stocks that are poorly studied. Two thirds of these 'data-poor' stocks, most of which are located in the waters of developing countries, could also deliver larger yields and make valuable contributions to nutrition if they were replenished. On the whole, these small unassessed fisheries are in a significantly worse condition than the assessed fisheries, and the trend towards depletion continues. Yet developing countries, too, have positive case studies to report (e.g. Namibia: Box 4.1-7). So clearly, it is possible to realize an effective and sustainable management of fish stocks.

Finding indicators for sustainable stock management is of crucial importance in this context. The most commonly used concept is still the simple MSY, i.e. the maximum sustainable yield of a stock over an extended period of time. This measure is incorporated into many international agreements (e.g. UNCLOS, FSA, the FAO Code of Conduct, WSSD; Section 4.1.4) and national laws. It forms the basis on which many stocks are managed (Box 4.1-5). From a scientific perspective, however, it has now become apparent that an MSY calculated in isolation for individual species usually leads to too high a figure being put on estimates of appropriate rates of use, partly because it does not take the interactions within the ecosystem into account (e.g. Larkin, 1977; Worm et al., 2009; from a historic perspective: Finley, 2011). The concept has therefore been elaborated (Box 4.1-5), but is still mostly used in its simple

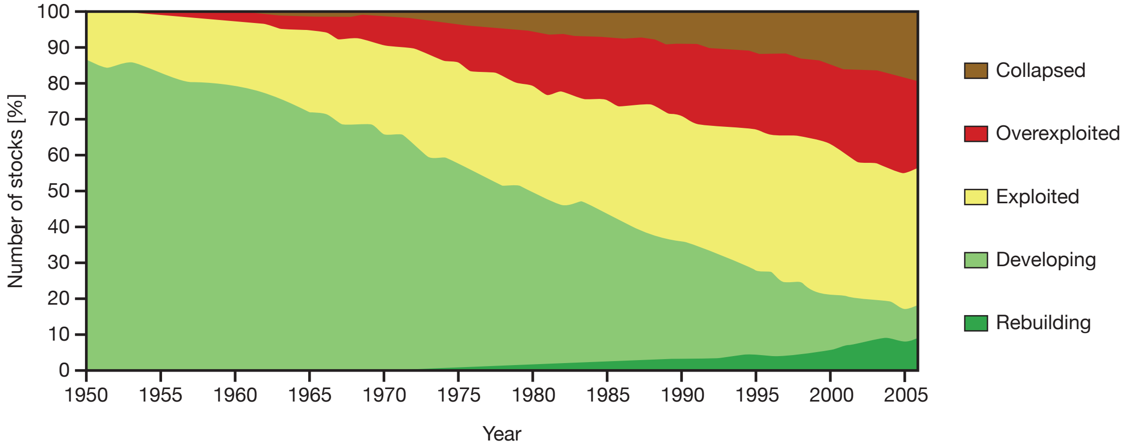


Figure 4.1-2
Development (since 1950) of global marine fish stocks for which fishing data are available (n=1006).
Source: Pauly, 2013

form when it comes to hands-on management.

Widespread problems include inadequate data about stocks and a lack of scientific capacity. Only a small number of countries have a robust scientific base with which to underpin their fisheries management (Mora et al., 2009). This is often a problem even in industrialized regions (SRU, 2011b) and is considerably worse in developing and newly industrializing countries due to capacity problems (CEA, 2012). The only comprehensive global fisheries database is operated by the FAO and depends primarily on the data submitted by countries. Some countries (especially China) consistently report catch figures that are too high, while others report figures that are too low. Still others submit no data at all (Pauly and Froese, 2012). Taking not only the FAO data but all available data sources together, the picture of the state of fisheries painted above could turn out to be too optimistic overall (Froese et al., 2012). This conclusion is made all the more serious, given that between one seventh and one third of catches do not appear in the statistics at all because they are made illegally (Agnew et al., 2009; Section 4.1.4.5). In addition, substantial quantities of the fish caught are unwanted bycatch, most of which is immediately thrown back overboard (Kelleher, 2005).

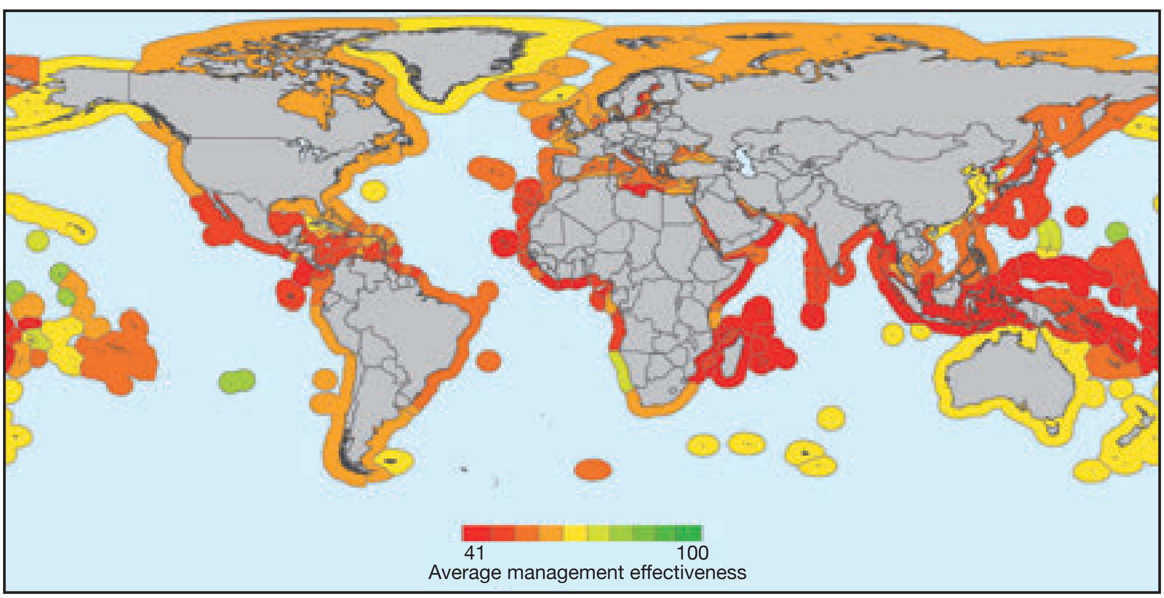


Figure 4.1-3
Overall effectiveness of fisheries management of the world's EEZs. The effectiveness indicator takes account of factors such as a robust scientific basis, transparency and the ability to enforce regulations.
Source: Mora et al., 2009

Box 4.1-1

Fisheries in the Arctic Ocean

The Arctic is particularly sensitive to anthropogenic climate change. In recent decades, temperatures in the Arctic summer have been higher than at any time in the past 2,000 years (AMAP, 2011). One consequence of this warming is that the sea ice in the Arctic Ocean is melting more quickly; it has already shrunk significantly in terms of both surface area and volume (Box 1.2-3). Within a few decades, the waters of the Arctic will probably be ice-free at the end of each summer, with thick multi-year ice increasingly giving way to thin single-year ice (Doney et al., 2012).

Far-reaching and rapid changes in both the Arctic terrestrial and marine ecosystems have already been observed as a consequence of anthropogenic climate change (Post, 2009; Doney et al., 2012). Dramatic structural changes have been observed among benthic communities near Spitzbergen, for example (Kortsch et al., 2012). Shrinkage of the Arctic ice also allows algae living under the sea ice to proliferate. These algae then become detached and are deposited on the deep sea-bed, which they deprive of oxygen, possibly triggering a considerable effects on the benthic communities (Boetius et al., 2013). In their review of the changes to the Arctic marine ecosystems induced by climate change, Wassmann et al. (2011) conclude that many species, including many fish species, are shifting their range towards the North Pole. Since the ecological conditions for species are changing, they react with increases or decreases in their populations, or with behavioural changes. In some cases, drastic structural changes (regime shifts) have also been observed in marine ecosystems. However, the quality of forecasts suffers from the fact that there has been comparatively little scientific investigation of the Arctic region and its ecosystems in the past (Wassmann et al., 2011).

Fishing grounds in the far north already rank among the most productive in the world today and are of great economic importance to a number of Nordic countries (e.g. Greenland, Iceland, the Faroe Islands and Norway; AMAP, 2011). The Atlantic herring alone yields annual catches totalling 2 million tonnes, while 1.2 million tonnes of Alaska pollock are caught every year in the Bering Sea, along with 1 million tonnes of Atlantic cod in the Barents Sea. In recent decades, an average of around 6 million tonnes of fish a year has been landed from Arctic and sub-Arctic waters, contributing about 10% to the word's supply of edible fish (CAFF, 2013). Yet despite these large numbers, most sub-Arctic fish stocks are in good condition; they are among the more carefully managed stocks in the world.

Shrinking sea ice will have a considerable impact on economically important fish stocks, both directly, by affecting their migratory movements, and indirectly via impacts on lower trophic levels in the Arctic marine ecosystems (e.g. primary production and zooplankton), which have an effect on the fish stocks' food supply (AMAP, 2011). The reactions of small pelagic species of fish in the North Atlantic (such as capelin and herring) are swift and pronounced, and they are quickly shifting their populations northwards (Rose, 2005). Similar shifts have also been observed in other regions (e.g. in the Pacific part of the Arctic; Grebmeier et al., 2010) and among other species (such as cod, pollock and snake pipefish; Wassmann et al., 2011). As a result, production conditions will improve for a number of stocks (such as Atlantic cod), possibly opening up potential for new and important fisheries in parts of the Arctic (ACIA, 2005). A study by Sherman et al. (2009) points to the indirect effects of relatively rapid warming in the Northeast Atlantic to explain rising fishing yields in this region. In the long term, this could be a significant advantage for industrial fisheries, whereas its effects on small-scale fisheries is complex and difficult to judge, partly because some stocks (such as the Greenland halibut) are expected to decline (e.g. Greenland halibut; AMAP, 2011), leaving them more vulnerable to overfishing (Brander, 2007).

Different species react very differently to climate change. Accordingly, the effects on fish stocks are very complex and diverse, varying from region to region. They can also have a profound effect on ecosystem structures (CAFF, 2013). Given the current status of scientific knowledge, these impacts can only be forecast qualitatively and with a considerable degree of uncertainty (Reist et al., 2006). The impact on fish stocks as a whole will depend essentially on the extent of climate change and the quality of fisheries management (ACIA, 2005), although adaptability is being impaired by a lack of scientific knowledge (Reist et al., 2006).

Alongside climate change, other anthropogenic factors may also have an impact on fishing; these are explained in detail in Section 4.4. The most important factors with regard to Arctic fishing are ocean acidification (Section 1.2.5), which is intensifying particularly rapidly at high latitudes, and the increasing risk of oil pollution due to intensified prospecting for oil reserves in the Arctic region (Box 5.1-2). Taken together, these factors pose a serious challenge to the management and governance of fishing activities.

Anthropogenic changes to nature and their effects on fish stocks require changes in the way fisheries are managed. In the future, marine research and the monitoring of fish stocks should be closely linked to flexible and adaptable practices of fisheries management (Brander, 2010). Since the Arctic waters are mostly within the EEZs of Arctic states (Figure 7.3-1), this is first and foremost a task for national governments.

One example of how the precautionary approach can be applied within an EEZ is the decision by the US North Pacific Fishery Management Council to ban commercial fishing in the US Arctic waters north of the Bering Sea for the time being, the rationale being that not enough is yet known about the effects of global warming in this region (CAFF, 2013). Since there are currently no significant commercial fisheries in the central part of the Arctic Ocean and not enough is known about the region, this approach is to be welcomed and can serve as an example for other Arctic regions.

Given that these changes will also affect straddling stocks, bilateral agreements will also have to be amended or renegotiated in some cases. In the Barents Sea, for example, fish stocks are expected to increase in the wake of climate change. Agreements between Russia and Norway will therefore probably have to be adapted accordingly (AMAP, 2011).

International fisheries governance also faces new challenges. Some of the boundaries of the Arctic states' EEZs are disputed, for example, leaving it unclear who has jurisdiction over the fish stocks (Box 3.2-3). However, new opportunities for fisheries could also arise in the Arctic regions of the high seas (Molenaar and Corell, 2009). Large sections of these Arctic waters are not covered by any of the regional fisheries management organizations (RFMOs) responsible for straddling stocks (Section 4.1.4.4), because no fishing on a significant scale has been possible in these regions up to now. One exception is the North Atlantic, which is covered by NASCO, NEAFC and NAFO (Figure 4.1-12). In any case, constructive cooperation between the existing RFMOs operating in Arctic waters is certainly advisable.

The Arctic Council (Box 3.4-1) has had no mandate for fisheries up to now, nor is there any sign that this will change in the foreseeable future. The option of extending the coverage of the existing RFMOs into the hitherto unregulated regions, or of setting up new RFMOs, is therefore worth considering (AMAP, 2011; CAFF, 2013). However, the danger is that these governance processes of negotiating appropriate regulations might be too slow – and could be outflanked by the fishermen themselves, who can move quickly to exploit new opportunities and regions (Molenaar and Corell, 2009).

Regional patterns

Around 90% of marine fisheries' yields come from the EEZs of coastal states (FAO, 2012b:94). Only about 10% originates from the high seas (Figure 4.1-4). According to Worm and Branch (2012), the picture in industrialized countries is one of well assessed stocks with a low but stable biomass (below the MSY). In EU waters, 47% of stocks are fished beyond the MSY (EU Commission, 2012a). In other words, the obligation under UNCLOS and FSA to manage stocks in line with the MSY is not being complied with. There is therefore a substantial need for action in Europe (SRU, 2011b; Froese, 2011; Section 7.4.1.7). In most newly industrializing and developing countries, the average biomass is higher, but lack of fishery monitoring and management capacity gives rise to concerns that stocks will be quickly depleted unless extensive reforms take effect (Worm and Branch, 2012; Section 4.5). At the same time, even industrialized countries that manage their own stocks sustainably cover a large or even predominant proportion of their consumption of wild fish by importing it from developing and newly industrializing countries (e.g. the figure for the EU is roughly 60%; Markus, 2012; Section 4.1.4.8).

Outlook

The world's population will continue to grow until the middle of the century, not least in tropical coastal regions, where fish is particularly important for local food security. On top of this, industrialized countries and the high-income groups of developing and newly industrializing countries are showing a growing preference for fish. The FAO (2012b) therefore expects demand for fish products to rise sharply in future. Marine wild fisheries will not be able to satisfy this demand (Jackson, 2008) for two reasons: first, yields are not going to increase any further, despite greater fishing effort; and second, the intensity of fishing needs to be eased off significantly, at least for a time, if stocks decimated by overfishing are to recover (Pauly et al., 2003). Dealing with the pressure of this demand, while at the same time initiating the necessary transformation of fisheries towards sustainability will thus be a major challenge in the future. While this would probably lead to a temporary decline in catch volumes between now and 2020, higher yields could be achievable by mid-century (UNEP, 2011b; similar forecasts for the EU: Froese and Quaas, 2013). The practice of artificially increasing marine primary production in suitable maritime zones by means of artificial upwelling (bringing water from the depths to the ocean surface) is still at an early stage of research (Box 4.1-2). One thing is cer-

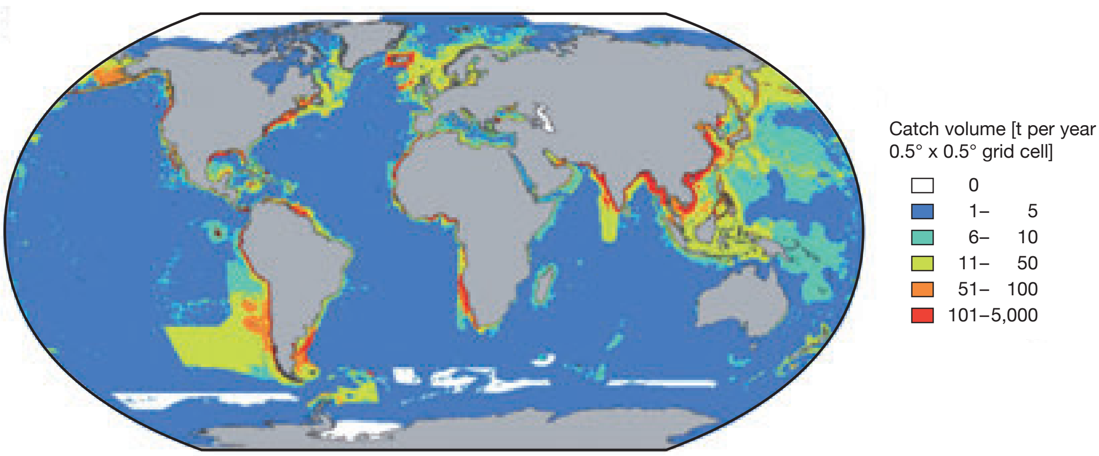


Figure 4.1-4
Regional breakdown of marine fishery yields between 2000 and 2007. The figure shows mean annual catches per 0,5°x0,5° grid cell.
Source: Sumaila et al., 2011

tain: persisting with the management practices used up to now spells doom for fisheries: declining biomass and yields accompanied by increasing ecological, economic and social risks (World Bank and FAO, 2009; Section 4.1.2.2, 4.1.2.3).

4.1.2 Importance and effects of fisheries

4.1.2.1 Food and food security

Seafood is a source of high-grade protein and an important element in many people's diets (Smith et al., 2010; de Schutter, 2012a). Marine fisheries and marine aquaculture together produced 98.2 million tonnes of fish and seafood in 2011, with fisheries accounting for the lion's share of 78.9 million tonnes. By contrast, aquaculture dominates production in fresh water, yielding 44.3 million tonnes, ahead of fisheries' 11.5 million tonnes (FAO, 2012b: 3). Since literature on the subject does not often distinguish clearly between these sources, the contribution made by aquaculture and fisheries to food and food security are examined together in this section.

In terms of calories, fish products account for a very small share of the world's food supplies. Spread across the global population, the 131 million tonnes of fish products consumed every year translates into approximately 360 g per person per week; the share of wild fish caught at sea is just over 210 g. However, as a source of protein, fish products are substantially more important. In 2007 fish contributed around 17% of the animal protein consumed by the global population and more than 6% of its total protein intake. About three billion people use fish products to meet almost 20% of their consumption of animal protein; for around 4.3 billion people the figure is roughly 15% (FAO, 2012b: 5).

However, these global averages obscure the fact that fish is an indispensable element in ensuring food security and a regular supply of animal protein in some countries and regions (Figure 4.1-5). In low-income food-deficit countries (LIFDCs), fish accounts for approximately 20% of human consumption of animal protein. Given the fact that small-scale fisheries' data (Section 4.1.2.4) are often incomplete in the official statistics, however, the actual figure is probably higher (FAO, 2010b: 67). In some countries, such as Ghana, Indonesia, Sierra Leone, Sri Lanka, the Solomon Islands, Bangladesh, the Democratic Republic of Congo and Cambodia, fish protein accounts on average for more than 50% of humans' intake of animal protein (MA, 2005b). The figure can be as high as 90% in small island developing states (SIDS) and poor coastal communities in developing countries (Noone et al., 2012). Furthermore, fish is important and often underestimated as a source of essential vitamins and minerals. In these countries, it therefore plays a key part in local food security (Roos et al., 2007; FAO, 2010b: 64).

The overfishing experienced to date and the danger that further fish stocks could collapse is therefore jeopardizing the oceans' important contribution to global food supplies. According to the analysis conducted by Srinivasan et al. (2010), around 20 million people could have been saved from malnutrition in 2000 if it had not been for the overfishing that had already taken place. Frid and Paramor (2012) are convinced that fishing will only be able to maintain its role as a key supplier of protein to the growing global population in the future if it is managed sustainably.

4.1.2.2 Socioeconomic significance and effects

Fish is not just an important ingredient in many people's diet, it is also a valuable trading commodity. Around three quarters of global fish production is intended for direct human consumption. Most of the remainder is used to make fish oil and fish meal, primarily for aquaculture or as animal feed (FAO, 2012b). The first-sale value of marine wild fisheries is over US$80 billion per annum (FAO, 2010b), and the entire market for fish products is estimated at around US$400 billion (World Bank and FAO, 2009). About a quarter of this is traded on the world market. Fisheries' median contribution to the global gross domestic product (GDP) is 1.3% (World Bank et al., 2010). Imports flow primarily into industrialized countries: Japan, the USA, Spain, France and Italy together import nearly half of all traded fishery products. A quarter of exports come from China, Thailand, Vietnam and Chile (2008 figures; FAO, 2010a; Section 4.1.4.8). Taken together, developing countries supply about half of total exports. For this group of countries in general – and for many LIFDCs in particular – this is an important source of foreign exchange. In the course of globalization, fish trading is increasingly being concentrated in the hands of a small number of large trading companies (FAO, 2009a: 44). The value of global fish exports is twice as high as that of coffee, the leading agricultural export, and has grown much faster in recent decades in response to rising demand (FAO, 2010b).

From an economic perspective, the management of fisheries is very unsatisfactory. Catches in the EU, for example, could be about 80% higher than they currently are if fisheries management was sustainable (Froese and Proelß, 2010). Drawing a comparison with the finance industry, EU Fisheries Commissioner Maria Damanaki (2011) thus referred to fish stocks as "underperforming

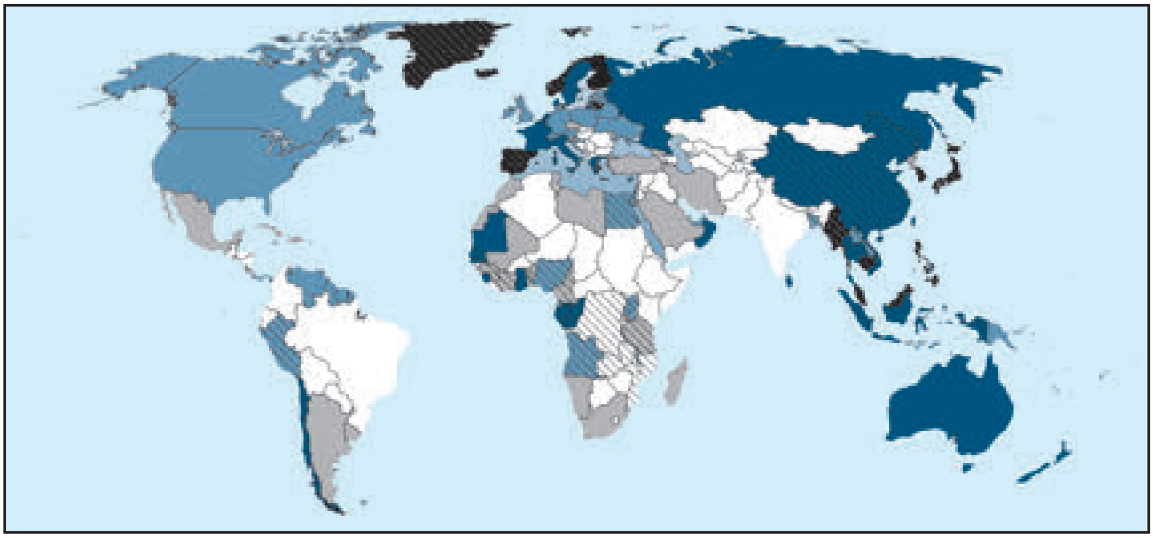


Figure 4.1-5
Contribution of fish to animal protein supply (average from 2007 to 2009).
Source: FAO, 2012b: 83

assets" which, if better managed, could deliver substantially higher macroeconomic returns. The World Bank and the FAO (2009) have estimated that global fisheries lose US$ 50 billion a year as a result of non-sustainable management and the resultant depletion of stocks. This amount only covers the macroeconomic losses resulting from the inefficient management of fish as a resource, i.e. the net benefits forfeited by fisheries because of overfishing and fishing-fleet overcapacity. The loss of biological diversity and ecosystem services as a consequence of current fishing practices is not included in the World Bank and FAO estimate, as this loss is difficult to translate into monetary terms.

The widespread subsidies are an important contributing factor to the poor level of efficiency (Section 4.1.4.7). Today's marine catch yield could be achieved with about half the current global fishing effort. The non-sustainable management of stocks also causes fisherfolk and the fish industry painful economic losses. Conversely, national economies could benefit considerably from the replenishment of stocks (Sumaila et al., 2012; OECD, 2012b). Although the economically optimal road to stock replenishment takes time, it also leads to much higher yields (Costello et al., 2012a).

Marine fisheries directly safeguards the employment and livelihood of about 34 million people worldwide (FAO, 2011a), and over 95 % of these jobs are in the small-scale fishing sector in developing countries (Section 4.1.2.4). Poverty is widespread in the coastal communities of these countries, especially in sub-Saharan Africa, South and Southeast Asia. For many coastal communities, therefore, overfishing and the decline in catch yields constitutes an existential problem, as their livelihoods depend directly on fish resources (Section 4.1.2.4). In addition, these communities are particularly vulnerable to climate change (Section 4.4.1). Since every employed fisherman generates several additional jobs in the processing and trading of fish products and supports several dependent family members, the total number of people who depend on the fishing sector is several hundred million (FAO, 2010b: iii).

Employment in the fishing sector has grown faster than the global population and employment in traditional agriculture, although the employment rate will probably continue to decline due to the structural transition in capital-intensive countries (Europe, USA and Japan), e.g. as a result of technological progress. As in agriculture, yields per job are substantially higher (by a factor of almost 10) in industrialized countries than in developing countries (FAO, 2010b: 7).

By no means least, fisheries and fish products are a formative element of the culture and lifestyle in many countries (e.g. Asia, Scandinavia and the Iberian peninsula), without which life would be inconceivable for many people (FAO, 2011a; Section 1.1.1).

4.1.2.3
Ecological significance and effects

More and more historical studies are showing that the impact of fisheries on marine ecosystems has been underestimated for many years, and that this impact has grown considerably more severe as the fishing

Box 4.1-2

Artificial upwelling: increasing primary marine production by pumping deep-sea water to the surface

Artificial upwelling is a technique by which the nutrient-rich, cold deep-sea water is brought to the surface layers of the ocean to boost primary production there. The technology can serve a variety of purposes:

- Artificial upwelling can 'fertilize' surface water in order to increase primary production and, via the food chain, ultimately increase the production of desired species of fish or seafood ('cultivation of the ocean desert'; Maruyama et al., 2004).
- The difference in temperature between the cold deep-sea water and the warmer surface water can be exploited to generate energy (ocean thermal energy conversion, OTEC; Vega, 2002; Section 5.2.1.2).
- It is also possible to combine higher marine primary production with energy generation. There are visions of a new 'blue revolution' (McKinley and Takahashi, 1991; Takahashi, 2000) and of 'open-ocean ranches' in which energy is generated (by OTEC power plants) and the nutrient-rich deep-sea water brought to the surface is simultaneously used for other purposes, e.g. for aquaculture or for fertilizing the surface water (Matsuda et al., 1998, 1999).
- Artificial upwelling can indirectly influence the production of seafoods (in this case mussels). Experiments have been conducted in Norway in which deep-sea water has been used to stimulate the growth of non-toxic algae in order to protect mussel farms from algal toxins (McClimans et al., 2010).
- The sequestration of CO_2 from the air can be stepped up to help protect the climate. This form of geoengineering is intended to stimulate greater primary production, which is supposed to lead to more carbon being exported to the deep sea (Lovelock and Rapley, 2007; Karl and Letelier, 2008; Oschlies et al., 2010).
- Layers of water close to the surface can be cooled by water brought up from the deep sea in order to weaken hurricanes or help coral reefs to survive during periods of climate change (Kirke, 2003).

Technologies

Relatively little energy is needed to overcome the density differences between cold deep-sea water and warm surface water. The following technical methods are used to bring nutrient-rich water from the deep sea to the surface:

- Pumps driven either by external energy (e.g. coupled with an OTEC power plant; McKinley and Takahashi, 1991) or by wave power (Liu et al., 1999; Kirke, 2003; Lovelock and Rapley, 2007; Kenyon, 2007).
- Injecting air and transporting deep-sea water upwards together with the movement of the air bubbles (Liang and Peng, 2005; McClimans et al., 2010).
- 'Perpetual salt-fountain mechanism': Due to the physical properties of layering with its different densities and temperatures, a long pipe would facilitate a constant, slow flow of deep-sea water to the surface without any need for an external energy supply (Stommel et al., 1956; Huppert and Turner, 1981; Maruyama et al., 2004).

Increasing primary marine production: potential

Marine ecosystem production is greatest where natural processes channel large quantities of nutrient-rich, cool deep-sea water to the surface. These upwelling zones account for 90% of the oceans' global natural production (Gauthier, 1997). The most productive fishing grounds in the world are situated in these natural upwelling zones, which are located off many coasts. The best-known example is the anchovy fishery off the west coast of South America, which is ultimately fed by the cool Humboldt Current. Despite the pronounced fluctuations caused by El Niño, on average Peru's anchovy stocks form the basis of the highest-yield fishery in the world (FAO, 2011a: 10) and are the world's biggest source of fishmeal.

The idea behind artificial upwelling is to create a similar effect in suitable regions and on a small scale by artificially bringing deep-sea water to the surface and using it there as the basis of a productive food chain (Kirke, 2003). Unlike conventional fisheries, artificial upwelling thus has similarities with agriculture, which also improves the production of biomass by artificially adding nutrients. There are two main differences, however:

First, in agriculture it is mainly plants that are cultivated and harvested. Where grasslands are grazed by livestock, the target organism is never higher than the second trophic level. By contrast, in the ocean the food chain usually passes through three or even four steps before it arrives at the desired organism for harvesting: (1) phytoplankton (primarily microalgae that build up biomass with the aid of nutrient inputs and sunlight); (2) zooplankton (small crustaceans, larvae etc. that eat the algae); (3) planktivorous fish, such as anchovies or sardines, which feed mainly on zooplankton; and (4) predatory fish that eat planktivorous fish. As a result, the conversion losses are much greater and efficiency levels correspondingly lower. However, mussel farms based on diatom blooms would equate to a two-link food chain (Roels et al., 1979; Liu, 1999; Aure et al., 2007).

Second, controlling artificially created or modified marine ecosystems is considerably more difficult than it is on land. A farmer can manage very precisely what grows where and how. However, a marine ecosystem using artificial upwelling can be controlled at best by intelligently choosing the depth of the water used and hence the balance of nutrients between nitrogen, phosphorous, silicon and carbon. This is in turn a crucial factor for the composition of species resulting from the stimulated phytoplankton production, for the impact on the carbon cycle and, ultimately, also for the carbon sink function.

A considerable amount of research needs to be done before far-sighted visions can be realized (the 'Laputa project'; Maruyama et al., 2004): careless application could end up 'buying' additional biological production at the cost of releasing extra CO_2 emissions from the deep sea into the atmosphere. That said, research in this direction would appear interesting even without immediate applications, as it facilitates the testing and improvement of the existing ecosystem models (Karl and Letelier, 2008).

Combining fisheries with energy generation

One option could be to use artificial upwelling to stimulate the production of algae to make biofuels. It is also conceivable to cultivate macroalgae and then use the biomass to produce biomethane (Section 5.2.1). One advantage of this combination is that, since nutrient-rich deep-sea water would be used, it would not be necessary to add either energy-intensive nitrate or phosphate, which is extracted from ever scarcer and more expensive mineral deposits. Phosphate is threatening to become a limiting factor in agricultural production aimed at securing global food supplies (WBGU, 2011:47).

A visionary concept known in the context of artificial upwelling as the 'blue revolution' involves linking OTEC power plants with platforms on the open sea where aquaculture or even the industrial production of biopharmacological products could be based (McKinley and Takahashi, 1991). Assuming the use of a 40 MW OTEC power plant, the authors' rough calculations arrive at annual production figures of 80,000 dry tonnes of kelp or more than 3,000 tonnes of fish. The concept of an 'ultimate ocean ranch' aims in a similar direction (Matsuda et al., 1998), as do publications by Ouchi and Nakahara (1999) and by Toyota and Nakashima (1987). Japan has a number of test installations with numerous pipelines that pump deep-sea water to the surface for a variety of purposes (Takahashi, 2000).

Challenges to governance

Using artificial upwelling for fisheries in EEZ waters also involves new challenges to governance. At the very least there is a need in particular to prepare guidelines to complement UNCLOS, although it would not seem imperative to negotiate a corresponding implementing agreement (Proelß and Hong, 2012). There is also a need to link together fishing rights, investment outlay and running costs for the upwelling installations to prevent classic free-rider behaviour, e.g. enabling fishermen to benefit without investing anything.

Further research needed into environmental effects

Artificial upwelling is a visionary concept which, at least in theory, opens up the possibility of making 'desert regions' of the open sea more productive. The technology is at an early stage of research and still far from being ready to implement. The following core problems remain unsolved: (1) the effect on the marine carbon cycle in order to ensure a net export of carbon to the deep sea; (2) the effect on the dynamics of the deep-sea water (Kirke, 2003); (3) the ability to predict the influence on ecosystem reactions (Karl and Letelier, 2008).

effort has increased in recent decades (e.g. Lotze et al., 2006; Roberts, 2007; Starkey et al., 2008; Holm et al., 2010). The studies reveal many examples of large fish stocks that have collapsed due to overfishing. Overfishing is regarded is one of the main causes of biodiversity loss in marine ecosystems (Jackson et al., 2001; Worm et al., 2009).

These effects have long been underestimated not only because analysing stocks and ecosystem structures in the ocean is so difficult and laborious, but also because of what is known as the 'shifting baseline syndrome'. Each generation of fisherfolk and fishery scientists takes the state and composition of stocks at the beginning of their career as the basis on which they evaluate observed changes. When the next generation starts work, stocks have already declined, and these smaller stocks implicitly serve as the new basis for comparison. This successive practice makes it difficult to notice degradation (Pauly, 1995; Roberts, 2007:xii).

The dramatic effects of industrial fishing are by now well documented: the fish biomass in biotic communities typically declines by 80% in the space of 15 years (Myers and Worm, 2003). It follows that stocks of large predatory fish in particular must have been considerably larger in the past than they are today. Fisheries prefer to concentrate on species such as tuna and cod, which are on a high trophic level in marine food webs. Since the introduction of industrial fishing, these species have been decimated to such an extent that their worldwide biomass has shrunk by around 90% (Myers and Worm, 2003; Ward and Myers, 2005; Baum and Myers, 2004). The NRC's 2006 report considers this figure exaggerated, but itself still cites figures of 65-80%.

One consequence of overfishing is that a smaller proportion of fish reach sexual maturity. Spawning therefore declines, reducing the overall number of offspring. Age and size structures thus experience a shift, with the result that commercially overexploited fish stocks are dominated by juveniles (Pauly et al., 1998). Fishing also puts severe selection pressure on the fished populations, which adapt in such a way that the fish are younger and smaller when they reproduce for the first time (e.g. Olsen et al., 2004). These evolutionary changes induced by fishing exert a negative effect on the reproductive capacity of the fish stocks. Even if there was a moratorium on all fishing activities, these trends would probably only be reversed slowly – which has a disadvantageous effect on the resilience and sustainable management of these stocks (Barot et al., 2002).

The loss of biomass is not the only issue, however, because selective fishing can also fundamentally alter the composition of the ecosystems affected. Sharks and rays, which play an important role in marine ecosystems, are currently in particular danger and have already suffered serious losses due to overfishing (mainly for shark's fin soup) and because of bycatch (Myers et al., 2007; Field et al., 2009). Around 17% of shark and ray species are endangered, and a further 13% are on the verge of being classified as endangered (Vié et al., 2008). Like sharks, swordfish and tuna species are high up on the marine food web. Their high market value makes them vulnerable to overfishing, with the result that several of these species are already endangered according to the IUCN's Red List criteria (Collette et al., 2011). Since large predatory fish are particularly important for maintaining the structure of the ecosystem, reducing their stocks on a large scale has a massive impact (Bascompte et al., 2005) which can cascade down through the entire food web (Jensen et al., 2012; Frank et al., 2005) and trigger a further loss of biological diversity. This in turn poses a threat to ecosystem services (Estes et al., 2011; Worm et al., 2006).

The increase in fishing effort has already measurably changed the structure of pelagic ecosystems, leading to a shift in yields away from large predatory fish that live near the bottom of the sea (demersal fish) towards small fish that inhabit the water column (pelagic fish) and live off plankton (Pauly et al., 1998; Essington et al., 2006). In extreme cases, this can cause the entire ecosystem to tip into a new state, which can prevent a return to original productivity levels for a long time (Jensen et al., 2012; Frank et al., 2011). One example of the possible consequences is that some pelagic ecosystems are experiencing increasingly high concentrations of jellyfish (Richardson et al., 2012). In the context of the Anthropocene (Chapter 1), human interventions in the marine ecosystems by pelagic fisheries might be regarded as a worldwide 'experiment' whose individual ecological consequences are scarcely understood at present (Jackson, 2008; Jensen et al., 2012).

The fishing methods used have widely differing effects on ecosystems and their biological diversity. Fishing methods that are not very selective cause damage to ecosystems because of the unwanted bycatch of fish that are too small, species that are not targeted, benthic organisms, marine mammals (such as dolphins), turtles, seabirds and creatures threatened by extinction, many of which are thrown back overboard dead or fatally injured. Estimates of bycatch volumes are vague, ranging from 7.3 to 27.0 million tonnes a year; the trend is declining (Alverson et al., 1994; Kelleher, 2005; Zeller and Pauly, 2005). If bycatch is defined as 'unused or unmanaged catches' in the broadest sense, one global estimate by Davies et al. (2009) puts the volume as high as 38.5 million tonnes a year, or more than 40% of all wild-caught marine fish.

Furthermore, there are destructive methods – first and foremost bottom trawling – that can cause serious damage to marine habitats (Jennings and Kaiser, 1998). The increasing spread of deep-sea fishing, too, poses particular challenges for sustainability, as most deep-sea ecosystems are very sensitive and not very resilient: organisms in such ecosystems do not reproduce until late in life, so that great care must taken when fishing there (Ramirez-Llodra et al., 2011; Norse et al., 2012). Certainly, deep-sea fishing in its current form cannot be described as sustainable – a criticism that must equally be levelled at the EU (Davies et al., 2007; Villasante et al., 2012). Some destructive methods even go so far as to use poison or explosives in coral reefs, and both are still practised in Southeast Asia and East Africa (Burke et al., 2011:26; Figure 4.1-10). Furthermore, between one seventh and one third of the global fishing catch is the result of illegal, unreported and unregulated (IUU) fishing (Agnew et al., 2009; Section 4.1.4.5). Developing countries in particular lose yields of considerable value to illegal fishing in their EEZs. In sub-Saharan African countries, for example, total catches are roughly 40% higher than the reported figures (Agnew et al., 2009). It is not unusual for illegal fishing operations to utterly ignore sustainability considerations (Section 4.1.4.5).

Overall, therefore, a great deal of biological diversity is being lost as a result of current fishing practices, which also threaten or destroy marine ecosystem services (MA, 2005a). Not least, these practices leave marine ecosystems less resilient to global environmental changes such as climate change or acidification (Section 4.4). Yet many of these destructive methods can be made less harmful by technical improvements, or be prevented by rigorous implementation of existing regulations (Beddington et al., 2007; Section 4.1.3.4).

If destructive fishing methods are no longer used and sustainable management is introduced, fish stocks and marine ecosystems can recover (Worm et al., 2009). An increase of 8-40% in global yields is thought to be possible (Costello et al., 2012b). However, the amount of time required varies: some fish stocks (small, planktivorous species such as sardines and anchovies) can replenish their stocks in a short space of time, whereas large predatory fish and above all deep-sea fish take longer (MacKenzie et al., 2008). There are even examples where stocks have not recovered many years after a ban on fishing has been introduced, as in the case of cod stocks off the coast of Newfoundland, which collapsed due to mismanagement (Walters and Maguire, 1996). Similarly, where sensitive ecosystems like those in the deep sea are damaged, regeneration can be expected to take a very long time (MA, 2005a; Ramirez-Llodra et al., 2011). In many cases, however, after a temporary reduction in catch volumes while sustainable fisheries management is being introduced, just a few years later yields will be bigger than before (Worm et al., 2009; Froese and Quaas, 2013).

4.1.2.4
Small-scale marine fisheries in the global context

Since small-scale marine fisheries are especially important to food security in many developing countries (Section 4.1.2.1), this section examines the specific challenges facing this type of fishing.

Three factors distinguish small-scale fisheries in developing countries from industrial-scale fisheries: (1) the socioeconomic background of the fisherfolk (relatively low incomes); (2) the fisherfolk's skills (relatively little technology but a good command of their craft; boats usually under 12 m long); and (3) the great

	LARGE SCALE FISHERY	SMALL SCALE FISHERY
Subsidies	$$$$$ 25–27 billion US$	$ 5–7 billion US$
Number of fishers employed	about 0.5 million	about 12 million
Annual catch for human consumption	about 30 million t	about 30 million t
Annual catch reduced to fishmeal and oils	35 million t	Almost none
Annual fuel oil consumption	about 37 million	about 5 million t
Catch per tonne of fuel consumed	1–2 t	4–8 t
Fish and other sealife discarded at sea	8–20 million t	Very little

Figure 4.1-6
Comparison of large-scale industrial marine fisheries and small-scale fisheries. The numbers refer to the global level.
Source: Jacquet und Pauly, 2008

importance of fisheries for food and people's livelihoods in the respective region (FAO, 2012b; FAO and WFC, 2008; Figure 4.1-6). Since the methods used vary considerably from country to country, technology use alone does not constitute a suitable criterion for defining small-scale fisheries. For example, some small-scale fisherfolk use motorized, others non-motorized boats. Nor does small-scale fisheries necessarily imply a subsistence economy, as many operators produce their goods for regional, national and global markets (FAO and WFC, 2008).

Relevance to food security

Every year, small-scale marine fisheries catch more than 30 million tonnes of fish for human consumption (Jacquet and Pauly, 2008; Figure 4.1-6). Since most of these fisheries are located in regions where fish accounts for a large proportion of the local population's protein intake, they are extremely important to food security (Section 4.1.2.1). The employment figures are substantial as well: the number of small-scale marine fishermen is estimated at 12–14 million (Jacquet and Pauly, 2008:384; World Bank et al., 2010).

If the entire value chain from catching to consuming fish is taken into consideration, approximately 52 million employees worldwide – and 85% of all jobs in the marine fishing sector – depend directly on small-scale fisheries (World Bank et al., 2010). It is estimated that women, who are usually employed in fish processing, account for over a third of the total labour force in small-scale marine fisheries (World Bank et al., 2010). The Millennium Development Goals (MDGs) stress that the equality of women plays a pivotal role in the fight against poverty (UNGA, 2001). In the light of such high employment figures, small-scale fisheries thus also contributes to the realization of MDG 3 ('Promote gender equality and empower women').

Advantages over industrial fisheries

Comparative analyses show that subsidies for industrial fisheries (at US$25-27 billion per year) are four to five times higher than for small-scale fisheries (Figure 4.1-6; Jacquet and Pauly, 2008). On the other hand, 24 times as many people are employed in small-scale fisheries. Given that a large proportion of small-scale fisheries work close to the coast with boats that have little or no motorization, fuel consumption per harvesting unit is about four to five times higher in industrial fishing. While industrial fishing generates substantial bycatch volumes every year (Section 4.1.2.3), small-scale fisheries throw few fish back into the sea. In other words, small-scale fisheries work much more effectively; they are more labour-intensive but consume less energy. From a global perspective, small-scale marine fisheries operate more sustainably than industrial fisheries (Jacquet and Pauly, 2008), although this does not apply in every individual case. Small-scale fisheries, too, can engage in destructive practices (such as dynamite fishing), as a result of inadequately regulated collective actions, while overcapacity can lead to overfishing (Marí, 2012). The key question of whether a fisheries operation is sustainable cannot, therefore, be answered only by pointing to its size; it is also necessary to look at how usage is regulated.

Challenges

Small-scale marine fisheries are under huge pressure. Industrial fisheries, land-based pollution, climate change and discriminatory national and international trading policies are some of the most important aspects (Jacquet and Pauly, 2008). Further challenges arise from the fact that small-scale fisheries are entangled in all kinds of complex political and economic processes around the world. This situation was exacerbated, for example, by the relocation of fishing effort from industrialized countries to developing countries in the 1990s, with the result that international fishing fleets have since then also been decimating the stocks traditionally used by small-scale fisheries. Figure 4.1-7 shows how industrialized and newly industrializing countries have relocated fishing operations from their own EEZs to the territorial waters of developing countries as demand has risen and fish yields have fallen. The external dimension of the EU's Common Fisheries Policy (CFP) is an example of how developing countries have so far gained disproportionately few benefits from fisheries agreements with industrialized countries, and of how small-scale fisheries can be negatively influenced by industrial fishing operations. The EU is aware of this problem and has initiated an extensive process of reforming the external dimension of its CFP (Sections 4.1.4.6 and 7.4.1.7).

Small-scale marine fisheries can make a significant contribution to exports, generating 60% of Senegal's export volume, for example (World Bank et al., 2010). However, this requires a certain administrative and logistical infrastructure: e.g. access to markets, a knowledge of market demand, and cold chains in order to comply with quality standards. However, the regulatory frameworks (laws, administration and infrastructure) for fisheries management are inadequate in many developing countries (Alder and Sumaila, 2004; Worm et al., 2009; Section 4.1.3). Because of the heavy subsidies they receive, the EU's fleet can often sell fish on African markets more cheaply than small-scale local fisherfolk (Marí, 2012). Another rival to small-scale fisheries on local markets in Africa is the bycatch, which is sold by joint ventures (Ngembo, 2008).

Due to global and local entanglements, political strategies on small-scale fisheries face the challenge of having to be coordinated and implemented across many different levels. Because small-scale fisheries often have deep local and cultural roots, there is a need to developed suitably adapted solution strategies involving considerable responsibility and participation on the part of the local communities.

For many years fisheries management in developing countries followed the modernization paradigm. In the meantime, co-management has proved to be a successful principle (Kurien, 1998). In the context of fisheries, co-management involves partnership and collaboration between the state, civil society and private enterprise. Its primary goal is to achieve strong participation on the part of local communities, and reliable access rights for small-scale fisheries play a pivotal role in this context. This point is given special emphasis in the current draft of the FAO's guidelines for small-scale fisheries (Box 4.1-3; FAO, 2012a).

On the subject of incentive mechanisms in the fishing sector, rights-based approaches in particular, such as individual transferable quotas (ITQs), have attracted

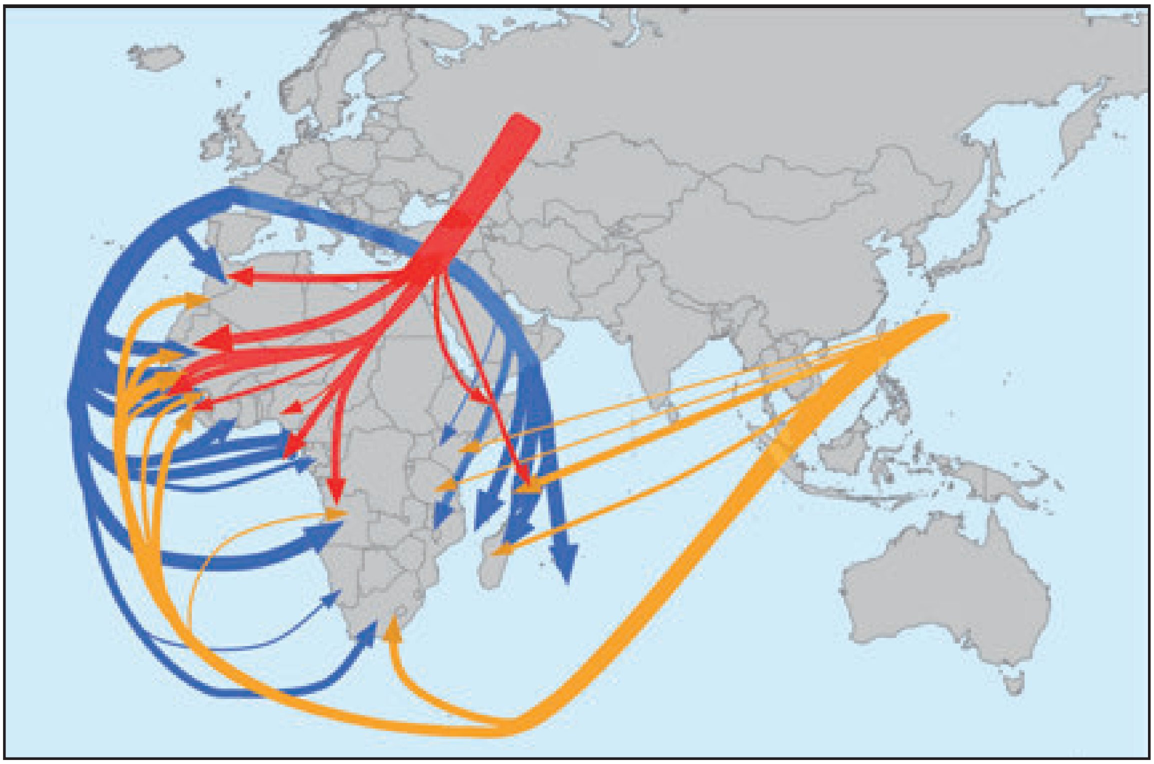


Figure 4.1-7
Relocation of fishing activities from industrialized nations to African countries during the 1990s (blue: from Western Europe; red: from Russia incl. the countries of the former Soviet Union; yellow: from Asia).
Source: based on Alder and Sumaila, 2004; Worm et al., 2009

a lot of attention (Cancino et al., 2007; Section 4.1.3.3). Rights-based approaches are controversial for small-scale fisheries, however. Together with many NGOs, Olivier de Schutter, UN Special Rapporteur on the Right to Food, believes that the rights-based approach runs the risk of edging out traditional fishing rights, thereby effectively encouraging 'ocean grabbing' by powerful companies (de Schutter, 2012b; UN, 2012b). As an alternative, de Schutter proposes setting up exclusive fishing zones that give small-scale fisherfolk privileged access. This kind of zoning could minimize competition between industrial and small-scale fisheries while prioritizing food security (UN, 2012b).

Territorial use rights in fisheries (TURFs), such as those set up in Chile (Cancino et al., 2007), illustrate how zoning can serve as an instrument to regulate small-scale marine fishing. TURFs have proved their worth in particular in the fight against illegal fishing and as a way to collect monitoring data (Hilborn and Hilborn, 2012:89). Over and above incentive mechanisms, good leaders and social capital in particular are crucial success factors (Gutiérrez et al., 2011). The participation of the local population is thus a fundamental prerequisite for sustainable small-scale fishing.

Other challenges for small-scale marine fishing include the systemic effects that result from interaction with land use (Box 4.1-4) or from climate change and pollution (Section 4.4).

Conclusions

It is difficult to overestimate the socioeconomic importance of small-scale fisheries in developing countries. Numerous examples show that global policies and business practices can have a negative impact on small-scale fisheries. Accordingly, action must be taken in many policy areas to ensure that small-scale fisheries can remain a key asset in the fight against poverty and for food security. In the process, different instruments will usually have to be combined to do justice to each specific local context. The WBGU's recommendations for action on this issue can be found in Section 7.4.1.8.

4.1.3 Sustainable fisheries management: methods and instruments

The situation of marine fisheries is extremely unsatisfactory (Section 4.1.1). Although considerable efforts have been made in some regions of the world, over-

Box 4.1-3

The FAO's guidelines for small-scale fisheries

Under the aegis of the FAO, the first draft of the International Guidelines for Securing Sustainable Small-Scale Fisheries was presented in May 2012 (FAO, 2012a). These guidelines should be seen as a supplement to the FAO's Code of Conduct for Responsible Fisheries (FAO, 1995). They aim to boost the contribution made by small-scale fisheries to poverty reduction, food security and economic growth. Numerous interest groups were consulted when the guidelines were being drawn up, including representatives of small-scale fishery associations, civil-society organizations and governments.

Part 1 of the guidelines outlines the general principles of small-scale fisheries. Part 2 discusses how small-scale fisheries can be integrated into various areas of political action – e.g. access to resources, social development, working conditions, value chains, gender issues, disaster risks and climate change. Part 3 spells out what is needed for implementation, above all with regard to policy coherence, research and monitoring.

Given that the socioeconomic importance of small-scale fisheries is systematically underestimated and given only weak political support, the WBGU believes this to be a valuable initiative on the part of the FAO. The guidelines provide a comprehensive framework with which to guide the actions of policymakers on the core issues of sustainable small-scale fisheries. Both the guidelines for small-scale fisheries and the FAO's Code of Conduct propose voluntary obligations. Accordingly, implementation will hinge largely on resolute action by national governments (Section 7.4.1.8).

fishing is still a major problem, and efforts to replenish stocks are not always successful (Beddington et al., 2007).

The following two sections begin by discussing approaches and instruments for sustainable fisheries management, before subsequently tackling the issue of international fisheries governance. The term 'governance', as used in Chapter 3, has a rather broad definition and also subsumes the concept of fisheries management, which is described here, in accordance with the FAO (1997a), as an integrated process whose purpose is to safeguard the permanent productivity of resources, among other things.

In its discussion of fisheries management, the WBGU concentrates first and foremost on the most important instruments and trends of the last few years. Due to higher-level considerations, some topics that are important in this context are dealt with at other points in the report. This is true, for example, of ecological certification, which is important as a supplementary instrument for placing commercial fisheries on a more sustainable and ecosystem-friendly footing (Worm et al., 2009; Gutiérrez et al., 2012). This question is discussed in Section 3.5.2. Marine spatial planning and marine protected areas – two further vital frameworks for the fishing sector – are discussed in Section 3.6.2.

4.1.3.1
Ecosystem approach and precautionary principle as the basis for sustainable fishing

The primary aim of classic fisheries management is to maximize the yield of individual target species. It pays little heed to trophic interactions or to the side effects of fisheries on ecosystems (Pikitch et al., 2004). Even the most frequently used indicator, the maximum sustainable yield (MSY; Box 4.1-5), relates to the respective, individual target species. The multi-species approach goes a step further, seeking to also make provision for the predator/prey relationships between different target species.

The ecosystem approach in fisheries goes far beyond merely analysing the target species and constitutes a paradigm shift for the fishing industry (Francis et al., 2007). It is posited on the understanding that marine ecosystems are complex systems which can, in some cases, be significantly influenced and damaged by fishing activities (Wolfrum and Fuchs, 2011; Section 4.1.2.3). In the context of sustainable development, the overriding goal of the ecosystem approach is to keep ecosystems healthy and working properly, so that both the present and future generations can benefit from their ecosystem services (FAO, 2003). It follows that the use of fish stocks, too, must be placed into the context of the ecosystem concerned (Pikitch et al., 2004). This is especially true where different target species are managed in one and the same ecosystem (Essington et al., 2006). Since social objectives often conflict with each other with regard to ecosystems, it is imperative to involve the relevant stakeholders in the management process (Cochrane and Garcia, 2009: 2).

Even though different terms are used ('ecosystem management', 'ecosystem-based management', 'ecosystem approach to fisheries') and there are no standard definitions, the ecosystem approach has achieved widespread recognition in the fisheries sector and serves as the basis for the management of marine ecosystems (Garcia et al., 2003). The Convention on Biological Diversity has coined the phrase 'ecosystem approach' and fleshed out its meaning (CBD, 2000, 2004c). In terms of content, the key international fisheries agreements over the past 20 years have also been built on this foundation. For example, the FAO Code of Conduct for Responsible Fisheries contains detailed stipulations on implementing the ecosystem approach

Box 4.1-4

Interaction between small-scale fisheries, land use and global economic processes in Ghana

A case study in Ghana illustrates the far-reaching indirect interactions linking small-scale fisheries both with land and ocean use and with local and global economic processes (Brashares et al., 2004). The analysis of a time series from 1970 to 1998 showed that, in years with low fish stocks, the density of 41 species of game in six nature-conservation areas near the coast declined dramatically. The latter phenomenon was caused by an increase in poaching: whenever the supply of fish ran low, the local population turned to other sources of protein, or compensated for the loss of income from the sale of fish by selling game products instead. The low fish stocks were caused by three main factors: (1) natural fluctuation; (2) population density in the coastal areas (more than half of Ghana's inhabitants live no more than 100 km from the coast); (3) the fishing activities of industrialized countries in Ghana's EEZ. Taken together, these three factors led to a threat to stocks of game in the nature-conservation areas studied. In effect, nature-conservation efforts on land were being undermined, at least partly, by the fisheries of industrialized countries.

This example illustrates, first, the direct importance of marine fish to food security in many developing countries; second, the direct effects that a shortage of marine fish resources can cause on the land; and third, the potentially far-reaching indirect consequences of industrial fishing activities for small-scale fisheries.

The study highlights the need for an integrated approach to fisheries management: the possibilities both on land and at sea must be taken into consideration to ensure an adequate supply of protein for the local population. Where there is overfishing, improving the land-based supply of protein could ease the pressure on this resource. Where game is hunted unsustainably, the potential afforded by fisheries and aquaculture must be carefully weighed up. Furthermore, the interactions between marine industrial fisheries and marine small-scale fisheries must be taken into account.

(Section 4.1.4.3), as does the UN Fish Stocks Agreement (Section 4.1.4.4).

One central aspect of the ecosystem approach is the application of the precautionary principle (Section 7.1.3; Pikitch et al., 2004), because decisions to implement sustainable fisheries management are often fraught with considerable uncertainties that can potentially conceal negative and irreversible consequences for fish stocks, ecosystems and people (FAO, 2010b). Fisheries operate within a complex, networked system of different aquatic ecosystems which are subject to constant change, due in part to substantial natural fluctuations, but also to human influence. To date, we have only a partial understanding of the overall complex of the many functions of the marine ecosystems, of anthropogenic effects and their potentially irreversible consequences (Section 3.1.1). The fisheries data are also often incomplete or not representative (Section 4.1.3.2). Precisely because of this complexity, the ecosystem approach can often only be implemented to a limited extent and only be introduced step by step.

It is therefore all the more important to follow the precautionary principle in sustainable fisheries management. Despite a lack of certainty about the nature, extent and probability of possible risks or irreversible damage, this principle seeks to facilitate prophylactic action so that such damage can be avoided in the first place by risk evaluation and suitable management measures (FAO, 1996). The importance of precautionary measures is all the greater, the less detailed the knowledge about ecosystem interactions is (Pikitch et al., 2004).

In practice, introducing an effective and sustainable system of fisheries management within the framework of an ecosystem approach involves severe challenges and can be a slow process at times (Garcia et al., 2003; Cochrane and Garcia, 2009). Apart from the lack of financial resources, institutional capacity and knowledge, implementation often runs into difficulties relating to the large number of stakeholders and their participation (FAO, 2003). In many areas, implementation of the ecosystem approach and the precautionary principle is still in its early stages. One study of 33 countries concluded that no country shows evidence of 'good' implementation overall. Only four countries were classed as 'adequate' while, in the view of the authors, more than half failed (Pitcher et al., 2008). Even though some developing countries scored higher marks than many industrialized countries, most of the former reveal serious weaknesses. There is therefore a need for capacity building in the context of development cooperation. Implementing the ecosystem approach also encounters particular difficulties regarding the management of fish stocks in the high seas (Section 4.1.4.4).

4.1.3.2
Knowledge-based fisheries management

Scientific monitoring, the modelling of stocks and a knowledge of ecosystem interactions (Beddington et al., 2007) form the basis of sustainable fisheries governance and effective management. This scientific basis is needed in order to assess the development of stocks and to define sustainable catch volumes (Section 4.1.3.3). Furthermore, measures such as setting up marine protected areas, the temporary closure of fish-

Box 4.1-5

What is sustainable fishery? The concept of maximum sustainable yield

The problem of overfishing can easily be explained by looking at the yield curve and the concept of 'maximum sustainable yield' (MSY), which is regarded as a key criterion for sustainable fishery. The yield curve (Figure 4.1-8) shows how catch volumes in a state of equilibrium (i.e. after many years of fishing) depend on the exploitation rate (the proportion of fish biomass removed from stocks each year).

On the left-hand side of the diagram (i.e. where the exploitation rate is low), the yield (total catch: blue curve) initially plots a steep growth trajectory as fishing activity increases. If catches continue to increase, the curve flattens, and even greater pressure from fishing ultimately causes the yield to decline, because ever fewer fish are there to be caught. The apex of this curve is the maximum sustainable yield – 'sustainable' in this case only in the sense that this yield can be repeated permanently, because this is the equilibrium state.

The diagram actually depicts the maximum multispecies sustainable yield (MMSY). In other words, it takes into account not just one species of fish, but a whole series of relevant species and their interactions. Although the basic concept of the yield curve can be readily understood when focusing on a single species of fish (MSY), the MMSY constitutes an important step forward because it accommodates the fact that some species serve as food for others and, hence, that catching such a species can negatively impact on the development of other fish stocks. The MMSY thus comes closer to an ecosystem approach to fisheries management. An unregulated fishery in which individual fishermen seek to maximize their individual yields will inevitably find its equilibrium far to the right of the MMSY, leading to the collapse of many fish stocks. Fishermen will continue to fish as long as their individual yield justifies the effort and expense they put in to it (Gordon, 1954; Box 4.1-9). However, what constitutes rational economic action for the individual is decidedly sub-optimal for long-term overall yields – a fundamental problem known in economic circles as the 'tragedy of the commons' (Hardin, 1968). In addition, the diagram shows the impact on the total biomass of stocks of all species of fish (green curve), the average maximum size of fish (yellow) and the number of collapsed fish stocks (red). Subsidies shift the point at which the effort and expense begins to be no longer worthwhile for the individual fisherman further to the right of the diagram. In other words, they lead to even more overfishing and even lower overall yields.

The economic optimum – i.e. the point at which the ratio of fishing effort to yield is optimized and returns are maximized – is a point to the left of the MMSY. It lies along the flatter part of the blue curve ahead before maximum – the marginal utility (extra yield) to be gained by increasing the fishing effort becomes very small as of this point. It is urgently recommended that fishing quotas be set well to the left of the MMSY, and not only for economic reasons:

1. Because of scientific uncertainties when putting a figure on the MMSY, a safety margin should be observed to avoid inadvertent overfishing with all the resultant negative economic and ecological consequences.
2. A low level of pressure from fishing is an essential precondition if stocks are to recover. Exploitation rates should therefore be significantly below the MMSY point, at least during the recovery phase.
3. Close to the MMSY the yield curve is flat. This means that sustainable yields scarcely decline even if the pressure from fishing operations eases. There is a broad arc of the curve in which yields exceed 90% of the maximum possible yield: in the example shown in the diagram this applies to exploitation rates of between about 25% and 60%. Between these points, however, the green and red curves are steep, meaning that utility – in the form of

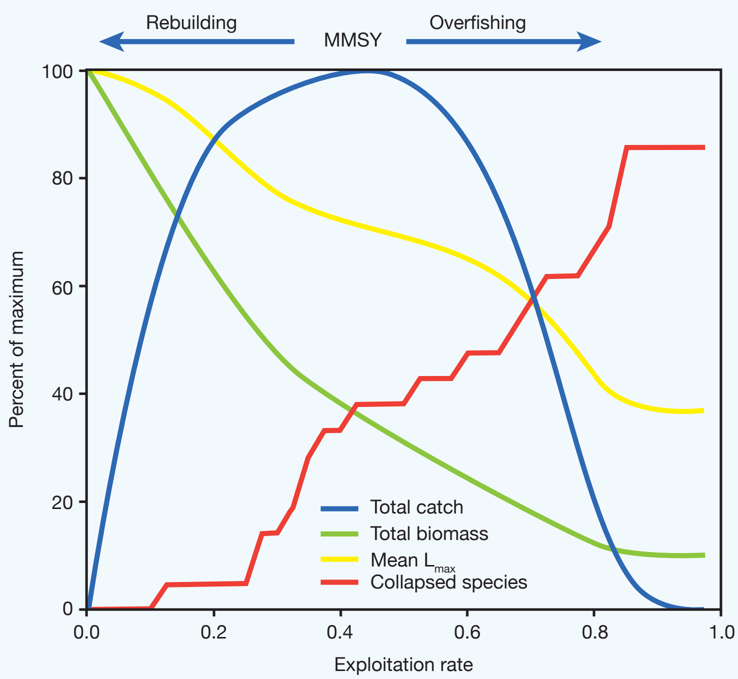


Figure 4.1-8
Impacts of increasing exploitation rates on catch volumes and fish stocks in a model fish community involving 21 species of fish, in this case in the Georges Banks. The exploitation rate is the percentage of the available fish biomass that is caught per year.
Source: Worm et al., 2009

significantly larger fish stocks – is very considerable even in the equilibrium state (after recovery). At a exploitation rate of 25%, virtually no fish stocks have collapsed, whereas half of stocks have collapsed at a exploitation rate of 60%, even though the yield differs only minimally between these two points (Worm et al., 2009). Ultimately, this is also the reason why the economic optimum lies to the left of the MMSY. In every respect it is better to catch a small percentage of a sizeable fish stock at low cost and effort than to invest a lot of money and effort in catching a high percentage of a decimated fish stock.
4. A lower fishing effort operating within larger stocks also reduces the damage done to the ecosystem, for example as a result of the bycatch of seabirds, turtles and marine mammals.
5. Larger stocks are more robust and offer secure yields, even under conditions such as climate change, ocean acidification and other stress factors.

Fisheries managers who think ahead will manage stocks in such a way that they remain on the left-hand (rising) side of the yield curve, rather than the unstable right-hand side, where yields are in decline and stocks threaten to collapse. A suitable instrument for achieving this goal is, for example, a system of fishing quotas that is based on scientific data (Section 4.1.3.3). Where sufficient data is not available, the fishing effort can be limited (e.g. by granting licenses only to a limited number of fishermen) and the development of yields can be monitored. Declining yields point to overfishing, to which an appropriate response could be to tighten the limitations imposed on the fishing effort.

eries, sustainable fishing methods, etc., also depend on a solid scientific basis.

Even so, only 7% of coastal states have so far built up this kind of solid scientific basis for sustainable fisheries management (Mora et al., 2009). In global terms, scientifically based estimates of MSYs simply do not exist for most stocks (Martell and Froese, 2012). The EU also still has a lot of catching up to do in this area: the data situation is inadequate on nearly two thirds of its stocks, especially on those that are of little commercial significance (EU Commission, 2012a). As a rule, industrialized countries have more capacity than developing countries for ensuring high-quality scientific assessment and advice (Worm and Branch, 2012). For this reason, developing countries in particular have a real need for methods to assess stocks and catch volumes which can function with small amounts of data. Initial approaches to estimating the MSY based on the normally available catch volume data have already been developed (Wetzel and Punt, 2011; Martell and Froese, 2012). However, there is disagreement in scientific circles as to whether catch volumes are suitable as a tool for estimating fish stocks (Pauly, 2013; Hilborn and Branch, 2013). Nevertheless, general rules for dealing with data-poor stocks can be derived. For example, where knowledge is lacking, it is especially important to apply the precautionary principle, i.e. it is expedient to add a generous safety margin when using rough estimates of the MSY (Pikitch et al., 2004; Punt et al., 2012).

Not least due to the growing pressure of demand on yields, it would appear necessary to increase developing countries' capacity to improve the scientific basis of fisheries management (Worm and Branch, 2012). Furthermore, improving the available basic data is of great importance to assessing the global situation of fisheries. The most important global pool of data on fisheries is maintained and regularly evaluated by the FAO (2012b). However, inadequate compliance with reporting duties on the part of FAO's member states gives reason to doubt the quality of this data. Over half of the data supplied by developing countries and a quarter of the data from industrialized countries is described as unsatisfactory (Garibaldi, 2012), leading to calls for improvement (Pauly and Froese, 2012). As a general rule, the transparency and accessibility of fisheries data must be ensured if scientists and NGOs are to be able to validate it.

4.1.3.3 Instruments for the sustainable management of fish-stocks

Once the stocks have been assessed in their ecological context on a scientific basis, the next step is scientifically-based policy advice, with the aim of developing concrete proposals to policymakers for measures and the application of relevant instruments to ensure a sustainable management of fish stocks.

One core problem, however, is that such scientific recommendations are not always implemented by governments. In particular, scientific recommendations on catch volumes are routinely ignored in many countries. In the EU, the recommendations of the International Council for the Exploration of the Sea (ICES) were exceeded for decades before efforts at reform began (Daw and Gray, 2005). Regional fisheries management organizations on the high seas (RFMOs; Section 4.1.4.4), too, experience similar difficulties in translating scientific recommendations into practical policies (Polacheck, 2012). In addition to scientific estimates, government agencies are exposed to all kinds of other factors and interests in the political arena, and, taken together, these tend to encourage overexploitation. By no means the least of these is the ongoing subsidies and the resultant overcapacity of fishing fleets (Section 4.1.4.7). Yet it is of critical importance to the sustainability of fisheries that scientific recommendations are implemented in practical policies in as undiluted a form as possible using a transparent and participatory process (e.g. definition of quotas, multi-year management plans; Mora et al., 2009).

Of the many instruments for regulating fishing activities, only the most important ones can be cited here. The FAO recommends recording the status, objectives, instruments, rules and players in a fisheries-management plan (FAO, 1997a). Such a plan should have a long-term orientation, but should also be regularly adapted to changing conditions of the fishery sector. These management plans are regarded as one of the most important cross-cutting tools in fisheries management within the framework of the ecosystem approach (Cochrane and Garcia, 2009). Case studies show that sustainable fisheries management is possible in principle in both industrialized and developing countries (Box 4.1-6, 4.1-7).

Catch limitations

Defining a sustainable total allowable catch (TAC) for a given fish stock lays the basis for the definition of quotas. In line with international objectives, the maximum sustainable yield (MSY; Box 4.1-5; Section 4.1.4.1) should be chosen as the basis for the TAC, although it is advisable to add a safety margin on top (Box 4.1-5; Worm et al., 2009; Froese et al., 2011). Long-term management plans are regarded as a suitable tool primarily for replenishing exhausted stocks, with defined annual TACs being allowed to fluctuate only within defined corridors. The TACs are also intended to serve the objectives of the plans (SRU, 2011a).

In the simplest cases a total quota is defined for all stakeholders. This approach is problematic because it encourages the individual fishermen to compete with each other in a 'race to fish' in order to fully exploit the entire quota as quickly and effectively as possible (Grafton et al., 2006) and thus maximize their own share of the TAC. It also creates an incentive to build up overcapacity (Eikeset et al., 2011). In addition to total catch volumes, minimum landing sizes are also frequently defined for fish.

The practice of splitting the TAC into individual quotas for the individual players (e.g. fishermen, boats, cooperatives) and, in particular, into individual transferable quotas (ITQs) is intended to avoid this problem by creating an incentive for fishermen to support the lasting protection of stocks in order to increase their future yields. An analysis of fisheries statistics in more than 11,000 fishing zones found that introducing ITQs greatly reduced the probability of the fish stocks collapsing (Costello et al., 2008). The conditions that must be met if ITQs are to be applied successfully are tough, however: not only is an in-depth knowledge of stocks and ecosystems required, as with quota regulations in general, sufficient institutional capacity is also needed to allocate the quotas and monitor compliance (Mora et al., 2009; Essington et al., 2012).

ITQs are by no means exempt from criticism, and they are certainly not a panacea for sustainable fishing (Bromley, 2009; Essington, 2010). Although introducing them may reduce fluctuations in yields, it seems to have little influence on overexploitation and the biomass of stocks (Melnychuk et al., 2012; Essington et al., 2012). The problems include the initial allocation or regular auctioning of quotas, the duration of rights of use (Costello and Kaffine, 2008), and the risk that quotas will become concentrated in the hands of just a small number of players over the years (Roberts, 2012: 280). The latter threat can be prevented by limiting the maximum share for any individual player, or by reserving certain contingents for certain players, such as small-scale fisheries (Section 4.1.2.4; International Sustainability Unit, 2012). Either way, additional regulations over and above ITQs are always needed as part of an ecosystem approach in order to minimize the risks and side-effects of fishing activities for the marine ecosystems (e.g. bycatch and habitat destruction; Section 4.1.3.5).

Transferable quotas are a useful option in developed regions with a large proportion of technologically advanced or industrial fisheries and in areas where primarily one target species is fished (Costello et al., 2012b). At present, less than 3% of the total value of all catches worldwide are managed using ITQs (e.g. in New Zealand, Australia, the USA, Iceland, Chile and Peru). However, there is potential for ITQs to be used effectively in about half of all EEZs (Diekert et al., 2010; Figure 4.1-9).

Multi-year management plans aim to help avoid the annual political quota-fixing negotiations and to improve the implementation of scientific recommendations in practised policy. For European fishing activities, Froese et al. (2011) have recommended 'harvest control rules': based on the MSY and adding a safety margin of 30% relative to the stock size, these rules can provide a simple way of defining permitted annual catch volumes. The regulations would then only have to be reviewed every few years.

Regulations governing fishing effort and fishing techniques

Fishing quotas regulate fisheries' yields directly by stipulating the volumes that may be caught ('output regulation'). Conversely, input regulations focus on the actual fishing effort, i.e. the methods used to catch fish. Examples include the number of days on which

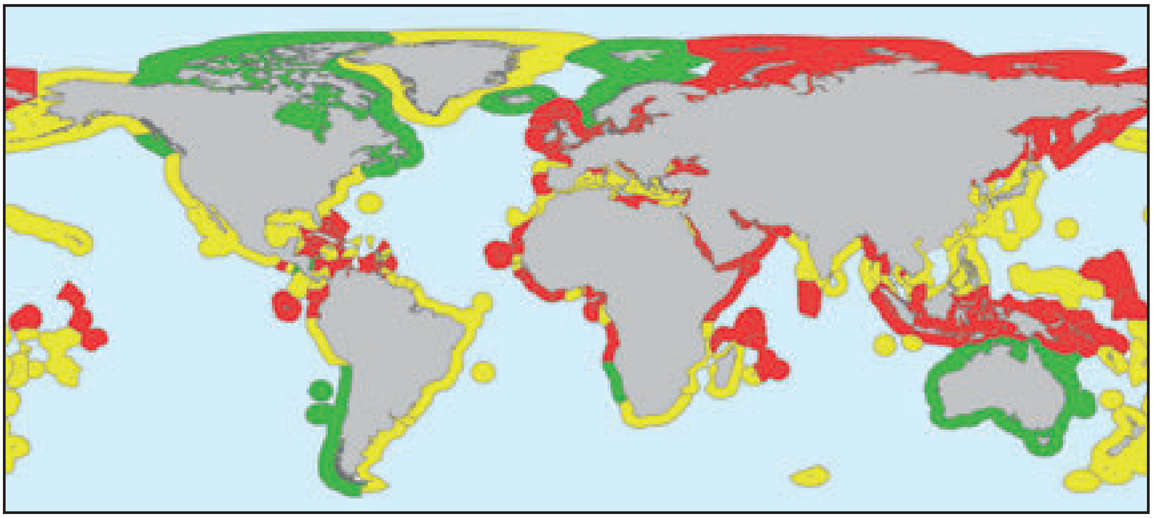


Figure 4.1-9
Cartographic depiction of the EEZs in which catch shares (or individual transferable quotas) are currently used for fisheries (green), those in which they potentially could be used (yellow), and those where use appears difficult, since the necessary political and institutional conditions are not met (red).
Source: Diekert et al., 2010, modified

fishing is permitted, closed seasons during which fishing is prohibited, and the number, size or equipment of boats or their fishing gear (e.g. the mesh size used in nets). These rules are much simpler to formulate and monitor and are therefore advantageous in complex situations, e.g. where several species and ecosystems are affected and adequate knowledge is not available (Eikeset et al., 2011). The downside is that the effects on catch volumes and stocks are difficult to estimate, one reason being that there is an incentive for fisherfolk to improve fishing efficiency within the existing system of regulations. The study by Melnychuk et al. (2012) shows that, compared to quotas, input regulation achieves poorer results in terms of avoiding overfishing. As a rule, therefore, knowledge-based output regulation should be preferred (SRU, 2011a).

From a global perspective and also in many regions, fishing-fleet overcapacity is regarded as one of the main drivers of overfishing. Subsidies for the fishing industry play a major role in fuelling such overcapacity (Section 4.1.2.2). The World Bank and the FAO (2009) estimate that today's yields could be caught with half of the current fishing effort. They therefore argue that subsidies should be phased out. The overall context and the links between these issues are explored in greater detail in Section 4.1.4.7. To reduce overcapacity, 'buy-back programmes' are being operated that give fishermen a certain sum of money for every vessel or item of fishing gear that is retired from service, as well as for terminated licenses (Eikeset et al., 2011: 200). From a global perspective, the aim is to avoid having these boats and this equipment sold abroad where they might further aggravate the problem of overfishing (Worm et al., 2009), or to ensure that premiums are used to modernize the fleet (resulting in fewer, more effective vessels). Buy-back programmes are regarded as comparatively expensive and their impact is disputed. They seem to be most effective in areas where the number of vessels and fishing licenses is readily manageable (Eikeset et al., 2011).

Participatory approaches to fisheries management

The policy of quotas being set by central government agencies which the actors concerned often perceive as 'far removed' and as 'outsiders' runs the risk of cultivating inner resistance to 'imposed' regulations among the fisherfolk affected by them (Eikeset et al., 2011). It therefore makes sense for the relevant stakeholders to participate in all decision-making processes when new regulations are introduced (Ostrom, 2009a). Stakeholders are defined here as individuals or groups who have a claim on the fish stocks or an interest in fisheries management (Berkes, 2009: 65).

Participation requires trust-based cooperation between fishery managers and fisherfolk. While not always easy to organize, such cooperation is today widely regarded as a key success factor for sustainable fisheries (Cochrane and Garcia, 2009: 7).

Distinctions are drawn between several different participatory approaches: co-management, community-based management (CBM) and territorial use rights in fisheries (TURFs). Co-management is the term used to describe the sharing of decision-making power and responsibility between government agencies, local

Box 4.1-6

Case study in sustainable fisheries I – Australia

Australia's fisheries stand out for the especially sustainable way in which they manage their fish stocks. The number of stocks classed as 'not overfished' has tripled since 2004 (Wilson et al., 2010). Australia landed around 170,000 tonnes of fish in 2010 (FAO, 2012g). Average annual imports of fish products totalled over 400,000 tonnes between 2005 and 2007, while about 70,000 tonnes were exported during the same period. Australia's per-capita consumption of fish, at 26 kg per year, puts the country slightly below the average for industrialized nations of 29 kg per year (FAO, 2012g). Around 80 % of the economic value generated originates from waters under national or regional regulatory control (DAFF, 2005).

National measures are decided on the basis of risk assessments in order to comply with the FAO's Code of Conduct for Responsible Fisheries (DAFF, 2005). While many regulations have been recently passed and follow the FAO's resolutions, deep-sea fishing was banned off parts of the west coast as early as the 1970s and 1980s (Fletcher et al., 2011), indicating that Australia historically has a deep-seated awareness of the ecological value of its territorial waters. The world's biggest no-take zone has been set up in the Great Barrier Reef world heritage site (Section 3.6.2.1). Australia also aims to maximize the profits of successful fisheries management for its population and to optimize its management of living resources. To this end, a series of management instruments, such as quota systems and access restrictions, are used to keep fish stocks at a sustainable level, protect the relevant ecosystems, and ensure compliance with the principles of sustainable development (AFMA, undated).

The ecosystem approach was adopted for a single region (on the west coast) in a pilot study and operationalized in close cooperation with representatives of all the relevant sectors. Successful implementation led to application of the ecosystem approach, subject to provisions for specific regional considerations, along the entire coast of Western Australia (Fletcher et al., 2011).

One significant factor in the success of Australia's fisheries management to date is seen to be the fact that existing regulations are backed by the force of law under the Fisheries Management Act of 1991 and the Torres Strait Fisheries Act of 1984. The Australian Fisheries Management Authority (AFMA) was established in 1992 as a division of the Department of Agriculture, Fisheries and Forestry specifically for this purpose. Besides enforcing national guidelines, the AFMA also oversees compliance with existing international treaties that are relevant to Australian fisheries. Fishing licenses are granted by the AFMA and renewed annually. The authority is also responsible for collecting data on yields and the fishing effort.

Special attention is paid to fighting IUU fishing activities (Section 4.1.4.5), both within Australian waters and in adjacent regions of the high seas that are regulated by corresponding RFMOs. An Australian action plan was adopted in 2005 to implement the FAO's action plan against IUU fishing (FAO, 2001). This national plan involves monitoring vessels that fish under the Australian flag but outside the country's national waters, and close cooperation with neighbouring countries such as Papua New Guinea and France regarding the Sub-Antarctic region (DAFF, 2005).

Instruments to ensure effective enforcement include training courses for fishermen, the participation of decision makers in developing management rules, a monitoring system, a comprehensive reporting system for landed catches, and the extensive and constant deployment of local patrols. Vessel monitoring systems (VMS) are widely used and allow the positions of fishing boats to be tracked. A broad list of sanctions has been defined, ranging from reminders to fines to license withdrawal and criminal prosecution. Moreover, the officials responsible are authorized to halt fishing activities, board vessels for inspection and have them towed away if they are discovered to be violating the rules (AFMA, 2010).

According to their own information, 'Management Advisory Committees' play a major role in successfully enforcing existing guidelines under the AFMA (undated). These committees comprise representatives of the fishing industry, fisheries management, the scientific community, environmental associations and, in some cases, the government. They provide a forum where the interests of individual stakeholders are represented. They also increase the likelihood of acceptance of the guidelines to be enforced.

users and other stakeholders acting as partners in fisheries management. Ideally, the institutional structure enables an adaptive approach (Section 3.2.4.3) to co-management, so that the use of experimental approaches can constantly generate new knowledge in the course of management (Armitage et al., 2009; Berkes, 2009:65). In view of global environmental changes and the resultant need for greater resilience, adaptive co-management is an important approach to dealing with uncertainties and responding to new situations (Daw et al., 2009). However, it requires close collaboration between administrators and scientific institutions (Eikeset et al., 2011).

Community-based management (CBM) goes one step further and leaves the process to the stakeholders for them to organize it themselves. This approach can be very successful, especially at the local level in smaller communities whose members have tightly knit relationships and where social control helps ensure that jointly agreed rules are enforced (Andrew and Evans, 2011). TURFs are an instrument that can be used to grant use rights to individuals or groups in geographically delimited areas with the result that, as with CBM, self-organization on the part of the users becomes possible (Charles, 2009). Like CBM, TURFs are especially well suited to small, clearly delimited fishing grounds in coastal areas that have local (i.e. non-migratory) fish stocks (Eikeset et al., 2011; International Sustainability Unit, 2012).

According to Ostrom (2009a), self-organization scenarios are more likely to succeed in relatively small communities where the fisherfolk have already noticed that

Box 4.1-7

Case study in sustainable fisheries II – Namibia

Among the developing countries, Namibia is regarded as a successful model of sustainable fishing. Between 2005 and 2007 its annual catches averaged just under 500,000 tonnes, of which nearly 400,000 tonnes was exported. Imports totalled a little over 20,000 tonnes (FAO, 2012g). The high export rate makes fisheries a major source of income for the country. In 1998 revenues from fisheries accounted for around 10% of GDP, although this proportion fell to 6% in 2005 as a result of restrictions on permitted fishing quotas (FAO, 2012f). Even so, an average of 30% of total export revenue is attributable to fishing (World Bank, 2009). Per-capita consumption averages 13.3 kg per year (FAO, 2012g).

To maximize income from fisheries, domestic capacity for processing fish products has been ramped up since Namibia gained independence in 1990. A large proportion of value creation now takes place within the country's own borders. This process has become known as the 'Namibianization' of the fishing industry and is accompanied by targeted trainee programmes designed to improve competitiveness relative to foreign fleets (TEN, 2012).

Before Namibia's independence in 1990, its territorial waters were supervised by the International Commission for the South-East Atlantic Fisheries (ICSEAF). However, yield data recorded by ICSEAF in the 1970s and 1980s are regarded as unreliable, since no controls were carried out and politically motivated disinformation is suspected (Hampton, 2003). Even so, the data do trace a sharp decline above all in hake and lobster yields between 1960 and 1980, which is attributable to overfishing of these stocks (Hampton, 2003). Generally speaking, stocks in Namibia's territorial waters are believed to have been heavily overfished prior to independence (FAO, 2012f).

The Namibian EEZ was proclaimed in the wake of independence in 1990, and a comprehensive system of fisheries management was set up on the basis of scientific appraisals (World Bank, 2009). At present, fisheries management is under the jurisdiction of the Ministry of Fisheries and Marine Resources (MFMR), which was set up in 1991 and is advised by the Ministry's National Marine Information and Research Centre (NatMIRC; UNEP). A White Policy Paper Towards Responsible Development of the Fisheries Sector, published in 1992, defined long-term objectives for the sustainable use of fish stocks, ultimately leading to the Sea Fisheries Act of 1992. Following a revision of this act, fisheries are now legally regulated by the Marine Fisheries Act of 2010. Successes have already been recorded: fishing yields have increased by 40% since the 1990s.

The principal management instrument is the granting of fishing rights based on a quota system for the most heavily fished stocks, which limits the catch volume each year (TAC). A charge is made for fishing quotas, so that free access to this general resource is no longer given. The quotas are sold exclusively to licensed fishermen who have a 'right of exploitation'. These licenses are granted for periods of 7 to 20 years, one of the criteria being the nationality of the applicant. At present, about 80% of the vessels that fish in Namibia's EEZ sail under the Namibian flag (FAO, 2012f). Other stocks are also controlled via these licenses, as well as by limits to the fishing season and a restriction on permitted bycatch. A charge is levied in the latter case (FAO, 2012f). The quotas are not transferable – a decision designed both to combat the centralization of the industry and to further encourage its 'Namibianization' (Huggings, 2011).

Clearly defined access rights and effective enforcement of regulations backed by law are cited as the reasons for successful fisheries management under which fishing quotas are complied with. Legal backing for the current regulations is attributable in particular to a strong political will which, in the years following the declaration of independence, primarily targeted the Spanish fishing fleet, which used to fish without licences in Namibian waters (World Bank, 2009). When the government instructed the estimated 100 vessels that were fishing illegally in Namibian waters to leave, it still had no means to monitor compliance. The government therefore chartered a private helicopter in order to arrest Spanish fishermen and take them to court (Huggings, 2011). Today, enforcement is assured by the presence of observers on all major fishing vessels. These observers are also responsible for gathering data and are funded by compulsory contributions from the fishing industry (World Bank, 2009). In addition, the MFMR has two patrol ships and one patrol aircraft (FAO, 2012b). VMS systems were recently installed. A large proportion of the fisheries-management effort is paid for out of tax revenues from fisheries and additional compulsory contributions.

Other favourable factors include the topography of the country and, linked to this, the comparative lack of a fishing tradition in Namibia. The country has only two ports, and the coast borders directly on the desert. When independence was declared, therefore, there were very few fishermen, and the number of vessels to be regulated was manageable, as were the landing points for catches (World Bank, 2009). Furthermore, there were no interest groups that could have presented an obstacle (Huggings, 2011). Heavy government control with the aim of 'Namibianizing' the industry is criticized in some quarters, as it potentially does not choose the optimal form of distribution in economic terms (Huggings, 2011).

the resource on which they are economically dependent is beginning to become scarce. It is also helpful if individual stakeholders in the community can assume a leadership function and if the community can determine its own rules. Similarly, the existence of social norms of cooperation, reciprocity and fairness simplify the process of self-organization.

Participatory approaches have proved their worth in small-scale fisheries in particular (Section 4.1.2.4; Cinner et al., 2012; Gutiérrez et al., 2011). Yet it is believed that the ecosystem approach could also be implemented in the USA if decentralized governance were to be introduced together with co-management and greater participation (da Silva and Kitts, 2006). Positive experience has been gained with TURFs in Vietnam and Chile, for example (International Sustainability Unit, 2012). Costello et al. (2012b) conclude that TURFs, fishing cooperatives and co-management approaches – in conjunction with no-take zones – are probably more suitable instruments than quota systems for data-poor stocks in developing countries. Small-scale marine fishing in developing countries is discussed in greater detail in Section 4.1.2.4.

4.1.3.4 Minimizing the ecological risks and side effects of fisheries

Marine protected areas as an instrument of sustainable fisheries

Marine protected areas (MPAs) are one of the most important instruments of marine ecosystem conservation and should be used within the framework of marine spatial planning. Both instruments are outlined in context in Section 3.6.2. At this point in the report, the focus is solely on the importance for fishing of no-take zones (NTZs), which represent exceptions even in marine protected areas. In most MPAs fishing is permitted within prescribed rules, and sometimes corresponding restrictions and bans are hardly enforced. NTZs are not only of crucial significance to the conservation of biological diversity, they can also serve as an instrument of fisheries management under certain circumstances (Gell and Roberts, 2003). Given suitable planning and implementation, NTZs can create areas of refuge that give overfished stocks a chance to regenerate. Not only can greater amounts of fish biomass build up in these zones, stocks there contain a greater number of large fish which can produce proportionally more offspring than smaller specimens (Lester et al., 2009; Francis et al., 2007). In this way, adjacent fishing areas can be supplied with migrating fish and larvae, although these effects are not always easy to prove (Pelc et al., 2010; coral reefs: Harrison et al., 2012).

The impact of NTZs depends on the ecological situation. In the case of highly migratory fish stocks that can be caught with little bycatch or other ecosystem damage, they have only a very limited effect. In the case of multi-species fisheries targeting fish that tend to stay in one place (e.g. on reefs: Jeffrey et al., 2012), involving a lot of bycatch and using fishing methods that have harmful side-effects (e.g. bottom trawling), NTZs offer considerable advantages for the protection of ecosystems and, given suitable planning, also for fisheries. Careful planning and adaptive management are necessary if the potential of NTZ is to be fully exploited (Hilborn et al., 2004). The positive effects on fishing can be improved if the NTZs are of an appropriate size and if they are intelligently integrated into networks of marine protected areas (Gaines et al., 2010; Halpern et al., 2010). Merely designating NTZs is not enough on its own, however. This should always be done in combination with complementary instruments of fisheries management (Section 4.1.3.3; WBGU, 2006). The fish biomass within protected areas is usually larger and offers tempting incentives for illegal fishing activities, which can jeopardize the positive effects. Monitoring and compliance enforcement are therefore of crucial importance if NTZs are to be effective (Lester et al., 2009; Section 4.1.3.5).

Avoiding unwanted bycatch

As a rule, fisheries do not only catch selected specimens of the desired targeted species, but also other organisms which accidently get caught in nets or on hooks (such as target specimens that are too small to keep, other species of fish, benthic organisms, marine mammals, turtles and seabirds; Section 4.1.2.3). In many regions, including the EU at present, this ‘bycatch’ is thrown overboard dead or dying (Kelleher, 2005); it is regarded as a major driver of marine biodiversity loss and should be avoided wherever possible within the framework of an ecosystem approach (Section 4.1.3.1). Fishing gear even continues catching organisms after it has been lost or discarded – for example when nets are left drifting in the sea (ghost fishing; FAO, 2005b).

Mortality as a result of bycatch can also have a significant influence on estimates of stocks. However, this data can only be incorporated into the models if the bycatch is registered. That is why monitoring the bycatch is another essential measure.

In many fisheries, the bycatch can be reduced relatively easily by technical methods – by following certain practices or avoiding certain regions or seasons. It cannot be avoided altogether, however (Bjordal, 2009: 184 ff.). Long-line fishing in Antarctic waters is an example of a special success story: thanks to regulations adopted by CCAMLR, the regional fisheries management organization responsible in these waters, technical measures have made it possible to reduce bycatch of albatrosses by more than 99% (Small, 2005). The promotion and compulsory introduction of selective, ecosystem-friendly fishing gear is essential if unwanted bycatch is to be avoided.

In Norway, the bycatch must be landed and offset against fishing quotas. The same solution has also been proposed in the EU as part of the fisheries reform (Section 7.4.1.7). Such a system could give fishermen an incentive to optimize their fishing practices and equipment with the aim of reducing the amount of unwanted biomass they catch in their nets. As well as minimizing bycatch, this management measure can improve control over (and data on) overall mortality and the state of fish stocks (BfN, 2009). The German Advisory Council on the Environment (SRU, 2011a: 23) recommends introducing a general ban on discards for all fish species in the EU.

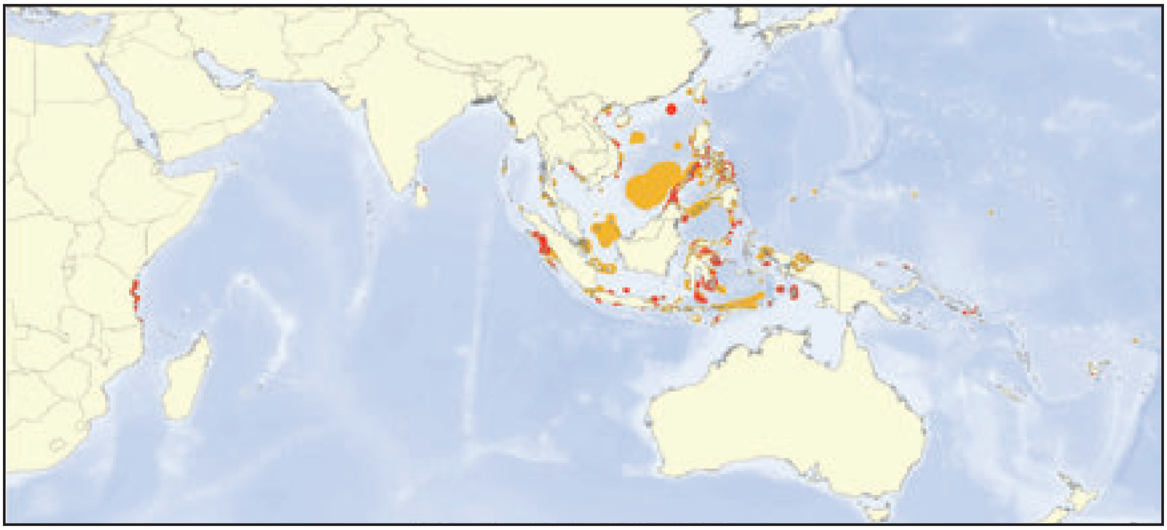


Figure 4.1-10
Global observations of blast and poison fishing. The areas of threat shown are based on survey observations and expert opinion. Yellow: moderate; red: severe.
Source: Burke et al., 2011

Bans on destructive and wasteful fishing methods

Destructive fishing methods that threaten to do serious or irreversible damage to marine ecosystems should be prohibited, and such bans should be strictly enforced (BfN, 2009). This applies above all to destructive fishing using dynamite or poison which, despite extensive bans, is still practised in some regions (Burke et al., 2011; Ferse et al., 2012; Figure 4.1-10). Fishing – especially using heavy bottom-trawl nets – can cause extensive damage to the seabed, the habitat structures it contains, and their biotic communities (Puig et al., 2012). Yet this method is still used even in sensitive ecosystems like rocky seabeds and reefs. Less damaging methods (pulse fishing) are already being tested (SRU, 2011a), and the use of passive methods (traps) with much less harmful effects offers interesting alternatives. The impact of destructive fishing methods on the deep sea (e.g. on cold-water corals and seamounts; Ramirez-Llodra et al., 2011) is described in Section 4.1.2.3.

One example of a particularly wasteful fishing method is shark finning, in which only the fish's fins are used (to make soup) and the dying body is often thrown overboard (Lack and Sant, 2006). This is one reason why sharks are regarded as particularly endangered (Section 4.1.2.3). Second only to Indonesia, the EU (above all Spain) catches the most sharks and is the biggest exporter of shark fins to Hong Kong and China. Existing legal loopholes in the European fishing industry must therefore be closed as a matter of urgency (Fowler and Séret, 2010).

4.1.3.5
Monitoring and enforcement

Section 3.7 noted that the failure to enforce existing agreements was a core problem that could be found in all areas of ocean governance. Especially the monitoring, control and surveillance (MCS) of fisheries (Berg and Davies, 2011) is a huge challenge in view of the vast expanse of the oceans and the fact that fisherfolk often operate in isolation, yet have a global reach.

Where there is a sufficiently strong social network between fisherfolk, compliance with regulations can often be ensured on the basis of social control, so that fisherfolk keep to the rules voluntarily. This condition is met above all in small-scale fisheries. If the stakeholders consider the rules, monitoring and enforcement of fisheries management to be fair and acceptable, this will make it easier to enforce these rules effectively in practice (Berg and Davies, 2011). In developing countries, where small-scale fisheries predominate, monitoring and enforcement faces different challenges to those in industrialized countries. This is partly because there is less technical and financial capacity available, but partly also because the number of stakeholders is larger and the level of organization higher. Participatory approaches are of great importance in this context. Section 4.1.2.4 examines the issue of small-scale fisheries in greater detail.

In industrial fisheries, the use of classic surveillance instruments will more often be successful. Table 4.1-1 provides an overview of the most important instruments, what they cost, and what their comparative advantages and disadvantages are. Monitoring and

Table 4.1-1
Examples of instruments used to monitor fishing activities.
*Vessel monitoring systems (VMS) are electronic devices which can communicate the location, direction and speed of a vessel to the supervisory authorities in real time.
Source: based on Berg and Davies (2011), modified and supplemented

Timing of measure	Instrument	Advantages	Disadvantages	Costs
Before fishing	Licenses for fishermen, monitoring of boats and fishing gear	Make it easier to check compliance with regulations	Illegal gear can be hidden	Low
During fishing	Inspection of logbooks	Supplies valuable data	Not all fishermen in all countries can read/ write; logbooks can be forged	Low
	Supervision of fisheries using vessels	Enables verification and the imposition of sanctions at sea	Limited range/coverage	High
	Use of aircraft and helicopters	Covers wide areas	No monitoring of catches or gear; no way of imposing sanctions at sea	High
	Observers on board	Can monitor all activities at sea; supply reliable data (including catches and discards)	Only possible on large vessels	Moderate
	Cameras on board	Monitor catches and discards	Only limited monitoring possible	Low/moderate
	VMS*	Can monitor vessels in real time	Not all vessels have VMS installed; risk of forgery	Low/moderate
	Satellite imaging	Can cover the entire area	Regular use and analysis is expensive; validation is needed	Low/moderate
	Coastguard, navy	Can take on relevant duties at no extra cost in some cases; can monitor national borders	Only limited availability and knowledge	High
During landing	Inspectors monitor catches when they are landed or transshipped; plausibility checks	Can check compliance with quotas and even make arrests in ports	Transshipment at sea is difficult to monitor; no monitoring of discards	Low
After landing	Monitoring of the market and sales (e.g. mean size)	Good source of information on landed volumes and demand	Origins of a catch are difficult to verify	Low
	Monitoring of exports and/or transportation	Good source of information about landed volumes in high-priced fisheries	Only parts of catches are exported	Low

enforcement are particularly necessary to curb the widespread activities of IUU fishing (Section 4.1.4.5).

Incentives encouraging illegal practices are highly dependent on the quality of enforcement and sanctions. The severity of fines, confiscation of vessels and nets, and loss of licenses are of critical importance: refusing to comply with the rules must not be allowed to pay off economically (FAO, 1995: para. 7.7.2).

4.1.3.6 Costs and financing the transition towards sustainable fisheries

According to the UNEP (2011b), one-off investments totalling at least US$ 190-280 billion would be needed to establish sustainable fisheries management worldwide and increase global yields from 80 to 90 million tonnes by 2050. These estimates take account of factors such as a reduction in the global fishing-fleet capacity via buy-back programmes, compensation payments for, and retraining of, fisherfolk, general management costs and research efforts. In addition, the running costs of fisheries management (including the introduction and management of quota systems, networks of marine protected areas, monitoring and control programmes) would have to be increased by 25% (from US$8 billion to US$10 billion worldwide per annum) to secure sustainable fishing in the long term. However, it is estimated that redesigning the fishing sector in this way will yield benefits that are three to five times the cost of the necessary initial investment at current prices (UNEP, 2011b).

Levying user charges (e.g. for fishing licenses, catch fees, bycatch taxes and port charges) could create selective incentives for a reorientation of management towards sustainability. A system of bonuses and penalties could further reinforce these incentives: e.g. user charges could be reduced for fisheries or aquaculture operations that are operated in a verifiably sustainable way. Conversely, where sustainability rules are violated, the perpetrator could be required to pay some form of 'punitive duty'. Furthermore, the granting of access rights to certain fishing grounds could be linked to conditions such as the use of sustainable fishing gear or low-carbon fuels, for example. Giving the fishing sector a sustainable and long-term focus may temporarily involve lower revenues. Government instruments and financial assistance would therefore make sense to cushion the transition towards sustainable fisheries management:

- *Payments for ecosystem services (PES):* Good experience has already been gained with this instrument in the field of forest conservation and the management of water catchment areas (Pagiola et al., 2002). In the context of sustainable fisheries, too, PES could be introduced to encourage fisherfolk to use sustainable fishing methods or avoid fishing in certain areas or at certain times (e.g. in marine protected areas or during closed seasons; Mohammed, 2012; Niesten and Gjertsen, 2010). One example is the Defeso programme in Brazil, where fisherfolk receive compensation during seasonal bans on fishing. To avoid abuse, PES payments should be linked to conditions that are easy to monitor, and be limited to a small group of users (Wunder, 2005). The conservation services provided by the recipients of PES should be continuously monitored, with payments being linked to the success of these services (Niesten and Gjertsen, 2010).
- *Compensation payments:* The primary purpose of paying compensation for the non-use of marine resources is to share burdens. Unlike PES, compensation payments are limited to a specific period. Their aim is to cushion one-off, temporary social hardships resulting, for example, from the designation of a protected area or cuts in fishing quotas in certain fishing grounds (e.g. compensation and retraining of employees in directly affected or downstream industries, offers of social welfare services, advisory services, buy-back programmes for fishing licenses, boats or fishing gear, etc.). It is important to ensure that the catch volume and the fishing effort as a whole are limited by regulation and that the withdrawn licences, boats and fishing gear are not simply replaced by new ones (Niesten and Gjertsen, 2010). When rezoning the Great Barrier Reef Marine Park, for example, the Australian government invested AU$230 million to offset the loss of revenue suffered by the local fishing industry and downstream industries.
- *New business models:* Many of the additional costs incurred as a result of sustainable fisheries management can be cushioned by using modified business models such as new cooperative organization models. One example is for a number of small fishing operations to join together to form a 'licence bank' (Ecotrust Canada, 2008; The Nature Conservancy, 2011), bundling their own investments with seed capital from an investing partner or a national development bank. They can then use this start-up capital to attract other private investors. 'Fisheries trusts' are a very similar model. They pool funds from private foundations, cheap government loans and additional bank loans (Manta Consulting, 2011) and use the money collected in this way to purchase fishing licences, which are then 'leased' for a fee to the fishermen. A proportion of the profits generated by the fishing operation is then paid out as a dividend to the external financial backers. Such a model also enables quite small fishing outfits with limited capital to acquire shares in fishing licenses. The 'licence banks' set up to date in Canada and the USA have consciously set themselves sustainability targets (such as the use of sustainable fishing gear). Members who fail to comply are threatened with sanctions (Ecotrust Canada, 2008; The Nature Conservancy, 2011). The system's long-term performance has not yet been evaluated.

4.1.4
International fisheries governance: institutions and focal points

This section introduces only the most important international institutions, conventions, soft law and

Box 4.1-8

UNCLOS and fisheries

UNCLOS lays down the framework for sustainable fishing, defining varying rights and duties for the different marine zones (Section 3.2). Article 61, para. 2 of UNCLOS spells out the obligation that the maintenance of the living resources in the EEZs must not be "endangered by over-exploitation". Article 62, para. 1 goes on to stipulate that coastal states "shall promote the objective of optimum utilization of the living resources" in their EEZs. Article 62, para. 3 targets a maximum sustainable yield (MSY; Box 4.1-5), but one which takes account of ecosystem interactions. In other words, UNCLOS places coastal states under obligation to take steps to conserve and manage the resources in their EEZs and to define catch volumes which safeguard the continued existence of the living resources (Proelß, 2004: 108). However, adequate protection is not guaranteed by these provisions, since the criterion of "over-exploitation" is not specified further and it is therefore left to the discretion of coastal states to decide on the quotas (Proelß, 2004: 108).

For the high seas, the provisions of UNCLOS follow the lead given by the 1958 High Seas Fisheries Convention, paying no attention to the already evident shortcomings in the implementation of this convention (Oda, 1983). Article 116 initially gives each state the right for its nationals to engage in fishing on the high seas. This right is linked to a condition, however: Article 117 stipulates that "All States have the duty to take, or to cooperate with other States in taking, such measures for their respective nationals as may be necessary for the conservation of the living resources of the high seas." This form of enforcement is weak, since it is left solely to the flag states and is not monitored by any other institution. Moreover, Article 118 requires states to cooperate "in the conservation and management of living resources" and to enter into corresponding negotiations or establish regional fisheries organizations in cases where identical stocks are exploited simultaneously. Article 119 obliges states to comply with the MSY on the basis of the best available scientific evidence. It also refers to the need to take ecosystem interactions into account, i.e. it goes beyond a narrow focus on target stocks only. States are also required to exchange scientific information and statistical data on fisheries. Wolfrum and Fuchs (2011) note that Article 119, para. 1 "[can] also be understood to mean that states are not themselves under an obligation to guarantee the conservation of stocks at the necessary minimum level, but merely that they must not obstruct actions by other states to conserve stocks." The provisions on straddling and highly migratory stocks are vague, as they are limited to calls for international cooperation between nation states. For this reason, the UN Fish Stocks Agreement (FSA) was adopted in 1995 as an implementing agreement on UNCLOS in order at least to close the regulatory gaps relating to straddling and highly migratory stocks (Section 4.1.4.4).

Overall, UNCLOS thus only creates the framework for sustainable fisheries governance (Section 3.2; Box 3.2-1). This framework must be filled with specific content by means of national regulations in the EEZs and by institutional arrangements on the high seas, particularly for the conservation of stocks in the context of the ecosystem approach. For example, in contrast to mineral resources in the 'Area', UNCLOS makes no provision whatsoever for the allocation of living resources on the high seas (Oda, 1983). Nor does UNCLOS provide adequate instruments to enforce its regulations or to impose sanctions. Similarly, no steward is appointed to administer biological resources. However, UNCLOS is one of the few international environmental treaties that prescribe a compulsory dispute-settlement mechanism (Wolfrum and Fuchs, 2011).

instruments whose purpose is to regulate fisheries. The institutional framework and the basis for these governance structures is provided by the United Nations Convention on the Law of the Sea (UNCLOS), which is outlined in Section 3.2 and, in relation to fishing, in Box 4.1-8. The WBGU restricts its attention here to the aspects that are currently shaping and dominating the political debate. It examines the international and global perspectives and therefore only touches on the European dimension in relation to cross-border effects and external impacts. The instruments of private governance and, in particular, the ecolabels are discussed in Section 3.5. As explained at the beginning of Chapter 4, whaling as such is not discussed here as it is now scarcely relevant to human food supplies. However, damage to the whale population caused by fishing activities (e.g. bycatch of cetaceans) is so serious that it is the subject of special regional agreements (e.g. ASCOBANS to protect cetaceans in the North and Baltic Seas, and ACCOBAMS for the Black Sea, the Mediterranean and the adjacent Atlantic zones). Examining this issue would, however, exceed the framework of this report.

4.1.4.1
Political objectives

There has been a political consensus for decades on calls for fisheries to be restructured to make it more sustainable. The topic has also been discussed at the United Nations, in particular within the framework of the 'Rio Process' and by the UN General Assembly (Section 3.3.1). At the first UN Conference on the Human Environment in Stockholm in 1972, it was already ascertained that many fish stocks had been damaged because regulation was too slow (UNCHE, 1972). In the context of marine fisheries in the EEZs, many of the problems that remain unresolved in many regions to this day – e.g. overfishing, illegal fishing, overcapacity, destructive fishing practices and the degradation of ecosystems – were already cited at the Rio de Janeiro Earth Summit in 1992. In the Agenda 21 then adopted, the states committed themselves to the conservation and sustainable use of the marine biological resources in their EEZs (UNCED, 1992a). At the World Summit on Sustainable Development (WSSD or 'Rio+10 Conference') held in Johannesburg in 2002, this abstract political agreement was fleshed out and given a time line. Here, the states approved the ambitious goal of making fisheries sustainable – i.e. managing fish stocks on the basis of the maximum sustainable yield (MSY; Box 4.1-5) – by 2015 (WSSD, 2002: para. 30a).

This objective was reaffirmed, and indeed reinforced (UNCSD, 2012: para. 168 ff.), at the UN Conference for Sustainable Development (UNCSD or 'Rio+20 Conference'). The aim is to reach the maximum sustainable yield (MSY) in the shortest possible time, e.g. using knowledge-based management plans, even if this temporarily leads to a loss of revenue or even the closure of fisheries in the case of overfished stocks. Another objective is to stamp out destructive fishing practices and illegal, unreported and unregulated fishing. Efforts to combat bycatch and other harmful ecosystem effects are to be stepped up. At the same conference, the decision was taken to negotiate a new implementing agreement for the conservation and sustainable use of biological diversity on the high seas (Section 3.3.2.2).

The Convention on Biological Diversity (CBD) likewise tackled the issue of fisheries, for example in its programme on marine and coastal biodiversity (CBD, 2004a; Section 3.3.2.1). As part of the convention's Strategic Plan, the parties in 2010 set themselves the political target of achieving sustainable management of all fish stocks by 2020 in such a way that overfishing would be avoided (CBD, 2010a).

Although these targets are not legally binding, their political importance and impact is nevertheless considerable. Not least the European Commission has committed itself to these targets and uses this as an argument for a thorough reform of fisheries policy (EU Commission, 2011c), since the Rio+20 targets cannot be achieved with existing management practices (Froese and Quaas, 2013). As things stand, then, the aim of achieving sustainable human interaction with marine biological resources is well established in international politics. Even so, getting this aim implemented in practical policies still causes considerable problems (Veitch et al., 2012).

4.1.4.2 The Food and Agriculture Organization of the United Nations

The Food and Agriculture Organization of the United Nations (FAO) is also responsible for fisheries and aquaculture (Section 3.3.1). It functions as the central repository for stock and catch data from fisherfolk in all the world's marine regions. The FAO does not gather this data itself, however, but depends on the delivery of data by authorities and fisheries institutions in the member states, and by the regional fisheries management organizations. This data is then collated, processed and published by the FAO without an assessment of its own. 'The State of World Fisheries and Aquaculture', a biannual publication, is of particular importance in this regard (FAO, 2012b).

The FAO's collection of data on fishing is regarded as the most comprehensive in the world (Costello et al., 2012b). In some regions, however, neither the scope nor the quality of the data is adequate to serve as a basis for a global picture of fisheries management. The gaps in data can be very large, particularly in developing countries: nearly two thirds of them supply inadequate data for lack of sufficient financial and personnel capacity. Yet the industrialized countries also have some catching up to do: nearly a quarter of the data they supply is also incomplete (Garibaldi, 2012). There is therefore a need to improve both the data that governments transmit to the FAO and the quality of the FAO database (Pauly and Froese, 2012). Data on the biomass of stocks in particular is extremely valuable for knowledge-based fisheries management (Branch et al., 2011; Section 4.1.3.2, 8.3.3.1). Assessing the corresponding 'data-poor' stocks is very difficult (Costello et al., 2012b; Worm and Branch, 2012). To simplify the tasks of fisheries management where data is scarce, new approaches are being developed with the aim of creating alternative bases for assessment (Martell and Froese, 2012).

The FAO's Committee on Fisheries (COFI) operates Sub-Committees on Aquaculture and Fish Trade and is the most important intergovernmental forum where member states meet regularly to discuss and negotiate recommendations and agreements. Together with the UN Convention on the Law of the Sea (Section 3.2) and the UN Fish Stocks Agreement (Section 4.1.4.4), the conventions drawn up under the aegis of the FAO form the backbone of global fisheries governance. Two of the most important ones are the FAO's non-binding Code of Conduct for Responsible Fisheries (Section 4.1.4.3) and its binding Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (Section 4.1.4.5). In addition, the FAO's non-binding guidelines serve to broaden the scope of global fisheries governance, especially in relation to topical issues. They include its 'International Guidelines for the Management of Deep-Sea Fisheries in the High Seas', FAO, 2009b; its 'International Guidelines for Securing Sustainable Small-Scale Fisheries', FAO, 2012a; Box 4.1-3; and its 'Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests', FAO, 2012d).

4.1.4.3 The FAO Code of Conduct for Responsible Fisheries

The FAO Code of Conduct for Responsible Fisheries (CoC) was ratified unanimously by all 188 FAO member states in 1995. The Code was formulated in response to the widespread realization that fisheries need to be developed in the direction of an ecosystem approach (Cury and Christensen, 2005). The Code seeks to promote sustainable fisheries management with a long-term perspective in all marine regions and inland waters (FAO, 1995). It provides a series of principles and rules relating not only to fishing methods, sustainable management (including the conservation of marine ecosystems) and the development of stocks, but also to wider issues such as fish processing and trading and fisheries research. Principles of responsible aquaculture are also covered in Article 9 of the Code (Section 4.2.3.1). The Code provides an integrated and comprehensive framework for sustainable fisheries and aquaculture that is widely recognized and accepted (Garcia, 2000). It is the first and only international instrument of fisheries governance of its kind (Hosch et al., 2011).

Among other things the Code calls on states to preserve aquatic ecosystems, to apply the precautionary principle, to base decisions on the best available scientific evidence, to ensure that conservation measures are implemented and enforced, and, in their capacity as flag states, to exercise their powers of enforcement effectively. It makes provision for an ecosystem-oriented approach to management, urging that management measures should ensure the conservation not only of target species, but also of other species belonging to the same ecosystem and of species dependent on the target species (Article 6.2 of CoC). It aims to extend the knowledge base and pursues integrative approaches (Bavinck and Chuenpagdee, 2005). The Code supports transparent decision-making processes and calls for the participation of fisherfolk, industry and environmental organizations (Article 6.13 of CoC), thereby getting important stakeholders involved (Friedrich, 2008). It also includes detailed rules and measures for sustainable fisheries management (based *inter alia* on the MSY; Box 4.1-5) aimed at giving orientation and assistance to governments as they develop their national regulations.

The Code is not a static body of rules and regulations. It can be revised and extended by the FAO (Edeson, 1996). In addition, the FAO's Fisheries and Aquaculture Department has developed technical guidelines to facilitate the implementation of the Code. On the basis and within the framework of the Code, the FAO has also drawn up four likewise non-binding international plans of action which contain rules to prevent bycatch of seabirds, protect sharks, manage fishing capacity and prevent illegal, unreported and unregulated (IUU) fishing. Section 4.1.4.5 takes a closer look at IUU fishing.

Implementation is monitored by means of regular surveys of FAO member states and by summarizing evaluations by the FAO's Committee of Fisheries (COFI). In its capacity as an international political instrument, the Code has remained relevant and adaptable both to the conditions in the various countries and to developments in the fishery sector (Hosch et al., 2011). Plans of action and guidelines create opportunities to tackle complex issues in greater depth and to respond flexibly to topical questions within the framework of the Code. With this content the Code meets the requirements of a number of the touchstones for assessing the existing governance of the ocean in the context of sustainability (Section 3.1.4).

Coll et al. (2013) regard the Code as an important instrument which is implemented only very weakly overall, albeit with regional variations. However, where the Code is successfully implemented locally, it does have positive effects with regard to the sustainability of fisheries management – irrespective of the geographic location of the countries concerned (Coll et al., 2013).

A regional study involving nine developing countries from Africa, Asia and the Caribbean shows that the successful translation of the Code into national political regulations is widespread (Hosch et al., 2011). However, the poor or non-existent implementation of these national regulations and the failure to enforce them locally represent major problems. Such poor implementation cannot be explained by a lack of scientific knowledge alone (Cury and Christensen, 2005). Hosch et al. (2011) cite short-sighted socioeconomic considerations, administrative inertia and a lack of political will as reasons for the poor implementation.

A study by Pitcher et al. (2009) underlines these insights: of 53 countries studied, not one earns a good grade for implementation. Overall, the lack of compliance with the Code is referred to as disappointing. There is a positive correlation in this context between the quality of implementation, the developmental state of the countries and the World Bank's governance index, which seeks to measure aspects likes political stability, the efficiency of institutions, corruption and violence. Lack of capacity alone, however, is not enough to explain the flawed implementation. After all, Namibia (Box 4.1-7) and South Africa are both developing countries, but both are also in the top group with better implementation ratings than all the EU countries (Pitcher et al., 2009).

In many countries, therefore, there is a broad gulf between good intentions and concrete results (Doulman,

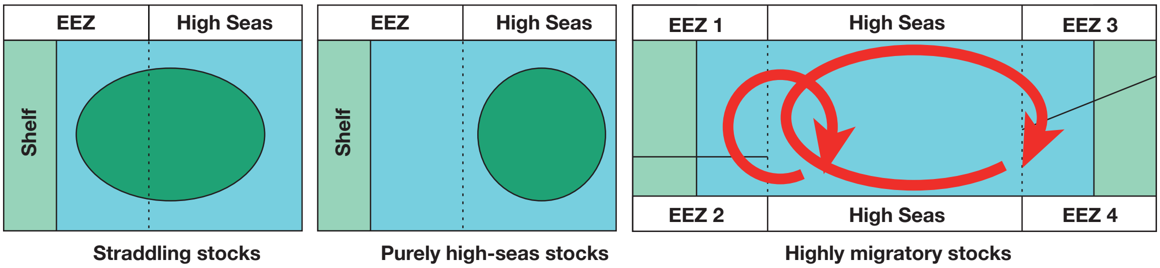


Figure 4.1-11
Different types of stocks relevant to the high seas.
Source: FAO, 2005a, modified

2007; Mora et al., 2009). Overall, the most significant shortcomings appear to be a failure to translate international regulations into national ones and, above all, a failure to enforce regulations at the local level.

4.1.4.4 Fisheries governance on the high seas: the UN Fish Stocks Agreement and regional fisheries management organizations

UN Fish Stocks Agreement

Although about 60 % of the world's oceans are seaward of the EEZs, the volume of fish caught on the high seas only amounts to a small fraction of global yields. Even so, it should be noted that around two thirds of global yields come from stocks that are not only found in EEZs, but also cross into the high seas, migrate over long distances between EEZs and the high seas (across entire oceans in some cases), or are only found on the high seas (Figure 4.1-11; Munro et al., 2004:7). Access to stocks in the high seas used to be largely free and unregulated. The UN's 1958 Convention on Fishing and Conservation of the Living Resources of the High Seas (UN, 1958) did little to change this and was largely ignored in practice (Oda, 1983). The provisions of UNCLOS – e.g. on the conservation of living resources and the principle of cooperation (Wolfrum and Fuchs, 2011; Box 4.1-8) – build on the failed 1958 convention but are themselves too vague and have been unable to avert the 'tragedy of the commons' (Hardin, 1968) with regard to fish stocks in the high seas. The resultant overfishing (Box 4.1-9) has affected stocks in the high seas as a whole, i.e. including those that overlap with the EEZs. Accordingly, attempts at sustainable management of these stocks based solely on national regulations in EEZs have not appeared very promising (Lodge et al., 2007:3).

These problems were placed onto the agenda of the United Nations Conference on Environment and Development in Rio Janeiro in 1992 (UNCED, the 'Rio Earth Summit'). In response, the UN Convention relating to the Conservation and Management of Straddling Stocks and Highly Migratory Fish Stocks (UN Fish Stocks Agreement, FSA) was signed in 1995 and took effect as an implementing agreement of UNCLOS in 2001 (UN, 1995; Section 3.2). The USA was a driving force in negotiations surrounding the FSA. Although some countries were highly sceptical at the outset, acceptance of the FSA does seem to have improved markedly in the meantime (Balton and Koehler, 2006). Today, 80 countries have acceded to the FSA (UN, 2013a). Japan, South Korea and Indonesia are among the prominent fishing nations that have been added in recent years. China, the biggest fishing nation in the world, has not signed up.

The FSA limits itself to 'straddling and highly migratory' stocks. Straddling stocks have a range that crosses the boundaries between an EEZ and the high seas. Highly migratory stocks (primarily tuna, swordfish and sharks; Figure 4.1-11) have a very extensive range which includes different EEZs and the high seas. The FSA is not responsible for discrete high-seas stocks, irrespective of whether they live pelagically, in the deep sea or on the seabed. In practice, these stocks, which are found exclusively in the high seas, are still exposed to an open-access regime. Overfishing is thus inevitable and has already taken place in some cases (Munro, 2010:44). This represents an obvious regulatory gap in international fisheries governance (Molenaar, 2007).

The FSA aims to strengthen the provisions of UNCLOS, specify them more clearly and implement them more effectively by making conservation and management compatible both in EEZs and on the high seas. The specific provisions relate primarily to straddling and highly migratory stocks that can be found in the high seas and for which the FSA is thus responsible in terms of access, conservation and management. The coastal states retain the sovereign rights to manage those parts of these stocks that are in their EEZs, but are also expected to apply the general principles of conservation and management of these stocks within their EEZs (Article 3.2 of FSA). Article 6 of the FSA, which explains the precautionary approach in more detail, and Article 7 on the compatibility of conservation and management measures also apply explicitly to those parts of straddling and highly migratory stocks that are found in EEZs. This coverage is intended to ensure that the same principles apply for conservation and management on both the coastward and seaward sides of the 200-nautical-mile limit (Lodge et al., 2007: 3). Accordingly, the FSA "codifies important new developments in international environmental law that were not (yet) taken into account during the UNCLOS negotiations" (Wolfrum and Fuchs, 2011).

The general principles (Article 5 of FSA) include the following: knowledge-based management with the aim of optimizing management; using the maximum sustainable yield not as a target but as a minimum standard (MSY; Box 4.1-5; Annex II para. 7 of FSA); applying the precautionary principle; assessing impacts on other species in the ecosystem; avoiding bycatch, wasteful methods and pollution; conserving marine biological diversity; preventing or eliminating overfishing and overcapacity; taking into account the interests of small-scale fishers; collecting and sharing data such as vessel positions, catches of target and non-target species, fishing effort, etc.; promoting research and technological development for conservation and management purposes; and effectively monitoring measures. These general principles thus embrace key elements that are today regarded as the basis for modern sustainable fisheries management (Section 7.4.1.1). Although the term 'ecosystem approach' had not been formulated at the time when the FSA was developed, the preamble and Article 5, letters (d) to (g), of the FSA include content which is today subsumed under the term. However, the FSA comprises only a very generally worded provision on developing plans to protect species and habitats, but no explicit provisions on the creation and management of marine protected areas (Section 3.6.2).

To improve enforcement, the FSA adopts innovative approaches, e.g. by tightening up the duties of flag states (Article 18 of FSA), and, given certain preconditions, even authorizing personnel from FSA states parties to board and inspect fishing vessels operating under the flag of any FSA state party (Article 21 of FSA).

The FSA formulates regulations on intergovernmental cooperation in much greater detail than UNCLOS. In particular, its provisions on regional fisheries management organizations (RFMOs) are more detailed and more precise. As a result, the FSA forms the new global institutional framework for RFMOs (McDorman, 2006). The FSA has considerably strengthened the position of the RFMOs, which are still regarded as key institutions to help regulate intergovernmental cooperation (Lodge et al., 2007: 4). RFMOs are discussed in detail in the next section.

On the whole it is fair to say that the provisions of the FSA with regard to sustainable fisheries management constitute a major step forward from UNCLOS, and that they meet the requirements of nearly all the touchstones for ocean governance in the context of sustainability (Section 3.1.4).

A Review Conference in 2006 examined the effectiveness of the FSA (Article 36 of FSA). It became clear that many countries, including non-states parties, regard the provisions of the FSA as a kind of fundamental standard for the sustainable management of fish stocks (Balton and Koehler, 2006). The outcomes of the conference strengthened the role of the RFMOs; it was urged that they be subjected to regular 'performance reviews' to assess the status of implementation. It was also recommended that the provisions of the FSA should be applied to discrete high-seas stocks. Apart from the special problems faced by developing countries, the most important recommendations were the call for overcapacity and subsidies to be phased out, for IUU fishing practices to be combated (see Section 4.1.4.5 for more details), and for an ecosystem approach to be implemented (ENB, 2006). The Review Conference was resumed in 2010 with a focus on flag states, many of which inadequately enforce the provisions of the FSA. Attempts to put marine protected areas on the agenda have failed so far (ENB, 2010; UNGA, 2010).

One remaining regulatory gap is the FSA's limited scope, which leaves discrete high-seas stocks (including their deep-sea species) unprotected (Figure 4.1-11). This gap has been recognized and there are signs that regional solutions could be implemented relatively quickly within the framework of the RFMOs. However, fundamental solutions requiring an amendment to the FSA or UNCLOS can only be implemented in the long term (Sections 7.2.2.2 and 7.3.4.3). A move to expand the provisions still further to include all stocks in the EEZs would make sense, but would undoubtedly be a very long-term project.

One major deficit is the fact that up to now countries have been reluctant to ratify the FSA (Molenaar, 2011). Although the FSA was adopted in 1995, the level of participation has hitherto been low compared to UNCLOS, even though many major fishing nations have signed up. The battle against IUU fishing practices in particular will become easier as more countries add their signatures (Section 4.1.4.5). With a view to the touchstones listed in Section 3.1.4, one shortcoming is that the FSA's mechanisms for resolving conflicts and imposing sanctions are rarely applied in practice.

Box 4.1-9

High-seas fisheries: cooperation and sustainability

Fish stocks can be regarded as a renewable natural resource and as natural capital. To conserve them permanently as a natural resource, the yield – i.e. the catch volume – must be smaller than the growth in stocks. Reducing catches to a level below the maximum sustainable yield (MSY; Box 4.1-5) implies waiving a certain catch volume and can be referred to as an investment. As with all investments, these too are undertaken in the hope that the non-utilization of capital in the present will result in its preservation or even maximization in the future. When there is overfishing, stocks decline and yields threaten to drop towards zero in the long term (Gordon, 1954).

In open-access fisheries that are regulated unsuccessfully or not at all, there is often no investment in the form of suitable reductions in fishing activities. As in the case of bluefin tuna in the East Atlantic, for example, the consequence is that catch volumes decline due to shrinking stocks that are in danger of collapsing unless drastic action is taken (Bjørndal and Brasão, 2006).

As Gordon (1954) already pointed out over 50 years ago, it is irrational for an individual fisherman in an open-access fishery to invest in conserving fish resources. If he reduces his yields, he can expect to achieve nothing – other than increasing the volumes caught by other fishermen. An individual fisherman therefore has a powerful incentive to regard fish stocks as a finite resource in much the same way as ore deposits that can be mined. According to Gordon, open-access fishing does not reach equilibrium until the stocks have collapsed.

The situation of fishermen in an open-access situation, if they do not cooperate with each other, is similar to the prisoner's dilemma in game theory. If they were to cooperate and agree to invest in the interests of sustainable management, this would be the most beneficial strategy for all parties in the long term. If they do not cooperate, investing appears disadvantageous from the perspective of each individual fisherman, because every other fisherman can benefit from his investment as a 'free-rider'. In the short term, therefore, it appears to be more advantageous for all participants not to invest in conserving fish stocks, but to maximize their own yields without considering the impact on long-term yields, until such time as stocks collapse. In the short term, this solution is the best one for the individual fisherman. In the long term it is the worst strategy for all fishermen (Lodge et al., 2007).

The current state of fish stocks in the high seas largely corresponds to what Gordon (1954) expected, because cooperation between the players concerned often functions poorly or fails completely. In order to safeguard long-term yields of renewable fish resources on the high seas and to replenish stocks, huge investments – in the form of a temporary reduction in fishing – are unavoidable (Munro, 2010). However, this will not be possible without effective cooperation and, in particular, stronger enforcement mechanisms between the states involved.

The various options which the FSA offers for conflict resolution can be applied only if both parties give their consent. In most cases, attempts are made to resolve conflicts via diplomatic channels instead of through the courts. Since the FSA is an implementing agreement of UNCLOS, certain conflicts are excluded *a priori* from solutions that use these mechanisms. For example, no coastal state can be sued for setting fishing quotas in its own EEZ at its own discretion, even if another state regards these quotas as too low or too high. Another shortcoming is reflected in the fact that instruments aimed at conserving biological diversity (such as MPAs) are only used hesitantly.

For the FSA, as for other fishery regimes, the biggest challenge is undoubtedly the general lack of local enforcement. The insufficient financial and technical capacity of developing countries is one factor in this situation. Another is the complicated process involved when RFMOs that already existed when the FSA was agreed adjust to the FSA's standards and procedures. The following section examines the RFMOs in greater detail. By no means least, there is also the problem of 'flags of convenience', countries that scarcely worry about their obligations in respect of their high-seas fishing fleet (HSTF, 2006:38).

Summing up, it is fair to say that the FSA's provisions provide a good basis and contain many approaches and instruments that are conducive to modern sustainable fisheries management. However, serious shortcomings exist in terms of its reach (the number of governments that have ratified it), its geographical scope and its implementation. Since the high seas are in a poor condition and subject to rapid change, adding more states parties to the FSA and dynamically developing its content and objectives are among the most important tasks for the future (Section 7.3.4.3). There appears to be broad global consensus on the problems and possible solutions. However, rather ineffective mechanisms for resolving conflicts and a failure to enforce regulations remain a weakness, leaving the agreement dependent on the political will of the states parties. At present, both the condition and the governance of the high seas are very poor.

Regional fisheries management organizations

Without the cooperation of the countries involved in managing fish stocks on the high seas, these stocks are threatened with overuse (Box 4.1-9). Although the freedom of fishing on the high seas is already restricted by UNCLOS in the form of a generally formulated call for cooperation to conserve stocks (Henriksen, 2009; OECD, 2010; Box 4.1-8), it has become apparent that in regions where functioning regional cooperation mechanisms are lacking, this leads to overfishing and disputes over resources. Today, regional fisheries management organizations (RFMOs) are the central institutions of fisheries governance on the high seas. They provide forums where states can negotiate terms for cooperation on the conservation and sustainable use of fish stocks. There are two groups of RFMOs: one manages straddling stocks, while the other focuses on highly migratory stocks that cover large expanses of the sea, and in some cases entire oceans (Figure 4.1-12).

The provisions of the FSA today constitute the *de facto* minimum standard for RFMOs, a standard which, above all, means paying greater attention to sustainable management. That said, about three quarters of the RFMOs were already established (and some of them with very different rules) when the FSA was ratified in 1995. Many of these organizations therefore only meet the FSA's requirements partially or not at all (McDorman, 2005). Moreover, by no means all RFMO members are also states parties of the FSA; these countries are therefore not bound by the FSA's provisions (OECD, 2009: 20). Conversely, decisions made by these RFMOs, because they may include countries that are not FSA states parties, are not always fully compatible with the spirit or the provisions of the FSA, especially since not all the major fishing nations have ratified the FSA (Lodge et al., 2007).

Even after the FSA, one core problem remains regarding fishing on the high seas: that non-RFMO members are not bound by the RFMO's rules, and that excluding them from using the stocks managed by the RFMOs is problematic. In addition, many RFMOs do not define catch volumes strictly enough on the basis of the scientific assessment, since there is significant political resistance in some quarters against reducing quotas, above all for valuable fish stocks such as tuna (MacKenzie et al., 2008). Furthermore, scientific work is often impeded by a lack of data. On the other hand, with a view to the touchstones for ocean governance discussed in Section 3.1.4, many RFMOs have adopted the precautionary principle and the ecosystem approach as the basis of their management practice. Similarly, a number of RFMOs apply a flexible, adaptive approach (Mooney-Seus and Rosenberg, 2007).

Up to now, when new members joined an RFMO, the total catch volume has sometimes been increased to enable the newcomers to participate – contrary to scientific recommendations – rather than reallocating the existing catch volume, which would have led to reductions in the shares allocated to the existing members (Lodge et al., 2007; OECD, 2010: 40). This practice is diametrically opposed to the requirements of sustainable management. Yet even where the agreed rules and quotas are adequate, there is still the problem of ensuring that the RFMO members and their fishing vessels comply with the rules. The monitoring and enforcement of agreed management measures is inadequate in many RFMOs, although there are also positive examples that can serve as best practices (e.g. CCAMLR, CCSBT and ICCAT; Mooney-Seus and Rosenberg, 2007). In some cases, the fact that most RFMOs lack well-functioning mechanisms to resolve conflicts and apply sanctions has led to overfishing. The problem of IUU fisheries is discussed separately in Section 4.1.4.5. Last but not least, some RFMOs do not have adequate rules against bycatch, or else existing rules are not properly enforced (Small, 2005).

Given these overall conditions, it is not surprising that many RFMOs are not doing a very good job of meeting their newly defined obligations under the FSA. Hilborn (2007) gives a damning verdict: "The existing governance regimes for high-seas fisheries have failed totally." Having analysed the performance of RFMOs, Cullis-Suzuki and Pauly (2010), too, conclude that they have failed when measured against their duties and their own standards. Accordingly, fish stocks in the high seas are in a very poor condition: nearly a third of highly migratory stocks and about two thirds of straddling stocks are overused or exhausted (OECD, 2009). Largely as a result of mismanagement, most of the long-lived and economically attractive species of tuna and swordfish in particular are already endangered (Collette et al., 2011), so that replenishing stocks could take many years (bluefin tuna: MacKenzie et al., 2008). The FAO is more diplomatic in its assessment: "The RFMOs, the cornerstones of international fisheries governance, are struggling to fulfil their mandate…" (FAO, 2009a: 69). Not least in the light of this realization, the external and internal pressure on RFMOs to improve their performance has increased sharply in recent years (OECD, 2009: 17). NGOs that have explicit rights of participation according to the FSA (Article 12) are playing a special role in this context (e.g. PEG, 2010; WWF, 2007).

Since the turn of the millennium, a series of conferences have called for the RFMOs to be reformed to make them more effective with regard to sustainability and the prevention of IUU fishing (Ceo et al., 2012). Finally, the UN General Assembly formulated a specific call for official performance reviews of the RFMOs, which further intensified the political pressure (UNGA, 2006). Since then, studies by such organizations as Chatham House (Lodge et al., 2007), the OECD (2009) and the FAO (Ceo et al., 2012) have provided an empirical basis and formulated recommendations which can give the RFMOs some orientation in their reform efforts. The FSA review conference, which resumed

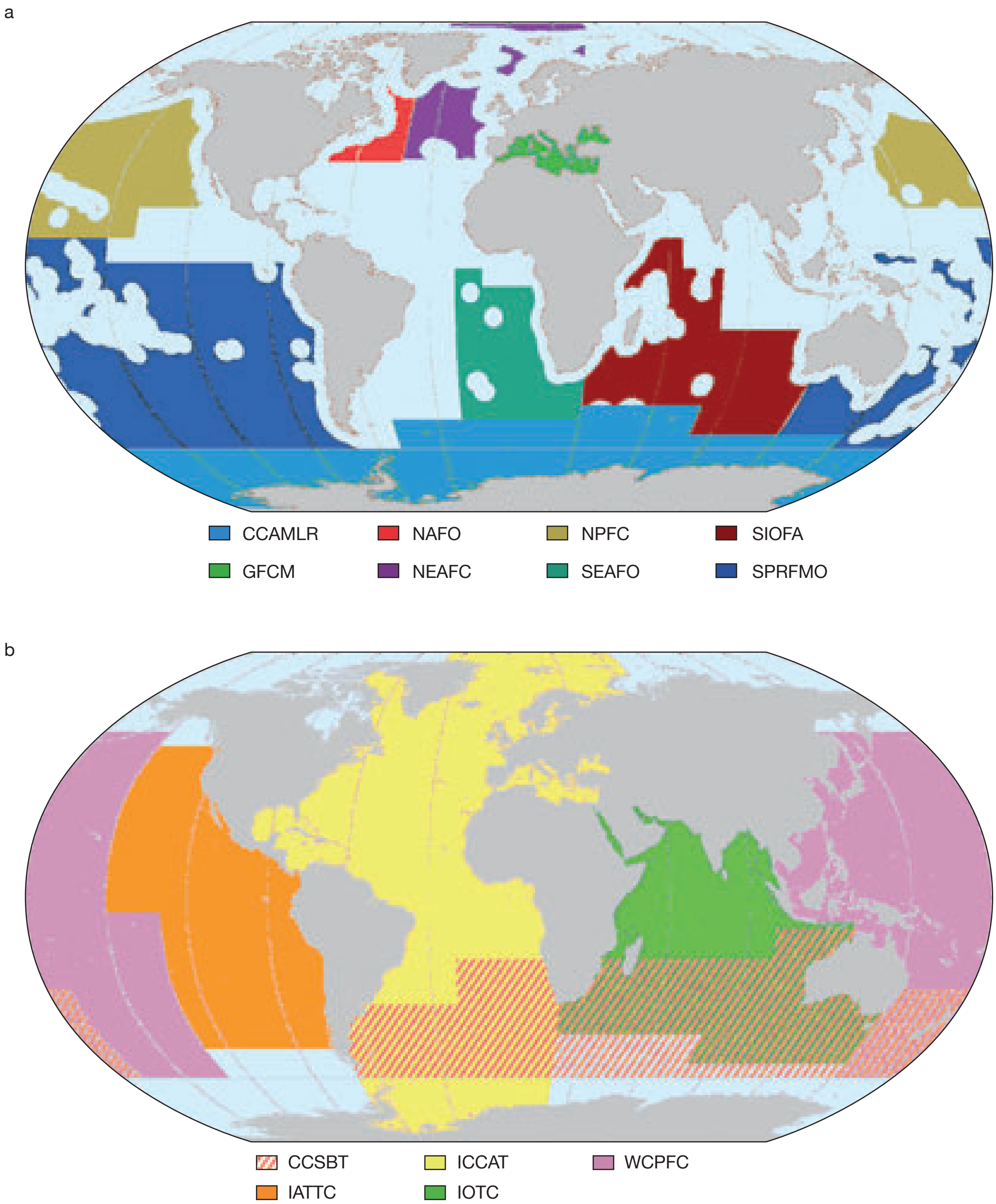


Figure 4.1-12
Regional fisheries management organizations (RFMOs) of relevance to the high seas: (a) RFMOs that manage straddling stocks; only the share of RFMOs in the high seas is shown; (b) RFMOs that manage highly migratory stocks (e.g. tuna).
Source: FAO, 2013d

in 2010, again showed that countries, UN institutions and NGOs today broadly agree on the goals of RFMOs, how they should operate, and the direction and content of the reform process. However, all the actors are well aware that not all the problems can be resolved at the regional level. One example is the overcapacity of global fishing fleets, which is driven primarily by subsidies, an issue that must be regulated by the WTO (Sections 4.1.4.7 and 4.1.7.8).

Several RFMOs have now begun – and some have already completed – the reform processes needed to comply with the FSA, the FAO Code of Conduct for Responsible Fisheries (Section 4.1.4.3), the FAO Action Plans (Section 4.1.4.2) and the FAO Agreement on Port State Measures (Section 4.1.4.5), albeit with varying degrees of success (OECD, 2009; Ceo et al., 2012). Success stories (such as NAFO and CCAMLR) do show, however, that the necessary transition is possible. The following points are cited as preconditions for successful RFMOs (Mooney-Seus and Rosenberg, 2007; Lodge et al., 2007; OECD, 2009; Ceo et al., 2012):

- Ratification of the FSA by all the member states of an RFMO and bringing all RFMO agreements into line with the FSA would create the common legal basis that is needed for the governance of high-seas fisheries. This would also create a common point of departure for the development of a strategic vision and shared objectives within each RFMO.
- The aim of the conservation and sustainable use of stocks within the framework of the ecosystem and precautionary approach should not only be stipulated, it should be given top priority in RFMO practice when use rights are allocated. The great challenge in this context is to allocate fishing rights in such a way that all member states benefit from the cooperative solution without overstepping the limits of sustainability for stocks and ecosystems.
- Political interventions in the scientific processes of RFMOs appear to be no rare occurrence (Polacheck, 2012). More transparent processes can play a part in ensuring that permitted catch volumes are not much larger than the corresponding scientific recommendations. Important preconditions include collecting and disseminating the necessary data (e.g. catch volumes, bycatch, fishing effort) and ensuring the transparency and public accessibility of this data for independent audits. Joint data management across RFMOs would also make sense.
- Clearly defined mechanisms for dispute settlement are an important institutional instrument in order to strengthen confidence in, and the credibility of, the RFMOs. Regular, transparent performance reviews which draw on external expertise – preferably based on criteria jointly agreed by the RFMOs – are a good way of identifying deficits and initiating the necessary change towards an adequate conservation of fish stocks.
- IUU fishing practices should be combated by appropriate RFMO regulations, for example by implementing port-state measures, flag-state controls, monitoring and surveillance measures, the mutual recognition of vessel lists, etc. (Section 4.1.4.5).
- The RFMOs can learn a lot from each other, especially by collecting and disseminating best practices. The joint conferences that have been held for a number of years are useful in this regard.

However, given the fact that overall progress is slow, and bearing in mind the fundamental nature of the problems, one must ask whether a fundamental reform of the governance of fishing activities on the high seas might not be necessary. Hilborn (2007) proposes that all marine bioresources seaward of the 200-nautical-mile limit be declared as the common heritage of mankind in a UN convention. The criticism levelled by Oda (1983) at the UNCLOS fishing regime for the high seas also concludes with the expectation that the concept of the common heritage of mankind will also be brought into the debate on high-seas fishing. The WBGU's approach to a fundamental reform of fishing on the high seas is outlined in Section 7.2.3.1, which is also based on the concept of the common heritage of mankind (Section 3.1.5).

4.1.4.5
Illegal, unreported and unregulated fishing

All in all, between about one seventh and one third of global catches are attributable to illegal, unreported or unregulated (IUU) fishing, and in some regions this poses a threat to the sustainable management of stocks (Agnew et al., 2009). IUU fishing is a collective term for widely differing types of fishing. In the 'International Action Plan to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing' (FAO Action Plan; FAO, 2001), the term *illegal fishing* refers to vessels fishing in the EEZ of a coastal state without a licence or in violation of the coastal state's regulations; to vessels fishing under the flag of an RFMO member state in that RFMO's waters, but violating the RFMO's regulations; and to fishing activities that violate national law or international obligations. The FAO Action Plan defines *unreported fishing* as fishing activities that are reported either incorrectly or not at all to the relevant national authorities, even though reporting is prescribed by national law; or as fishing activities within an RFMO's territory that are reported either incorrectly or not at all to the RFMO in contravention of the latter's stipulations. *Unregulated fishing* refers to fishing activities conducted in an RFMO's territory by vessels that are either without nationality or flying the flag of a state that is not a member of the RFMO; or to fishing activities conducted in areas or targeting stocks for which there are no applicable conservation and management measures, but that violate the obligations of states under international law to conserve marine bioresources (FAO, 2001).

IUU fishing takes place on the high seas when fishing boats flying the flag of states that have not ratified the FSA, or are not members of the relevant RFMO, do not keep to the respective rules. However, IUU fishing can also have a major impact in EEZs where coastal states lack the capacity to prevent fishing boats from other countries from entering their waters and fishing without a licence (Agnew et al., 2009). It is no rare occurrence for the catch volumes agreed in bilateral agreements to be exceeded, or for unlicensed methods to be used, in the EEZ of a coastal state by fishing boats from partner countries (Section 4.1.4.6; HSTF, 2006).

Unlicensed fishing activities by a coastal state's 'own' fishing boats in its EEZ are also classed as IUU fishing. However, such infringements fall under the jurisdiction of the coastal state itself and are not discussed any further in this report, since they have no international dimension.

Agnew et al. (2009) estimate the global extent of IUU fishing at 11-26 million tonnes per annum (excluding discards) with a value of US$10-23.5 billion. If the global catch volume from IUU fishing were counted like that of an individual country, it would come second only to China's catch volume. Developing countries are especially vulnerable to IUU fishing. Total catches in West Africa, for example, are estimated to be 40% larger than the catches that are reported (Agnew et al., 2009). One key problem in such countries is the lack of institutional and financial capacity with which to combat IUU fishing. The high market prices for highly migratory tuna and swordfish represent very powerful incentives for criminal behaviour (OECD, 2004:11; WWF, 2007). This is one reason why the responsible RFMOs are fighting IUU fishing, as it creates a further obstacle to their generally ineffective management (Section 4.1.4.4).

IUU fishing can threaten the sustainability of a stock, because IUU fishing operations have no regard either for agreed catch volumes or for the ecological side-effects of their often destructive and wasteful fishing methods (e.g. bycatch; OECD, 2005:34). The ecological consequences, which can be considerable, are difficult to assess, however (Agnew et al., 2009; HSTF, 2006). Illegal fishing also reduces the income of legal fisherfolk and deprives the relevant government agencies of legitimate fees and taxes (OECD, 2005:34). In the countries of sub-Saharan Africa, the loss of income due to IUU fishing is estimated at US$1 billion a year – roughly a quarter of Africa's total exports (HSTF, 2006). There are also negative effects on the living conditions of small-scale fisherfolk in developing countries, who are particularly hard hit by the illegal catches of foreign industrial fishing vessels (HSTF, 2006). This in turn can affect food security for people living in coastal areas (Section 4.1.2.4). In addition, IUU fishing vessels often ignore social and safety standards for their crews (Whitlow, 2004). Lastly, IUU fishing distorts reporting on catch volumes and thus makes it more difficult to produce scientific assessments of stocks or sustainable fishing quotas (Polacheck, 2012; Le Manach et al., 2012).

IUU fishing is made possible primarily by inadequate overall governance with insufficient implementation and monitoring, as a result of which non-cooperative behaviour is allowed to pay off (Box 4.1-9) and illegally caught fish can find its way onto the world market. For species sold at high prices (such as the Patagonian toothfish), illegal fishing can be between two and eight times as profitable as legal fishing (HSTF, 2006:23). At the same time, IUU fishing is encouraged by overcapacity in the global fishing fleet, which is largely caused by subsidies (Section 4.1.4.7). When fishing boats are surplus to requirements in one fishing area, people will always look for new opportunities in other ocean regions. These will then be 'opened up' at least to some extent by IUU fishing (OECD, 2010:35 ff.).

UNCLOS neither systematically combats nor prevents IUU fishing because the supervision of fishing vessels and their activities is entrusted primarily to the flag states, and some of these countries violate their obligations – wilfully or through negligence ('flags of convenience'). Belize, Honduras, Panama and St. Vincent have the biggest fishing fleets of the flag-of-convenience states (Gianni and Simpson, 2005:4). Under a flag of convenience, IUU fishermen have little to fear from sanctions because many of these states do not join RFMOs to avoid being bound by their regulations. About 2,900 large fishing vessels – equivalent to around 17.5% of the global fleet in terms of tonnage – fly flags of convenience (HSTF, 2006:36). Other flag states are unable to provide effective supervision of their ships, not due to any malicious intent, but because they lack the capacity.

In order to do anything about this failure, there is a trend – among RFMOs, for example – towards placing greater emphasis on the obligations of port states (Tarasofsky, 2007). Port-state measures aim to prevent the landing of illegal fish in ports (either straight from the fishing boats or after transshipment at sea) and thus to make it more difficult for IUU catches to reach the global markets. For example, vessels that have already been involved in IUU activities in the past and are on corresponding lists can be denied access to ports and to the services available there (refuelling, repairs, etc.). The effectiveness of port-state regulations depend above all on the involvement of the states and the quality of implementation. Flothmann et al. (2010) criticize the ineffectiveness of port-state measures taken by the RFMOs and the lack of coordination between them. For example, RFMOs do not do enough to communicate, coordinate and standardize lists of IUU vessels (Tarasofsky, 2007; Berg and Davies, 2011). Furthermore, port states fail to check the lists in three quarters of cases. Until such time as port-state measures are implemented seamlessly in an entire region, IUU vessels will always be able to find alternative options (Flothmann et al., 2010). Other trade-related measures, such as bans on imports or exports, are discussed in Section 4.1.4.8.

There is a proven correlation between a lack of national governance capacity and the extent of illegal fishing in EEZs (MRAG, 2005; Agnew et al., 2009). The risk of discovery, the small scale of penalties threatened and the low risk of enforcement stands in no relation to the profits that can be made, so that there is no effective deterrent to IUU fishing. A full catch can be worth more than the fishing vessel itself (Sumaila et al., 2006), so that even the confiscation of the vessel does not constitute adequate punishment.

IUU fishing on the high seas is a well organized and very lucrative global business. Indeed, boats are built specifically for the purpose of IUU fishing: just under 24 metres long to avoid being bound by the rules of the IMO and some RFMOs on 'large' fishing vessels (Gianni and Simpson, 2005). The owners of fishing vessels that fly flags of convenience are mostly domiciled in the following countries: Taiwan, Honduras, Panama, Spain and Belize. If a list of countries is compiled showing where the owners of fishing vessels sailing under flags of convenience come from, it is topped by the EU countries added together. Spanish companies domiciled on the Canary Islands account for about half of this fleet. Most of the companies domiciled in Honduras, Panama, Belize and St. Vincent are probably front companies whose owners are based in other countries (Gianni and Simpson, 2005: 4). The global range of the fishing boats and the ease with which they can switch to another flag of convenience under a different vessel name owned by a rapidly changing chain of different front companies makes it much easier for them to ply their illicit trade and more difficult to identify the real profiteers behind them (Mooney-Seus and Rosenberg, 2007; Flothmann et al., 2010). Reflagging is effective because fishing boats are currently under no obligation to have a number allocated by the International Maritime Organization (IMO), which would make unambiguous identification possible. There are many documented cases of forged catch documentations, certificates of origin and logbooks, reprogrammed electronic positioning equipment, mixing of legal and illegal catches, corruption, bribery and similar practices. For an in-depth analysis of the workings and drivers of IUU fishing along with a number of case studies, see for example HSTF (2006), OECD (2004, 2005), and Gianni and Simpson (2005).

Political objectives and instruments against IUU fishing

IUU activities peaked in the 1990s and have since been slowly declining (Agnew et al., 2009). Since about the turn of the millennium, this ruthless exploitation has increasingly been attracting the attention of international forums. In 2001 the 'International Action Plan to Prevent IUU Fishing', which is not binding under international law, was passed within the framework of the FAO (FAO, 2001; OECD, 2005: 113). It includes a list of concrete measures (including cooperation, controls and sanctions) which focus on a variety of actors (e.g. coastal states, flag states, port states and RFMO member states). To date, however, few states have actually gone ahead with voluntary implementation in the form of national action plans, a fact that raises doubts about the effectiveness of this non-binding instrument (Billé et al., 2011). Only if the FAO Action Plan were implemented across the board by countries would it be an effective weapon against IUU fishing (OECD, 2005: 113), as this could make it difficult for IUU fish to access the world's markets.

The World Summit on Sustainable Development held in 2002 ('Rio+10') issued an urgent appeal for the implementation of the FAO Action Plan and for monitoring and enforcement of the related measures (WSSD, 2002: para. 30, letter (d)). At about the same time, the RFMO reform process began to gather momentum (Section 4.1.4.4). In 2009 the FAO's binding Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (PSMA; FAO, 2009c) was agreed, which contained specific measures and obligations on the part of port states (e.g. to cooperate, exchange information, inspect vessels, and ban IUU fishing vessels from entering ports and landing catches). It was signed by 23 states, but only four states and the EU have ratified it to date. When the PSMA comes into effect, the states parties will be under obligation to close their ports to illegal fish and to refuse IUU fishing boats access to port services (Flothmann et al., 2010). According to PEG (2012), the agreement would have the potential to become an effective weapon in the fight against IUU fishing if it were to receive sufficiently broad support and be fully implemented.

The lack of effectiveness of the RFMOs is reflected not least in the failure to contain IUU fishing activities. Conversely, RFMO measures can at least partly defuse the IUU problem (Section 7.4.1.5; Cullis-Suzuki and Pauly, 2010). Some RFMOs are already applying port-state measures and banning vessels that engage in or support IUU fishing from landing their catches or even entering the ports.

In 2010 the parties to the Convention on Biological Diversity agreed to the target of implementing sustainable and legal fishing based on the ecosystem approach and eliminating IUU fishing by 2020 (Aichi-Target 6: CBD, 2010a, b). Most recently, the topic was raised again at the UN Conference for Sustainable Development in 2012 (the 'Rio+20 Conference'). At this conference, countries – in their various roles as coastal states, flag states and port states – were placed under obligation to take action against IUU fishing (UNCSD, 2012: para. 170). Ultimately, however, these global objectives constitute nothing more than an appeal.

Few countries have national legislation that directly targets IUU fishing and makes all trade with illegally acquired species a punishable offence. One exception is the USA's Lacey Act, which prohibits every individual from buying or trading in fish caught in a manner contrary to the legal provisions or legislations of other countries. This act has led to convictions with lengthy prison sentences and fines of up to millions of dollars (HSTF, 2006: 33).

In the European Union, the IUU Regulation came into force at the start of 2010. Its intention is to prevent IUU fish from accessing the EU market. The system of controls includes port inspections, catch certificates for the entire procurement chain, an EU-wide black list of IUU vessels and states that tolerate IUU fishing, regulations on dealing with third countries which refuse to cooperate, and sanctions (see detailed discussion in Markus, 2012). Access to EU ports and the transshipment and landing of catches requires prior registration, validated catch certificates and inspections. On the basis of this regulation, eight third-party states were threatened for the first time in 2012 with being put on the black list of IUU states if they remained uncooperative (Damanaki, 2013). However, it is too early for a definitive assessment of the effectiveness of the IUU Regulation (Markus, 2012).

Interpol, too, is now concerning itself with the subject and launched the 'Project Scale' initiative in early 2013 with the aim of detecting, suppressing and combating fishery-related crimes (Interpol, 2013). These activities bring it home ever more clearly what illegal fishing really is: a crime

Conclusions

IUU fishing is a complex and dynamic problem for which there are no easy or fast solutions. If progress is to be made, a large number of stakeholders must coordinate their efforts at different levels of governance. Several reports and commissions have looked into the subject and proposed solutions since the turn of the millennium (e.g. OECD, 2004, 2005, 2010; MRAG, 2005; HSTF, 2006). These proposed solutions are briefly summarized in the following.

Solutions to the problem of IUU fishing on the high seas depend essentially on the implementation of the FSA, the PSMA and the FAO Code of Conduct for Responsible Fisheries, as well as on institutional improvements to the RFMOs (Section 4.1.4.4). Yet ultimately, it is national governments, in their various roles, that must summon the political will for reforms – be it by ratifying and implementing the FSA and PSMA, by taking action to combat IUU activities as member states of an RFMO, by taking their obligations as flag or port states seriously, or by ramping up their monitoring and surveillance capacity and phasing out subsidies. Diplomatic pressure on flag and port states that fail to cooperate can be a useful instrument. Port-state measures undertaken by RFMOs, countries or the EU, including import bans, can be effective instruments to combat IUU fishing. They are especially effective if coordinated on a supraregional or global scale.

IUU fishing can also be made more difficult by means of improved cooperation and exchanges of information between governments and institutions, more extensive documentation and reporting obligations, and heavier fines. These steps require a central shipping register for all high-seas fishing vessels (including those less than 24 metres long) and support vessels (for transshipping catches, supplying fuel, etc.) with an unequivocal IMO number, technical data and history of owners, instances of renaming, reflagging and any IUU activities, as well as a shared 'black list' of IUU fishing vessels and a 'white list' of vessels licensed by the RFMOs. Harmonized minimum standards for documentation and shared global RFMO databases detailing catches (including reliable proof of origin), the fishing effort, transshipments at sea and the landing of catches in ports are also recommended. Sophisticated technical methods for the monitoring and control of vessels, their activities and their catches are already available: examples include vessel monitoring systems (VMS) and satellite-based and airborne surveillance (e.g. Brooke et al., 2010). Nevertheless, effective coastguards and the on-board presence of inspectors remain indispensable.

Many poor developing countries often need assistance with capacity building to meet their obligations in combating IUU fishing. Depending on the nature of a given measure, the costs of monitoring and enforcement vary considerably. Licensing, controls (e.g. of logbooks on land) and electronic monitoring with cameras or VMS tend to be less expensive. Having inspectors on board costs more. By comparison, building up an effective fisheries inspectorate or coastguard service that is equipped with ships and aircraft is very cost-intensive (Table 4.1-1). Fishermen who operate legally have an interest in helping to combat illegal fishing activities, for example by reporting sightings of IUU vessels. In West Africa, this is now done in the form of the Community Sciences Programme, supported by the World Bank, to combat IUU activities (Community Sciences, 2013).

With regard to IUU fishing, the biggest deficit in governance lies in the fact that countries that do not ratify an international agreement are not bound by its provisions. The provisions of the FSA, the PSMA and the FAO Action Plan are very promising. Ultimately, however, they can only have an effective and comprehensive impact if all the relevant countries involved in fishing activities actually accede to these agreements or undertake a voluntary obligation to apply the measures agreed in the Action Plan. Practical implementation remains weak at the present time. Despite visible progress in recent years, IUU fishing will remain a challenge to the international community for as long as it remains profitable to the perpetrators (OECD, 2010: 15).

One way out of the institutional difficulties could be to declare the high seas and their bioresources to be the common heritage of mankind (Hilborn, 2007), as is already the case under UNCLOS for the mineral resources of the seabed (Section 3.2). Access could then be linked to clear, harmonized and verifiable regulations. The OECD (2005: 51) believes this to be a viable option and expects this approach to build a more solid platform for the effective use of economic instruments, even though a reform of UNCLOS to this end is unlikely to be achieved in the short to medium term (Section 7.2.3.1).

4.1.4.6
The external dimension of the EU Common Fisheries Policy

The EU's fisheries policy – and in particular the renewed process of reforming its Common Fisheries Policy (CFP) begun in 2009 – has been discussed exhaustively by the German Advisory Council on the Environment (SRU, 2011b; Salomon et al., 2013) and is therefore only touched on briefly at the beginning of Section 7.4.1.7 in this report. From its global perspective the German Advisory Council on Global Change (WBGU) restricts its analysis to the cross-border effects of European fisheries – in particular to the 'external dimension' of the CFP and the problem of imports (Section 4.1.4.8).

In addition to regulations governing fishing activities within the EU's waters, the CFP also covers the activities of the EU fleet in waters outside of Europe. The latter is referred to as the policy's 'external dimension' (SRU, 2011b). The external dimension includes fishing both on the high seas and in the EEZs of non-EU countries. It also includes participation in international agreements and institutions (UNCLOS, FSA, RFMOs; Sections 3.2, 4.1.4.4) and the fight against IUU fishing (Section 4.1.4.5), which are not discussed in this section.

The EU is committed to the principle of complying with the same sustainability criteria in non-European waters as in its home waters. Between 2004 and 2006, fishing on the high seas accounted for about 20% of the EU's total fishing yield, while 8% was accounted for by fisheries agreements with non-European countries (EU Commission, 2011e).

Alongside the 'Nordic fisheries agreements', on the basis of which the EU cooperates with partner countries (Norway, Iceland, Faroe Islands; EU Commission, 2011f) to manage shared stocks in the North Sea and North-East Atlantic, the most important agreements from a development-policy perspective in the context of this report are the EU's fisheries partnership agreements (FPAs) with developing countries. At the end of 2012, the EU was committed to 20 of these agreements, although five of them were currently inactive (EU Parliament, 2012). The annual budget of € 160 million for these agreements is comparatively small. Annual payments to individual partner countries range from € 385,000 (Cape Verde) to €70 million (Mauritania; EU Commission, undated, 2012b). Most of the FPAs have been signed with African countries. Initially, the agreements between the EU and developing countries were exclusively commercial in nature, paying financial compensation in return for EU access to fish resources (Kaczynski and Fluharty, 2002). In the meantime, however, these agreements have been replaced by contracts which support sustainable fishing practices and are designed to help build up local fisheries and develop opportunities for cooperation.

However, there is still a long way to go before these FPAs become fully focused on sustainable fisheries, and the situation varies from country to country. Most of the agreements include quotas on the number and size of vessels. In many partner countries, however, fish-stocks monitoring is based on inadequate data. Since it is not unusual for both partners to fish the same stocks, the small-scale fisheries are frequently damaged by the foreign fleets, thus putting the local population's food security at risk (Marí, 2012). At the same time, fish from heavily subsidized European fisheries can often be sold on African markets at much lower prices than the produce of small-scale local fisheries. This has far-reaching socioeconomic consequences for the local population (Marí, 2012). Bycatch, too, is often sold at dumping prices, which can do huge damage to the fishing industry in partner countries (Ngembo, 2008). The inadequate administrative structures and surveillance technology in many developing countries often make it impossible to guarantee that catches are monitored and inspected. This opens the door to illegal fishing by foreign fleets, especially as there are often no sanctions if contractually defined fishing quotas are exceeded.

Some of the money that flows within the framework of FPAs is contractually tied to being used in developing the partner country's fisheries policy. Under the terms of FPAs, for example, the EU commits itself both to strengthening the fishing sector in partner countries and to helping to build up a scientific system for monitoring the fish stocks. To establish the development of the partner countries' fisheries policy as a key aspect of FPAs, the European Commission recommends that the corresponding sum be made available in a way that is independent of payments for resource access (EU Commission, 2011f). The contribution to the development of partner countries' fisheries policy varies between 25% and 100% of the total transfer payments (EU Commission, 2012c). In practice, however, it is difficult – nor does it lie within the EU's sovereign rights – to ascertain whether the money paid under the aegis of FPAs really is used effectively to strengthen the national fisheries sector and build up corresponding administrative structures. This requires functioning, transparent administrative structures. Moreover, money is not necessarily passed on to the lower levels of administration or to local fisheries associations (Tindall, 2010). To some extent, partner countries can also become financially dependent on FPAs.

Since the EU's negotiating position is usually stronger than that of developing countries, it seems questionable in some cases whether the financial support provided constitutes fair compensation for the fisheries, especially when measured against the value of the fish caught (Kalaidjian, 2010). The fact that the EU fleet often does not properly meet its accountability obligations is indicative of the imbalance that exists between the EU and third countries (Marí, 2010). On the other hand, many partner countries do not disclose the extent to which quotas outside the remit of the FPA with the EU are sold to other countries (EU Parliament, 2012). Since other fleets apart from those of the EU also operate in foreign EEZs, multiple sales and resultant overfishing cannot be ruled out. To ensure a sustainable fishing practice, the surplus should always be calculated based on the cumulative fishing effort of all licensed fleets. This lack of transparency on the part of the partner countries makes it impossible to lay down sustainable quotas on a scientific basis. Not least, this behaviour is inconsistent with the Cotonou Agreement signed in 2000 (EU, 2000).

Reform of the external dimension

Via the FPAs, the EU is partly responsible for the fishing crisis in other regions of the world, e.g. West Africa. The European Commission is essentially aware of the problem. In 2009 the green paper on the 'Reform of the Common Fisheries Policy' (EU Commission, 2009c) initiated a consultation process with public participation. In 2011 the European Commission then published a communication on the reform of the CFP analysing the shortcomings of FPAs, among other issues (EU Commission, 2011f). The European Commission saw significant weaknesses in the poor data situation on the state of fish stocks, a lack of transparency in the terms of FPAs, and inadequate options for partner countries to use the EU's transfer payments to improve their respective fisheries sector (EU Commission, 2011f). The EU aims to redesign the existing architecture of the FPAs in such a way that they can contribute to all aspects of sustainability, both in the EU and in the partner countries. Fearing painful economic losses for their fishing fleets, however, many EU countries are resisting this process.

The European Commission's Communication on the External Dimension (2011f) includes extensive proposals on redesigning the agreements as part of its reform of the CFP. Its principal demands are for agreements to be concluded based on the best available scientific information; for observance of human rights to be a condition of all agreements; for ship owners' financial participation to be increased; and for administrative structures to be strengthened in terms of surveillance, control and competency. Overall, however, the external dimension should not only support the build-up of administrative structures on the ground, but also ensure compliance with ecological and social standards by including development-policy aspects (food security, national fisheries policies, value chains) to a greater extent (EU Commission, 2011f).

One problem in this regard is that coordination of the CFP within the EU – and hence the involvement of the institutions responsible for the various aspects of sustainable fisheries – is relatively weak. Much greater cohesion is needed in particular between the EU's Directorate-General for Maritime Affairs and Fisheries (DG Mare) and its Directorate-General for Development and Cooperation (DG Devco). In addition, substantial improvements in coherence are needed between the EU's CFP and fisheries policies in the individual member

Box 4.1-10

The new Protocol to the EU's Fisheries Partnership Agreement with Mauritania

In July 2012 Mauritania and the EU initiated a new Protocol to their Fisheries Partnership Agreement (FPA) for a period of two years. Unlike the previous agreement, it contains a number of important innovations:

- The scientific basis for the determination of quotas has been improved.
- The coastal pelagic zone for exclusive use by small-scale fisheries has been extended from 13 to 20 nautical miles.
- The ship owners' financial contribution to the FPA has been substantially increased.
- Irrespective of payments for access rights (€67 million per annum), the EU will also provide €3 million a year to support the national fisheries sector.
- Vessels sailing under an EU flag are only allowed to fish within the framework of the FPA.
- Inside the Mauritanian EEZ, EU fishing vessels are obliged to hire Mauritanian nationals to make up 60% of their crews.
- A human rights clause has been introduced: the FPA can be immediately terminated if human rights are violated in any way.
- All fish caught in Mauritania's EEZ must be landed, provided that the Mauritanian infrastructure can ensure adequate refrigeration and processing.
- 2% of the fish caught by the EU fleet is to be made available (with no financial compensation) as a contribution to food security for the local population (EU Commission, 2012b).

On the last point, civil-society representatives have pointed out that catches made available by the EU fleet to ensure local food security could potentially have a negative influence on small-scale fishermen's market situation (Pêchecops, 2012). For this reason, the WBGU recommends that this measure be carefully evaluated. Another criticism is that the contribution in support of the Mauritanian fishing sector has been greatly reduced. While the previous protocol provided for €20 million a year, the current one specifies only €3 million. On the other hand, the amount set aside to support the Mauritanian fishing sector in the current protocol is independent of the payments made for access rights. Despite these isolated criticisms, the protocol has been largely welcomed by Mauritanian civil society (Pêchecops, 2012).

This new FPA protocol could show the way forward for future agreements, not least because the innovations listed above are backed up by detailed provisions on monitoring, control and enforcement. The plans for compulsory reporting and regular controls will enable swift action to be taken in the event of any undesirable developments. Before the protocol is ratified, it must first be approved by the European Parliament. After that, it is up to the EU and the Mauritanian government to jointly and rigorously implement the agreements and, in so doing, to prove that FPAs can be a suitable instrument for promoting sustainability in the fisheries sector.

states (Carbone, 2008).

If the EU nevertheless manages to give its FPAs a more sustainable design, they could be transformed into powerful partnerships for economic and development policy, creating a win-win situation for both parties. The analysis of weaknesses in the existing CFP conducted by the EU Commission (2009c) is largely accurate; and the reform proposals, supplemented by the European Parliament as described above (2012), are comprehensive and promising. The FPA between Mauritania and the EU launched in 2012 also gives reason for optimism (Box 4.1-10). The EU's efforts to reform the CFP are deserve explicit praise. However, only implementation will show whether the proposals represent more than just lip service. The WBGU outlines its recommendations for action on the external dimension of the CFP in Section 7.4.1.7.

4.1.4.7 Subsidies in the fishing industry

Seen from the sustainability perspective there is substantial overcapacity in the fishing industry, and its unregulated deployment poses a threat to fish stocks. On the one hand, this situation is due to technological development: the fishing capacity of large trawlers – which are also fish-processing factories – has increased roughly six-fold since 1970, while earnings per shipping unit have declined by two thirds (World Bank and FAO, 2009). On the other hand, government subsidies are one of the main reasons for the development and use of existing fishing capacity.

Widespread forms of subsidies in the fishing industry include, among other things, concessionary loans, tax breaks, fuel subsidies, exemption from fuel taxes, decommissioning programmes for ships, fixed minimum prices, investments in infrastructure and income support (World Bank and FAO, 2009). Narrow definitions limit subsidies to direct financial transfers from the government to fishery employees or fishing operations. Broader definitions describe subsidies as all measures – including things that governments do not do – which increase benefits to fishing operations in the short, medium or long term (Schrank, 2003). One attempt at an exact definition of subsidies can be found in Article 1 of the WTO Agreement on Subsidies and Countervailing Measures. Here, subsidies are defined as the direct or possibly direct transfer of funds from governments to individuals or companies; government revenue that is foregone; the provision by government of goods and services for less than market prices (with the exception of infrastructure); and government support for prices and income (WTO, 1994).

Scale of subsidies

Worldwide, total government subsidies to the fishing industry in 2003 were estimated at US$25-29 billion, of which an estimated US$16 billion was used to increase fishing capacity (Sumaila et al., 2010). The OECD estimates that its member countries made 'government financial transfers to fisheries' amounting to about US$7.3 billion in 2010 (OECD, 2012c). The global subsidies are of considerable importance, since they account for about a third of the fishing industry's total gross revenues of US$80-85 billion worldwide (Sumaila, 2012). Roughly 80% of subsidies are paid out in industrialized countries (World Bank and FAO, 2009). Sumaila et al. (2010) estimate that subsidies paid by 12 fishing nations (Japan, South Korea, Russia, Spain, Australia, Ukraine, Faroe Islands, Estonia, Iceland, Lithuania, Latvia and France) for bottom-trawl fishing on the high seas – a particularly problematic method from an ecological point of view (Section 4.1.2.3) – come to a total of US$152 million, of which fuel subsidies account for US$78 million.

The World Bank and the FAO (2009) put the figure for subsidies that directly influence the build-up of fishing capacity at over US$10 billion in 2000. Five types of subsidies are included in this calculation: fuel subsidies; the purchase of fish in the event of surplus supply; subsidies for vessel construction and modernization; tax breaks: and the expansion of fishing grounds by means of agreements to access the waters of third countries (World Bank and FAO, 2009).

Effect of subsidies

Depending on their nature and design, subsidies create incentives to increase fishing capacity and corresponding fishing activities by increasing fishermen's income, altering the cost/yield ratio, reducing investment risks, making fish products cheaper, or boosting demand. If, in the next step, catch and bycatch volumes increase as a result, this can cause long-term damage to fished stocks and marine ecosystems. Ultimately, subsidies help ensure that fisheries can continue operation even when it would not make commercial sense to do so without the subsidies (Pauly et al., 2002; Brown, 2007; World Bank and FAO, 2009; Markus, 2010; UNDP and GEF, 2012a).

The impact of subsidies on fish stocks and marine ecosystems can be seen in the changes they cause to the behaviour of fishermen (Schrank, 2003). Whether and how a certain subsidy contributes to overfishing also depends on the nature of the fishery, the biological state of the stocks, the existence of a system of fisheries management, the effectiveness of monitoring and enforcement mechanisms, and the prevailing socio-economic conditions (Markus, 2010). A badly designed subsidy can likewise contribute to overfishing. One example of this is decommissioning programmes that have no restrictions on the reinvestment of the decommissioning bonus in more modern vessels or fishing gear (Markus, 2010).

The contribution made by subsidies to overfishing is increased when there is no effective, sustainable national and international fisheries management. For at least in theory it is conceivable to actively promote fisheries – through income support or fleet modernization measures, for example – while simultaneously enforcing sustainable fisheries-management practices, thus causing only limited damage to fish stocks and ecosystems. Support measures on the one hand and limits on fishing activities on the other must therefore be weighed very carefully for reasons of environmental protection. The WBGU believes that in many cases the decline in catch volumes needed to effect the transition towards sustainable management would only be temporary, and that catch volumes could increase again within limits under certain circumstances, once stocks have recovered under a system of sustainable management. Fishermen's incomes are also more secure and predictable in the long term under a sustainable fisheries-management regime. Direct payments could be made to support the fishing industry during the transitional phase when catch volumes are being reduced until sustainable management is fully operational (UNEP, 2011b; Section 4.1.2.4).

Whenever subsidies are granted, free-rider effects must always be expected. There are also other reasons for the build-up of overcapacity, such as management mistakes or an expectation of growing demand. For this reason, abolishing subsidies does not inevitably lead to a reduction in fishing capacity, even though this effect is to be expected in many cases due to the scale and importance of subsidies for individual fisheries. The impact of a subsidy thus depends on the context.

Helpful and harmful subsidies

It is possible to distinguish between helpful and harmful fishing subsidies depending on their impact on the state of fish stocks and the marine environment (Kahn et al., 2006; UNEP, 2011b). Helpful subsidies lead to investments in natural capital such as fish stocks even if they are used for economic gain. In other words, helpful subsidies boost the growth of overfished stocks by applying conservation measures and prevent overfishing by introducing sustainable fisheries management. Harmful subsidies increase fishing capacity and contribute towards reducing investment in natural capital. This is the case when fishing capacity grows to a size at which catch volumes lead to overfishing and fisheries are no longer able to manage fish stocks sustainably (Kahn et al., 2006; Heymans et al., 2011).

Phasing out harmful subsidies

National and international fishery policies should ensure that fishing capacity is brought into line with the long-term, sustainable availability of stocks. In the light of the continuing overfishing of certain stocks and the existing overcapacity in fishing fleets, reducing or abolishing harmful subsidies is an effective way to combat overfishing.

Coastal states can identify harmful subsidies in a three-step process. *Step one*: assess the state of a fishery and define sustainable management thresholds. *Step two*: determine and assess the effect of existing fishing activities on fish stocks, and identify those aspects of the fishing industry that cause damage. *Step three*: examine how existing subsidies affect the fishing industry and the defined management thresholds; then make suitable adjustments (Markus, 2010). Despite the known difficulties in applying this process – such as exactly defining the thresholds of sustainable management (Section 4.1.3) and determining the effects of certain subsidies – it is nevertheless a suitable guideline for political action.

As in other branches of industry, the beneficiaries themselves are usually named as being the biggest obstacles to reducing subsidies in the fishing industry. Subsidies involve economic benefits. Over time – especially if the subsidies are not limited in time from the outset – the recipients gradually come to regard them as status-quo entitlements, i.e. as payments to which they have a right. Since cuts could lead to economic disadvantages, the recipients use political means to oppose any reduction, let alone phasing-out of subsidies.

The task of reducing subsidies is also made difficult by the fact that average incomes in the fishing industry remain comparatively low, despite the modernization of fishing methods, due to dwindling catch volumes and stagnating fish prices. As a result, representatives of the industry actively lobby for subsidies (World Bank and FAO, 2009; UNDP and GEF, 2012a; Sumaila, 2012).

Since cutting subsidies in the fishing industry can be linked to losses of income and jobs, it should, where necessary, be accompanied for a limited period by compensation, retraining and labour-market measures. These measures can be funded out of the money that is now no longer needed for the subsidies (UNDP and GEF, 2012a). The funds freed up in this way could also be used to support innovative measures such as 'fishing for plastic' or 'fishing for data' (Sumaila, 2012).

Both Norway and New Zealand, for example, have had positive experience with reducing fishing subsidies. In Norway, fishing subsidies were cut by 85% between 1981 and 1994 and replaced by financial support for alternative income options. In New Zealand, subsidies were reduced in the mid-1980s as part of a wider reform of fisheries. Neither case had any negative long-term effects on the economy as a whole (International Sustainability Unit, 2012).

In practice, it has also become clear that overcapacity is a major obstacle to introducing and implementing sustainable fisheries management (UNEP, 2008; Markus, 2012). Whatever means a management plan uses to achieve its ends, effectively reducing yields runs contrary to the short-term interests of the fishery, since it must either cut back capacity or make less use of it, leading to income losses. On the other hand, scaling back harmful subsidies and the resultant effects on overcapacity makes it easier to introduce sustainable fisheries management.

International negotiations and the WTO

Although many subsidies only affect a given nation's territorial waters and its fish stocks, there is also an international dimension to the harmful effects of national subsidies. Where national government subsidies contribute to the overfishing of a highly migratory fish stock, the subsidized national fishing industry benefits economically, while the consequences of possible damage to fish stocks and ecosystems must also be borne by other countries (Sumaila, 2012).

Since the late 1990s, civil-society stakeholders and the Friends of Fish group of countries (Argentina, Australia, Chile, Columbia, Ecuador, Iceland, New Zealand, Norway, Pakistan, Peru and the USA) have been calling on the WTO to look into the issue of fishing subsidies. In 2001 the final declaration of the WTO negotiations in Doha gave the WTO a mandate to conduct negotiations to clarify how fisheries subsidies might be treated within the WTO framework. Similarly, the final document of the World Summit for Sustainable Development in Johannesburg (WSSD or 'Rio+10 Conference') contains a passage calling for agreement on the treatment of fisheries subsidies within the WTO (WSSD, 2002: para. 86). At the 2005 WTO Ministerial Conference in Hong Kong, agreement was reached that future WTO rules should include a ban on all subsidies that lead to overcapacity and overfishing (UNEP, 2008). At the 'Rio+20 Conference', the international community again agreed to abolish subsidies that contribute to IUU fishing, overfishing and overcapacity (UNCSD, 2012). However, the WTO's specific negotiations in the context of the Doha Round have come to a standstill (Section 4.1.4.8).

Conclusions

It makes sense and is necessary to phase out harmful subsidies. In the context of sustainable fisheries management, there are no valid arguments why governments should support fishing for stocks that are either already overfished or threatened by overfishing. Subsidies create an incentive to overfish, especially when catch volumes are in decline. The World Bank and the FAO (2009), too, have called for global fishing fleets to be halved, arguing that the additional costs to the fishing industry are disproportionate (Section 4.1.3.6; Munro, 2010). Phasing out harmful subsidies can help reduce fishing capacity and thereby ease the pressure on fish stocks. The funds released when subsidies are reduced could be used to finance the implementation of more a effective system of fisheries management, compensation for fishermen over a limited period, or research and development activities. In developing countries, due consideration must always be given to the local population's food security when scaling back subsidies.

4.1.4.8
International trade and trade policy

Section 4.1.2.2 showed that both the volume and the value of internationally traded fish and fish products have increased significantly over the past ten years (FAO, 2009a, 2012b). Part of this increase is attributable to technological developments in the storage, processing and transportation of fish and the ever increasing use of information and communication technologies in logistics. Further contributions have been made by the growing integration of developing and newly industrializing countries into the global market and the associated international division of labour (FAO, 2009a, 2012b; Markus, 2012). On top of these factors comes a growing demand for fresh fish and fish products. In industrialized countries, demand has increased as a result of price cuts for aquaculture products and health-conscious eating habits. In newly industrializing countries, income growth has driven stronger demand and led to changes in eating habits (Section 4.1.2.1; FAO, 2012b; Markus, 2012). Growing demand for fish products in industrialized countries is primarily being met by imports of fish and aquaculture products.

The EU, the USA and Japan are the biggest importers. Imports cover 60% of fish consumption in both the EU and the USA and 54% in Japan (FAO, 2012b; Markus, 2012). Within the EU, Spain, France, Italy, Germany, the UK and Sweden rank among the major importing countries. All in all, the EU – including internal trade within the single market – is the world's biggest market for imported fish products, and an increasing proportion of these come from aquaculture (Section 4.2; FAO, 2009a). Excluding internal trade, the EU imported fish products worth US$23.7 billion from third countries in 2010, a figure equivalent to 26% of total global fish imports in that year (FAO, 2012b). Developing countries (e.g. China, Vietnam and Thailand) were major suppliers of fish and fish products in 2010, accounting for more than 50% of global exports (FAO, 2012b). Since 2002 China has increasingly been assuming a special role in the international trade in fish and fish products. It is not only the leading exporter, accounting for 12% of global exports in 2010, but also increasingly a significant importer, having built up a fish-processing industry over the past ten years (FAO, 2009a, 2012b). Other important exporting countries include Norway, the USA, Canada and Chile, as well as the EU. Within the EU, Denmark, the Netherlands and Spain are the biggest exporters (FAO, 2012b).

International trade in fish and fish products has brought forth not only a new division of labour between developing and industrialized countries, but also new value chains that are increasingly being vertically integrated by large fisheries, international food corporations and restaurant companies (FAO, 2012b; Markus, 2012). By engaging in direct investments, large fishing companies are seeking to gain direct access to fish resources and fish stocks in the EEZs of developing countries, and also to build up a local processing industry in these countries. At the same time, international food corporations and restaurant companies are also using direct investment to gain influence in the fish-processing industry, in order to enforce private standards. These private standards are intended to help avoid overfishing and combat illegal fishing (Section 3.5; FAO, 2009a; Markus, 2012). With the aid of direct investment it is to some extent possible to bypass exporting countries' restrictive trade policies, for example in the form of export duties (Markus, 2012; WTO, 2010). The process of internationalization is leading to a form of market concentration whose the effects on sustainable fisheries and aquaculture are currently unclear. Considerable research is still needed in this field.

Impact of international trade

Two-country economic models can be used to show that an international fish trade under a regime with free access to fish stocks leads to overfishing, and that the benefits of specialization do not accrue to both countries (Asche and Smith, 2010; WTO, 2010). The specification and allocation of ownership rights is a precondition if both countries are to reap welfare gains from international trade. There is also empirical evidence suggesting that the international trade in fish in countries operating a sustainable fisheries-management system does not have a negative impact on stocks (Markus, 2012). At least in theory, the introduction of EEZs (Section 3.2) has solved the problem of free access to the waters of coastal states (Asche and Smith, 2010). This does not apply to the high seas, however, as UNCLOS does not define any ownership rights in this area. Use of the high seas is limited only by general provisions on the conservation of living resources according to the maximum sustainable yield (Box 4.1-5) and the equally general principle of cooperation between the states (Box 4.1-8). The more detailed provisions of the FSA and the RFMOs apply only to their respective states parties or member states (Section 4.1.4.4). It follows that the current state of fish stocks in the high seas corresponds largely to that of a free-access regime (Box 4.1-9).

As shown in the preceding sections, ownership rights are a prerequisite for the sustainable management of fish stocks, but they are not a sufficient condition if the rights of ownership or use cannot be enforced (Sections 4.1.2.3 and 4.1.3; Asche and Smith, 2010). If ownership rights cannot be enforced, the free-rider problem remains (Section 3.1), and the result is overfishing, which can be exacerbated by international trade (Asche and Smith, 2010; WTO, 2010). If negative external international effects cannot be internalized by national measures or international agreements, then trade-policy measures are regarded as the second-best solution (WTO, 2010). The introduction of an import tax in the two-country model leads to a reduction in the demand for fish in the importing country and thus can theoretically contribute to sustainable management of fish stocks in the exporting country (WTO, 2010). The same effect could also be achieved by imposing an export tax in the country specializing in fish production. However, the positive effect of this trade-policy measure depends on alternative economic sectors in the exporting country.

Another possibility is to introduce ecolabels to designate goods produced in an environment-friendly way (Section 3.5). In this case, consumers can decide which fish or fish products they wish to buy: either more expensive fish products from sustainable fisheries and aquacultures, or less expensive fish products that do not comply with sustainability standards (Section 3.5). Where such a voluntary instrument is used, the effect of this trade-policy measure depends on the purchasing power and preferences of consumers in the importing country (WTO, 2010). In theory it can be shown that, for trade with natural resources (assuming that the overuse of the resource is simultaneously avoided), bilateral trade agreements with transfer payments or regional integration (as in the EU or NAFTA) together with a common fisheries policy are beneficial to the welfare of the countries that participate (WTO, 2010). Both alternatives are cooperative solutions that maximize overall welfare in the countries concerned.

The international trade regime for fish products

International fish-trade policy is subject to the regulatory system of the World Trade Organization (WTO), whose goal is to eliminate barriers to trade. Under the WTO's rules, fish products are regarded as normal industrial goods and are not covered by the separate Agriculture Agreement (Asche and Smith, 2010; Markus, 2012). For this reason, the General Agreement on Tariffs and Trade (GATT) is most relevant treaty. Alongside GATT, the Agreement on Subsidies and Countervailing Measures (ASCM), the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS), and the Agreement on Technical Barriers to Trade (TBT) number among the other WTO regulations that are potentially relevant for fish products.

One of the aims of GATT is to reduce tariffs in the long run and avoid distortions of competition caused by discrimination or preferential treatment. Exceptions and principles on the protection of the environment or of fish as a resource are conceivable, provided that compliance with the requirements laid down in Article XX of GATT is assured (Markus, 2012; WTO, 2010).

Subsidies in the fishing industry are estimated at just under a third of global gross revenues from fish production (Section 4.1.4.7). Since they distort production and trade, the ASCM could be applied, although it contains no rules that are specifically tailored to fisheries (Markus, 2012). To date, ASCM has not been relevant to the international fish trade (Section 4.1.4.7; Markus, 2012).

As the fish-processing industry is increasingly being offshored to developing and newly industrializing countries, the SPS Agreement is becoming increasingly important in relation to trade with fish and fish products, because many developing countries do not have the capacity to meet the import standards demanded by industrialized countries (FAO, 2009a).

The TBT Agreement has been applied in one case which went to arbitration at the WTO and became known as the Shrimp/Turtle Case. The USA had demanded that all imports of shrimps be caught using a technology that would enable turtles inadvertently caught along with them to escape from the nets. In 1997 India, Pakistan, Malaysia and Thailand brought the matter before the WTO and won their case – because the USA had discriminated between WTO member states, having provided technical and financial assistance to some countries to enable them to meet these import requirements (Asche and Smith, 2010). However, measures to protect endangered species or the environment are generally permitted even if they restrict trade, provided that the legal requirements of Article XX of GATT are met and compliance with minimum requirements such as non-discrimination and information obligations is assured (Markus, 2012). That is why, when Malaysia filed a further suit with the WTO in the Shrimp/Turtle Case in 2001, the USA this time won on the basis of Article XX GATT, having this time designed its import policy in a non-discriminatory way.

Parallel to the WTO rules there are also trade-restricting agreements on the protection of fish stocks and the environment. To date there has been no open dispute between the WTO and other agreements under international law (WTO, 2010; Markus, 2012). The agreements of relevance to the fish trade are the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), trade-restricting measures by regional fisheries management organizations, the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing, and the FAO's Code of Conduct for Responsible Fisheries (Sections 3.3, 4.1.4.3, 4.1.4.5; Markus, 2012).

The EU's fish-trade policy

Because of its standing as the world's biggest import market for fish products, the EU exerts a major influence on fisheries in other countries through world trade. Up to now, the goals pursued by the European fish-trade policy with third countries have been those of supplying the EU with fish products, advancing economic development, and implementing its policies on health and the environment. In some cases, import restrictions involving selected developing countries have been phased out (Cotonou Agreement and, today, economic partnership agreements). In other cases, however, there have been replaced by non-tariff trade barriers in the form of quality and hygiene standards (Markus, 2012).

Within the EU, the internal market facilitates the free movement of goods and prohibits member states from introducing import or export duties, import or export restrictions or discriminatory taxes. At present, the trade in fish between the member states can only be controlled by the 'Council Regulation establishing a Community system to prevent, deter and eliminate illegal, unreported and unregulated fishing'. In accordance with this regulation, member states are authorized to withdraw illegally caught fish from the market. The same applies to fish imported from other member states (Markus, 2012).

In principle, the EU's fish-trade policy with third countries gives it a way of promoting sustainable fisheries at the international level. The EU should step up its use of this possibility in future, too, especially as it is a member of eleven RFMOs and represented at 17 RFMOs (Section 4.1.4.4; Markus, 2012). Within the framework of its bilateral and multilateral agreements with exporting countries, for example, the EU could support the development of sustainable fisheries management by means of transfer payments (Section 4.1.4.6). It could analyse the development of trade flows in fish products into the EU and their effects in the exporting states at regular intervals in order, where appropriate, to combat overfishing. This would also involve studying the effects of direct investment, treaties with third countries, and private fishing activities in the waters of third countries. The EU has committed itself to taking steps to conserve fish stocks in the context of its implementation of fish-stocks management rules under international law (UNCLOS, FSA and RFMOs; Markus, 2012). One example of such a measure is the 'Regulation on certain measures in relation to countries allowing non-sustainable fishing for the purpose of the conservation of fish stocks', which was adopted by the Council and the European Parliament in 2012 (Markus, 2012). Armed with such a far-reaching instrument – which can restrict imports from such countries, for example, while simultaneously being consistent with WTO rules – the EU can exert considerable international pressure on exporting countries which fail to provide the targeted level of protection for the maximum sustainable yield.

Within the framework of the ongoing Doha Round of negotiations, the EU should give its backing to the initiative launched by the Friends of Fish group and actively support the abolition of subsidies in the fishing industry (Section 4.1.4.7). In addition, the EU should show a strong commitment to ensuring that measures such as ecolabels and import restrictions to protect the environment are in line with current valid WTO rules.

While the specific recommendations for action contained in Section 7.4.1.7 provide important ways to target greater sustainability, it should be remembered that international trade-policy instruments are only a second-best solution in order to achieve sustainable fisheries worldwide.

4.2 Aquaculture

Aquaculture has a tradition that goes back millennia. For example, integrated fish-farming practices have existed in China for 4,000 years. However, only in the last few decades has aquaculture developed into a major, global industry (Frankic and Hershner, 2003). In 2010 it contributed almost half (47%) of humanity's consumption of fish and seafood (FAO, 2012b: 24, 26). Aquaculture production has been growing rapidly over the last 40 years, with the global annual growth rate averaging around 8%. Growth between 2006 and 2008 was still high at 5% (FAO, 2010b: 18).

Table 4.2-1
Global aquaculture production in millions of tonnes (excluding aquatic plants).
Source: FAO, 2012b: 3

	2006	2007	2008	2009	2010	2011
Inland	31.3	33.4	36.0	38.1	41.7	44.3
Marine	16.0	16.6	16.9	17.6	18.1	19.3
Total	**47.3**	**49.9**	**52.9**	**55.7**	**59.9**	**63.6**

At the same time, per-capita consumption of aquaculture products has increased more than tenfold since 1970 – to 8.7 kg in 2010 (FAO, 2012b: 26). Since yields from fisheries are stagnating (Section 4.1.1), aquaculture production looks likely to overtake landed catch volumes in the near future and become the most important global source of fish and seafood. In this chapter the term 'aquaculture' is used to mean both land-based and marine aquaculture (mariculture). Since both the number of farms and the quantities produced by marine aquaculture worldwide are small compared to land-based aquaculture, most studies do not analyse mariculture separately, and figures on the development of marine aquaculture are rarely available. The Food and Agricultural Organization (FAO) is an exception here (2012b: 3); it breaks down some of its global statistics according to inland and marine aquaculture (Table 4.2-1).

Aquaculture has the potential to continue expanding production in the coming decades, thus contributing to world food security and to meeting the growing demand for aquaculture products. However, aquaculture at present involves significant negative effects on the environment in many areas. Depending on what form it takes, aquaculture can cause considerable environmental stress. Also, feeding the farmed organisms can, in some species, require several times more fish than is ultimately produced (Section 4.3). Progress has already been made in addressing these problems, and there is great potential for making aquaculture more sustainable by means of improved management and technological development. Political decision-makers and civil society can provide important stimuli in this respect.

4.2.1
Definitions and principles

Aquaculture is defined as the cultivation of aquatic organisms involving controlled intervention in the breeding process with the aim of increasing production. The cultured organisms include fish, mussels and other molluscs, crustaceans, aquatic plants, as well as crocodiles, turtles and amphibians.

Unlike the situation in fisheries, organisms bred in aquaculture are the private property of the respective producers according to the FAO's definition (FAO, 2013a). Since part of this chapter focuses on the interactions between aquaculture and fisheries (Section 4.3), Section 4.2 concentrates on the production of animals. Cultivation of plants and algae are only mentioned briefly (Box 4.2-1).

Production systems used in aquaculture differ according to the type of feeding strategy. *Extensive* cultivation requires no external additions to the feed; it is based on naturally occurring food sources and is considered to have little impact on the environment in most cases (FAO, 2013b). Filter feeders such as mussels are often grown extensively. They hang on lines in nutrient-rich waters, feed on plankton from the surrounding sea water, grow and are eventually harvested. Fish and other organisms can also be cultivated extensively; they are given little or no additional feed, and stocking densities are low. *Semi-intensive* systems involve little feeding or fertilizing (FAO, 2013b) and are often combined with agriculture; as forms of a subsistence or local economy they are often ecologically more sustainable than intensive systems. *Intensive* systems are completely dependent on the provision of additional feeds, either fresh or in processed form (FAO, 2013b). This production method can generate high yields in a small space, as in the case of salmon farming in Chile. However, intensive aquaculture can also cause ecological damage, e.g. by polluting the water, interfering with adjacent wild stocks or using large amounts of resources.

Aquaculture farms range from small subsistence ponds in Africa to international companies with annual turnovers in excess of US$ 1 billion (Bostock et al., 2010). According to the FAO (2012b: 25), about 600 aquatic species are cultivated globally in fresh, brackish or marine water.

Distinctions are made between freshwater aquaculture in cages, tanks and ponds, brackish-water use in coastal basins and lagoons, floating cage farms installed near the coast, and other open-water cultures such as long-tube, long-line or lantern cultures (Bostock et al., 2010).

Box 4.2-1

Algae cultivation and use

Aquaculture also includes the farming of algae, which have a very wide range of uses: as food and dietary supplements for people; in agricultural animal husbandry and aquaculture; as a fertilizer for soil; for treating wastewater; and in the medical and pharmaceutical field (Olsen et al., 2008; Hasan and Chakrabarti, 2009; Paul et al., 2012).

Since the 1970s, algae cultivation has grown at an average rate of 7.7% a year. East and Southeast Asia dominated the market in 2010 with nearly 99% of total output. The biggest producer was China with 58%, followed by Indonesia with 21% and the Philippines with just under 10% (FAO, 2012b: 41).

19 million tonnes of algae worth US$5.7 billion were produced in 2010. 98.6% of global production was dominated by marine macroalgae such as Japanese kelp and other species of sea grass. Freshwater microalgae (mainly cyanobacteria such as *Spirulina spp.*) only made up a very small proportion (FAO, 2012b: 40). Macroalgae accounted for 23% of the biomass produced by global aquaculture, but only 8% (2007) of the traded value (Paul et al., 2012: 268).

Algae are rich in proteins, vitamins and minerals. Macroalgae therefore have a very long tradition as a human food and are especially widespread in Asia (MacArtain et al., 2007). They are also increasingly being used as additives in animal feed (e.g. for fish; Section 4.3.3) because of their positive effects on the growth and development of the farmed fish. Microalgae are used mainly as a feed in animal husbandry and aquaculture (Hasan and Chakrabarti, 2009). In addition, marine macroalgae contain valuable lipids, which could in fact be used more as a feed in aquaculture. Since their fat content only makes up about 2% of their dry matter, and intensive use would require the use of modified industrial processes, algae are not yet used as a source of fat (Olsen et al., 2008).

In addition, offshore aquaculture is also practised – on a small scale up to now. This method is exposed to a variety of harsh conditions and is usually located at least 8 nautical miles from the coast. However, there is no uniform definition of offshore aquaculture, and the crucial factors tend to be the harsh conditions rather than the distance from the coast (Buck et al., 2004; Ryan, 2005; Troell et al., 2009). Offshore aquaculture uses either nets floating on the surface, cages anchored to the sea floor, or hanging systems for growing mussels (Naylor and Burke, 2005; Bostock et al., 2010). Breeding marine organisms in brackish water or marine environments is also known as mariculture (CBD, 2004b).

Furthermore, some countries such as South Korea, Iceland and Germany have developed sea-water culture systems using tanks on land. The water circulation is connected with the open sea by means of pumps, so these systems are not completely isolated (Bostock et al., 2010).

Different groups of organisms have very different needs when it comes to rearing and feeding, and this can in turn be a determining factor for environmentally compatible production. A choice can be made between filter feeders (e.g. mussels) and plant-eating (herbivorous), omnivorous, carnivorous or waste-processing (detritivorous) species.

Filter feeders, detritivorous and herbivorous species occupy a lower trophic level in the aquatic food web, the carnivorous ones a higher level. Mussels and some freshwater fish are produced without feed additives. In 2010 this form of aquaculture accounted for about a third (by volume) of all animal aquaculture products for human consumption (FAO, 2012b: 29). Much of the feed of the carnivorous species consists of fresh fish or fish meal and oil produced from wild-caught fish, so that some forms of aquaculture contribute to the overfishing of wild stocks (Section 4.3.1).

The biggest share of global aquaculture production does not consist in the production of carnivorous species, which are bred mainly in mariculture operations. In 2010 almost 62% of the quantity and 58% of the value of animal aquaculture products were grown in lakes or freshwater ponds; almost 92% were fish with a mostly herbivorous and omnivorous diet. By way of contrast, marine aquaculture made up more than 30% of the quantity and just under 30% of the value. In terms of quantity, 76% of marine aquaculture output comes from the breeding of molluscs, especially mussels, 18% is fish, and less than 4% marine crustaceans. Brackish-water culture in 2010 made up just under 8% of the total quantity, but almost 13% of the value, mainly due to economically valuable shrimp farming, which accounts for more than 57% of brackish-water aquaculture. Freshwater and diadromous fish accounted for approximately 34% of the total value (FAO, 2012b: 34 ff.). In 2006 species at lower trophic levels (including plants, filter feeders, herbivorous and omnivorous fish) made up about 74% of global production (Tacon et al., 2010: 98).

4.2.2
State of aquaculture and trends

4.2.2.1
Growth and regional overview

Aquaculture is the world's fastest-growing animal food sector. In 2010 output totalled 60 million tonnes (not including plants and products not bred for human consumption) and had a value of US$119 billion (FAO,

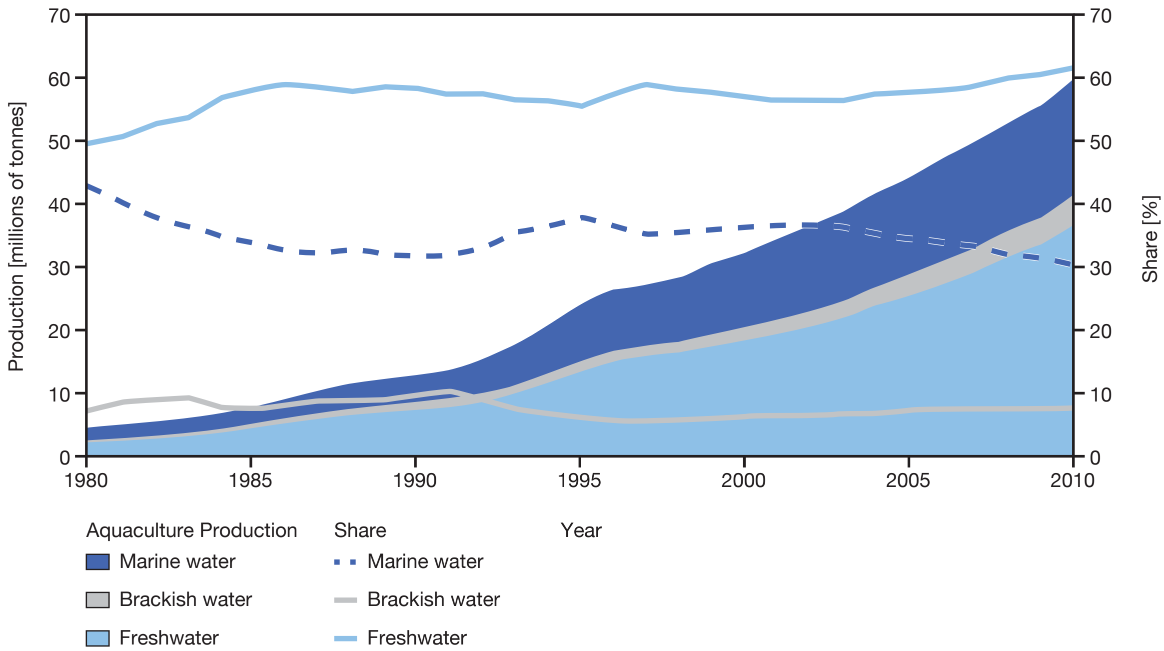


Figure 4.2-1
World aquaculture production from 1980 to 2010 (in millions of tonnes); trends in types of production (freshwater, brackish water and marine water). The coloured areas show the absolute production; the lines show the relative share.
Source: FAO, 2012b:34

2011c, 2012b:24; Figure 4.2-1). In order to meet the per-capita consumption of 280 g of fish per week recommended by the British Scientific Advisory Committee on Nutrition, annual per-capita consumption would need to increase from 17 kg (live weight equivalent) of fish to 23.3 kg. In order for this increase not be offset by additional yields from fisheries, 40 million more tonnes of fish would have had to be produced in aquaculture in 2008.

It is estimated that 23.4 million people were directly employed in aquaculture and secondary industries like processing, marketing and sales in 2005; 92% of these were in Asia. Assuming an average family size of five people, aquaculture thus contributed to the livelihoods of about 117 million people (FAO, 2011c:62).

Aquaculture records its highest growth rates in developing countries, above all in Asia. Average annual growth rates in industrialized countries have declined from 2.1% in the 1990s to 1.5% in the 2000s (FAO, 2012b:29). Between 2000 and 2010, worldwide freshwater aquaculture posted growth rates of 7.2% per year, while marine aquaculture grew by 4.4% per annum in the same period (FAO, 2012b:34).

The majority of freshwater fish cultivation takes place in Asia and is dominated by the production of carp species; almost 71% of these were produced in China in 2008 (Hall et al., 2011:10; FAO, 2011c). For several years there has been a trend towards the cultivation of tilapia and pangasius (Bostock et al., 2010). Despite the development of larger farms, the majority of aquaculture production in the Asia-Pacific region is still generated by small farmers (FAO, 2011c). In industrialized countries, production concentrates on economically high-value species of fish, more than 90% of which are at a high level of the food chain: e.g. Atlantic salmon in marine aquaculture and rainbow trout (Tacon et al., 2010:99). However, aquaculture production has been stagnating or declining in some industrialized countries, e.g. in the USA, the UK and Japan. Norway is an exception; here, the cage culture of Atlantic salmon grew by an average of 7.5% a year in the 2000s (FAO, 2012b:29). Global production of aquaculture salmon has almost quadrupled since the early 1990s (Naylor and Burke, 2005).

Of the world's ten leading nations – which contribute nearly 88% of the volume and about 82% of the value of the globally cultivated fish and seafood – eight are from Asia. The biggest non-Asian producers are Norway and Egypt. China alone accounts for 61% (2010 figures: FAO, 2012b:27 ff.; Table 4.2-2). The reasons usually given for the rapid expansion of China's aquaculture production are economic growth, population growth, the presence of traditional aquaculture practices, increasing export opportunities, and relatively weak regulation (Bostock et al., 2010). A considerable proportion of China's aquaculture production is exported. There is some scepticism about the reliability of the figures reported from China, although

Table 4.2-2
The world's top ten aquaculture producers in 2010. Each country's aquaculture production is shown in millions of tonnes and as a share of global production.
Source: FAO. 2012b: 28 (figures roundes)

Country	Amount [millions of tonnes]	Share [%]
China	36.73	61.4
India	4.64	7.8
Vietnam	2.67	4.5
Indonesia	2.30	3.9
Bangladesh	1.30	2.2
Thailand	1.29	2.2
Norway	1.01	1.7
Egypt	0.92	1.5
Myanmar	0.85	1.4
Philippines	0.74	1.2
Others	7.40	12.4
Global	**59.87**	**100**

data collection and reporting to the FAO have improved (Rawski and Xiao, 2001; Pauly and Froese; 2012; FAO, 2012b). Incomplete and unreliable data are still a problem in other countries, too, especially in developing countries, yet the data are supposed to provide information, for example, on production and development in the aquaculture sector, or on environmental and health hazards (Hishamunda et al., 2012).

Due to the limited availability of fresh water and space on land, coastal sea-water and brackish-water aquaculture is expected grow more strongly in the future. This will aggravate the competition for space on the coasts (Duarte et al., 2009; Bostock et al., 2010). Furthermore, the growth of marine fish farming is still limited by the production of fish feed, because this is still dependent on fish meal and fish oil from wild-caught fish (Section 4.4). Much of the growth of marine aquaculture takes place in what are often weakly regulated coastal waters of developing countries (Adger and Luttrell, 2000; Buck et al., 2008). The density of breeding farms in coast-based aquaculture production can vary by a factor of up to 50 (Figure 4.2-2). The differences suggest that there is still considerable development potential along hitherto little-used coasts. However, there are no estimates of future global yield potential, partly because offshore aquaculture is still in its infancy.

4.2.2.2 Contribution to food security and poverty reduction

Products from aquaculture and fisheries are among the most intensely traded agricultural commodities worldwide, and with a global export value of US$92.8 billion in 2007 they are second only to fruits and vegetables (US$150.9 billion; WFC, 2011a: 18). Developing and newly industrializing countries, especially China, Thailand and Vietnam, are the main producers of aquaculture and fishery products worldwide. They accounted for 80% of global production and 50% of the global export value of these products in 2008 (US$50.8 billion; FAO, 2011c). The developing and newly industrializing countries are net exporters of aquaculture and fishery products, and their main markets are Japan, the USA and the EU.

Since FAO statistics on the international trade in fish products do not distinguish between fisheries and aquaculture, aquaculture's share of global trade is difficult to determine (FAO, 2011c). Estimates for China made in 2006 suggest that 39% of the production volume and 49% of the production value of China's aquaculture production was exported (Fang, 2007: 200).

Aquaculture can make a contribution to food security and poverty reduction in developing countries. This contribution involves several factors: the consumption of these products; increases in income as a result of employment or sales; reductions in the price of competing products such as wild fish compared to a market without aquaculture products; local extensions of the value chain; the location of complementary industries; and increased consumption in other areas (Gordon and Kassam, 2011; WFC, 2011a).

Cultivation in small cultures in people's gardens or backyards plays an important role in developing countries, especially in Asia (Kongkeo and Davy, 2010). However, although subsistence aquaculture farmers can increase the food security of their households (especially in Africa), their low level of productivity means that they do not make major contributions to food security at the national level (Beveridge et al., 2010).

According to the FAO's assessment, aquaculture's contribution to food security is widely recognized and consists mainly in providing poorer people with affordable freshwater fish, employment and income effects, and the promotion of women (FAO, 2011c). Critics point out, however, that the effects are not inevitably beneficial and depend greatly on the respective context (WFC, 2011a).

Several studies document such positive effects. A study in Bangladesh found positive effects on income, consumption and employment among poor households practising aquaculture (Jahan et al., 2010). Case stud-

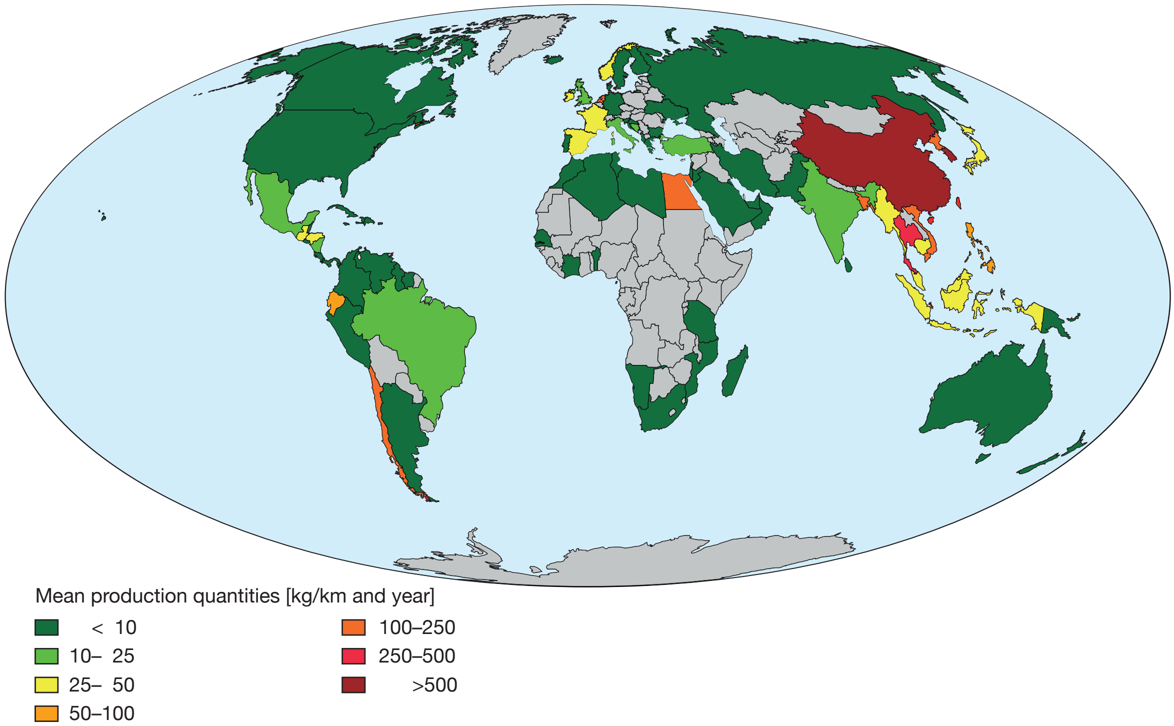


Figure 4.2-2
Mean production quantities from coastal aquaculture systems in different countries as function of coastline length for the period 2005 to 2007.
Source: Bostock et al., 2010

ies, for example in Malawi and China (Dey et al., 2000, 2006), show that households that practise aquaculture consume fish more frequently than households that do not. Another relevant aspect is that in many parts of the world women play an important role in the production and marketing of fish and seafood from aquaculture. When women receive additional income from aquaculture, they tend to use it more frequently than men to improve food security in their households. However, this has not yet been sufficiently proven by studies (Kawarazuka and Béné, 2010). Taking gender issues into account is an important prerequisite for improved food security and poverty reduction (WFC, 2011a).

Whether aquaculture develops beyond self-sufficiency or supplying local markets depends on numerous factors. Apart from access to suitable areas for cultivation, it requires market demand and competition, access to technologies, infrastructure, a trained workforce, a functioning institutional system, and a sufficient willingness to invest.

In many cases, the necessary conditions for the development of aquaculture are not given, however. Lack of access to water, land, capital or credit, inadequate technical or other specialist knowledge, and high risks (such as loss of stock) that must be insured are real obstacles, especially for poor sections of the population (WFC, 2011a; Stevenson and Irz, 2009). In some countries, however, initial actions to specifically support capital-poor and small-scale aquaculture farmers are being taken (Box 4.2-2).

Especially in Africa and Latin America, aquaculture development is hindered by weak demand, poor infrastructure and insufficient quality controls for export products (Bostock et al., 2010). In Asia, by contrast – where demand is rising due to a growing urban population, a dynamic private sector exists, and there has been investment in research, development and infrastructure – many small and medium-sized enterprises have become established over the last 15 years serving the domestic and international markets (WFC, 2011a).

In general, aquaculture's potential contribution to food security depends greatly on the context of institutional, political, economic, social and natural factors (Stevenson and Irz, 2009). For example, the success of aquaculture development as an effective strategy for fighting poverty remains controversial (WFC, 2011a). Although there is often potential for poverty reduction, it is often not the poorest who benefit, but more highly capitalized farmers (Beveridge et al., 2010). Aquaculture creates employment opportunities, but because

Box 4.2-2

Promotion of small-scale aquaculture: aqua clubs in Asia

Poorer populations can also run aquaculture farms if they are supported by public or private funding, assured access to resources like land and water, and given assistance in hedging against risks (WFC, 2011b).

Various forms of self-organization are particularly promising. One example is aqua clubs in Asia. These are regional associations of producers that can range from self-organized self-help groups (often made up of local neighbouring farms) to official supraregional networks. They cooperate with national and international insurance companies (Subasinghe et al., 2009).

Such an association can reduce costs, e.g. by joint purchasing (leading to quantity advantages), build up partnerships with the public or private sector, improve access to financial resources, and enable knowledge transfer. They can also make it easier for their members to reach the necessary quality standards of national and international markets by changing the production process (Padiyar, 2005; FAO, 2011c; WFC, 2011b). Consumer expectations (product quality, food safety, environment-friendly production) can be better met by cooperating with small farmers and applying best-management practices (BMPs; de Silva and Davy, 2010). Export-relevant product certification becomes easier. BMPs and joint management can also help local associations to set up rules on minimizing negative environmental effects or preventing the spread of disease. Cooperation can ultimately also prevent conflicts (Padiyar, 2005; Bondad-Reantaso et al., 2008).

In general, promotion measures are more likely to be successful if they meet the following conditions: if they support small, owner-operated farms; if there is small-scale investment; if production is in line with demand; if the species bred are at a lower trophic level; if farmers and families participate in development; and if locally adapted methods and technologies are used (FAO, 2011c).

the wage level is very low, they often do not help people escape from poverty, but usually simply replace one source of income with another. Indeed, informal rights of access and rights to use resources are often destroyed by the privatization of land for aquaculture development. It is primarily farm owners, better trained employees and wholesalers who benefit. In addition, poor sections of the population are often hit particularly hard by the environmental damage caused by aquaculture; after all, they are especially dependent on freely accessible natural resources, and these can be impaired by the introduction and expansion of aquaculture. As a consequence, where the aim is to improve the supply of fish to poorer sections of the population, politicians currently prefer to encourage investments in larger enterprises, rather than promote resource-poor small-scale aquaculture (WFC, 2011b; Box 4.2-2).

4.2.2.3 Environmental risks from aquaculture and conflicts over use at the coasts

Existing aquaculture practices have led to a number of problems that could involve risks for the ecosystems affected – and even the industry itself – if there is further expansion and regulation is weak. For example, shrimp farming in Mozambique recently suffered a total loss following a disease outbreak (FAO, 2012b:9). The main target of criticism here is the often unregulated development of intensive production systems for shrimp and carnivorous fish such as salmon and tuna (Tacon et al., 2010).

Intensive breeding involves the risk that water bodies and the seabed become contaminated. Nutrients from feed residues and faeces accumulate, which can lead to eutrophication and subsequently to a lack of oxygen in the water column and on the seabed. The use of chemicals such as pesticides, herbicides, antiparasitic agents and antibiotics can contaminate the sediment and the water column and harm the organisms that live in them (Frankic and Hershner, 2003; Hernando et al., 2007).

The high stocking density in intensive cultures facilitates the spread of parasites and diseases. Genetically modified or exotic organisms repeatedly escape from the farms into the marine environment and can transmit diseases and parasites or spread genetically modified material into wild populations (Naylor et al., 2000; Youngson et al., 2001; Stickney and McVey, 2002). Similarly, the transfer and introduction of mussels and oysters, the cultivation of which is considered less harmful to the environment, can also disturb the surrounding ecosystems if parasites or other species are unintentionally imported and enabled to spread (ICES WGMASC, 2011). Moreover, the risk of diseases breaking out within intensive cultures has led to the use of large amounts of pharmaceuticals. Antibiotic substances can have a detrimental effect on fish, land animals, human health and the environment in general, especially if resistance to antibiotics grows amongst pathogens (Cabello, 2006).

Seafood from aquaculture that is contaminated with antibiotics has already led to critical debates in the consumer countries and to deliveries of goods being stopped (Ronnback et al., 2002). The very strong expansion of aquaculture production and corresponding farms in some regions can also pose a threat to the surrounding ecosystems (Telfor and Robinson, 2003). Especially where ecosystems straddle borders, the

Box 4.2-3

Mangrove forests: importance and the threat from aquaculture

Mangroves are salt-tolerant plants that form forests in the tidal regions of tropical and subtropical coasts (Seto and Fragkias, 2007). They perform important ecosystem services such as protecting coasts from hurricanes and erosion, stabilizing sediments, controlling floods and providing nutrients for the marine food web (MA, 2005a). Mangroves provide important habitats for many species and are of great importance as 'nurseries' for many commercially used species. People fish for fish, crab, shrimp, molluscs and seaweed in mangrove forests, providing a source of income and food security. Mangroves are also important suppliers of building materials, firewood and charcoal, as well as other products such as tan-bark, fibres, pet food and traditional medicinal products (Seto and Fragkias, 2007; FAO, 2007; Primavera and Esteban, 2008; Krause, 2010).

Mangroves are highly endangered, and efforts to conserve them face serious competition from other uses such as aquaculture, agriculture, salt production, urbanization, infrastructure development and tourism (FAO, 2007). It is estimated that only 15.2 million hectares still remain (2005) of the 18.8 million ha of mangrove forests that existed worldwide in 1980; this corresponds to a fall of about 20% (FAO, 2007:9ff.), although the speed of loss was slower between 2000 and 2005 compared to the previous decades (FAO, 2007). In 2002 the largest share – about 6 million ha or approximately 38% of the global area – was to be found in Asia. However, the highest losses were also here, totalling more than 1.9 million ha since 1980 (FAO, 2007:9ff.). Mangrove forests are particularly threatened by the expansion of aquaculture, although it is difficult to make a systematic assessment of the destruction of mangrove forests and their conversion into aquaculture farms – for political reasons and for lack of capacity (Seto and Fragkias, 2007). In Asia the main causes of mangrove decline lie in over-exploitation and conversion to shrimp farms (FAO, 2007).

At the beginning of the 20th century, the Philippines were covered by approximately 450,000 ha of mangrove forests (Primavera and Esteban, 2008). Half of the 279,000 ha of mangrove area lost between 1951 and 1988 was converted into aquaculture ponds (Primavera, 2000:93). In Thailand, this loss affected about 55% of the mangroves between 1961 and 1993 (Menasveta, 1997). Globally, shrimp cultivation was responsible for about 38% of the loss of mangrove forests in the last two decades of the 20th century (Valiela et al., 2001:812).

From the ecosystem perspective, the economic value of mangrove forests for the environment and society is estimated as being higher than the value of shrimp farms for society as a whole. Barbier et al. (2008:322) show for Thailand that the economic value of mangroves for coastal protection, coastal fisheries and as a source of wood is about US$17 million, i.e. much higher than the value of a shrimp farm using all the available space (about US$10 million). However, the total economic value of all uses (shrimp farms and ecosystem services) would be highest (US$17.5 million) if only a small area of mangrove forest were converted into shrimp farms.

To counteract the advancing deforestation, several countries have been carrying out reforestation programmes and protecting mangrove forests for years (FAO, 2007). However, reforestation is often not very successful. In their analysis of reforestation projects in the Philippines since the 1980s, Primavera and Esteban (2008), for example, show that despite strong financial support the survival rate of the planted mangroves is only around 10-20%. This is mainly due to unsuitable choices of species and locations.

Another alternative for the protection of mangrove forests is to develop a mangrove-friendly form of aquaculture, since the plants could process the effluent from the shrimp installations (e.g. Bush et al., 2010; Ha et al., 2012). Seaweed, mussels and fish, for example, can be bred within mangrove forests, which is a good technique for small farmers and in mangrove conservation areas. Integrated forestry/fishery/aquaculture systems exist, for example, in Hong Kong, Vietnam, the Philippines and Indonesia (Primavera, 2006).

above-mentioned environmental problems can lead to conflicts between the neighbouring states. The problem is exacerbated when there is no cross-border cooperation between authorities and producers.

Section 4.3 discusses the problem of the dependence of certain forms of aquaculture on fishing as a supplier of feed and the related harmful effects on wild fish stocks and ecosystems.

One problem that is being aggravated by the growing appropriation of coastal regions is conflicts resulting from uses that compete for the same space. Competing uses can include tourism, port development, recreational and commercial fishing and nature conservation, e.g. the protection of mangrove forests (Stickney and McVey, 2002; Buck et al., 2004; Bostock et al., 2010; Box 4.2-3).

There can also be conflicts over use if aquaculture farms make it difficult or impossible for local communities to access the resources of coastal regions. The destruction of mangrove forests can threaten village communities who depend on these forests for their livelihoods (Ronnback et al., 2002). Since property rights are often unclear and wetlands historically undervalued in developing and newly industrializing countries, this can promote forms of use that are not sustainable and put poorer sections of the population at a disadvantage (Adger and Luttrell, 2000). Moreover, negative environmental effects of aquaculture can spread to adjacent land uses and cause economic damage, e.g. by reducing rice harvests (Ahmed and Lorica, 2002).

However, many of the problems in aquaculture should become largely preventable as technical development progresses. Hall et al. (2011) show that the aquaculture sector has taken on – and in some cases solved – several of the above-mentioned problems. According to Asche (2008), most damage is done when

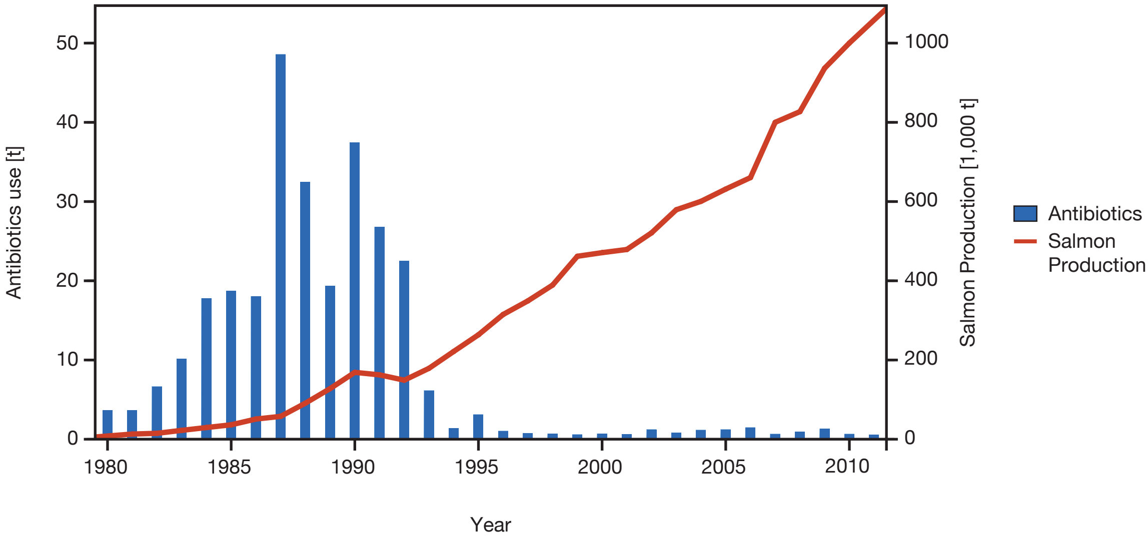


Figure 4.2-3
Norwegian salmon farming: use of antibiotics and salmon production, 1980 to 2011.
Source: Asche et al., 2010; updated Asche, 2013 (pers. comm.)

the intensification of a production system is beginning, and tends to decrease as more and more control is gained over the production process. The example of Norwegian salmon farming illustrates the possibility of reducing the use of antibiotics as yields increase (Figure 4.2-3). The reason for this is primarily the development of new vaccines (Hall et al., 2011:55). Also, the fall in organic pollution from Norwegian salmon farms was achieved by the development of pollution-reducing technologies (Tveterås, 2003).

However, often the self-regulation of the aquaculture sector does not begin until after considerable damage has already been done – in response to public pressure or for fear of a loss of image. A critical public and government intervention before damage occurs, therefore, play an essential role in shaping sustainable aquaculture.

An important question in this context – and one that has not yet been adequately answered by research – is whether an ecologically responsible form of aquaculture production based on resource conservation would be able to meet the ever-growing demand for aquaculture products. It might be more sensible (recalling the discussion on meat consumption) to strive for a lower general level of consumption, especially in industrialized and newly industrializing countries, in order to minimize negative environmental effects – certainly in situations where food security and protein supply are not the most important factors.

4.2.2.4
Promoting ecologically sustainable aquaculture

Certain forms of aquaculture are ecologically more sustainable than others. Breeding filter feeders, herbivorous freshwater fish or extensive polycultures is more environment-friendly than the intensive cultivation of marine predators or shrimp. This is because carnivorous species are fed with fish meal and oil from wild-caught fish, and antibiotics, chemicals, faeces and uneaten feed residues can cause serious environmental pollution in intensive cultures (Frankic and Hershner, 2003; Naylor and Burke, 2005; Bostock et al., 2010). However, much progress has already been made towards improving environmental compatibility, particularly in the case of salmon farming in northern Europe and Canada (Frankic and Hershner, 2003).

Improving practices in aquaculture can considerably reduce the environmental impact. In addition to replacing fish meal and oil with vegetable feeds, for example (Section 4.3), three main developments are looking promising in this context: the integration of aquaculture systems; the use of largely closed, land-based aquaculture systems (recirculating systems); and, under certain conditions, offshore aquaculture systems

Integrated production systems have a long tradition, especially in Asia, and can play a bigger role in the future (Soto et al., 2008). There are several different methods involving integrated systems. For example, terrestrial and aquatic systems (agriculture and aquaculture) are often combined, as in breeding fish in rice fields (Halwart and Gupta, 2004). Another example is integrated multitrophic aquaculture (IMTA), in which species from different trophic levels are bred together in the same body of water (Troell et al., 2009). IMTA systems are comparatively environment-friendly, since accumulating waste materials are recycled or used as food by other organisms. Fish need supplementary feeding in some cases, mussels or seaweed extract feed residues and fish excrement as nutrients from the water (Chopin et al., 2010a). The use of seaweed for producing bio-fuel is regarded as having a promising future (Issar and Neori, 2010; Section 5.2.1). Industrial-scale marine IMTA systems are already commercially successful in China and are approaching the commercialization stage in other countries (e.g. Chile, Ireland, the UK, Canada). Corresponding research is being conducted in many other countries (Troell et al., 2009; Bostock et al., 2010; Chopin et al., 2010b).

Multitrophic systems can also be used to reduce eutrophication in coastal areas, since the organisms extract nutrients from the waters in a process called nutrient bioextraction. Research on the effects of these systems on the marine environment is already being conducted in several countries such as the USA and Sweden (Landeck Miller and Wands, 2009; Long Island Sound, 2013). In this context there is also a discussion on the possibility of trading in nutrient certificates (nutrient trading credits), similar to CO_2 certificates, in order to reduce the anthropogenic input of nutrients into waters (Chopin et al., 2010a). The integration of different components is an important element in the ecosystem approach to aquaculture; waste products and effluent are regarded as valuable resources in this context (Troell et al., 2009).

Another interesting development is land-based, recirculating aquaculture systems (RAS), in which the wastewater is treated, purified and fed back to the system, creating a virtually closed system. This makes it possible, for example, to produce shrimp far inland from the coast (Stockstad, 2010). However, the use of this method still limited by high capital costs and a complex, not yet mature technology (Bostock et al., 2010). Moreover, this type of farming requires a high energy input (Tyedmers and Pelletier, 2007).

Finally, offshore aquaculture has the potential to ease conflicts over the use of scarce space on the coasts. As the use and pollution of coastal regions increases, aquaculture production using offshore cage technology or other systems that are adapted to the harsh conditions of the ocean can be expected to be increasingly moved to regions further from the coasts (Holmer, 2010), where they will have to contend with strong currents, often rough seas and changeable winds. This is already happening in some countries like Norway, Chile and the USA. However, commercial offshore aquaculture is still in its infancy, since it is very capital intensive (Bostock et al., 2010). The USA positioned itself as an important major player in the development of this technology a few years ago and intends to promote sustainable developments in the offshore sector (Naylor and Burke, 2005; Benetti et al., 2006).

The growing expansion of offshore renewable-energy technologies offers the additional opportunity of using installed structures for aquaculture. Offshore wind farms offer the most promising option of dual use (Buck et al., 2008; Buck and Krause, 2012). Although there are technical and economic challenges when it comes to integrating offshore wind farms with the cultivation of marine organisms, the analysis of geophysical and biological parameters indicates that, to date, common mussels, oysters and seaweed seem to be best suited for offshore aquaculture in the North Sea. Farming fish inside offshore wind farms has been neither biologically nor technically well researched up to now (Buck et al., 2008). In cooperation with industry, however, several large EU pilot projects are being carried out to explore the extended use of offshore installations by aquaculture. The research is not limited to wind farms in this context, but also includes the development of new multi-use platforms in which renewable-energy generation, aquaculture, transport services and leisure activities might be combined (Buck and Krause, 2012).

Another possible technology of the future that is posited is cages that float freely in the water with the current (Naylor and Burke, 2005). An unanchored spherical cage floating in the open sea was tested with amberjack off Hawaii for the first time in 2011 and 2012. The net cage was 132 m^3 in size and drifted with the ocean current at a depth of several kilometres at times (Kampachi Farms, 2011; Sims and Key, 2011).

Offshore aquaculture can also represent a burden on the environment, for example when nutrients are not fully used up, especially since such farms are likely to be much larger than those on the coasts and could thus generate more effluent. Farmed species could also escape from the cages and cross with wild stocks (Naylor et al., 2000; Tett, 2008; Troell et al., 2009). However, the negative environmental impact of freely floating offshore cages is thought to be very small (Sims and Key, 2011). Because only a small number of systems have been tested up to now, the environmental impact cannot be adequately estimated at present (Holmer, 2010). Moreover, the problem of requiring feed made from fish meal and fish oil for carnivorous species remains. Integrated offshore multitrophic systems can at least ease the problem of nutrient pollution by integrating organisms at lower trophic levels (e.g. algae) to recycle nutrients (Chopin, 2008).

4.2.3
Governance of aquaculture

On the positive side, the rapid growth of the aquaculture industry secures incomes and food supplies. After all it meets almost half of the world's demand for fish and seafood at present (FAO, 2012b: 26). The negative side, however, is that it is associated with negative ecological and social repercussions. Sustainable aquaculture (both in freshwater and in the sea) requires effective and enforceable approaches to governance at all levels, from international to local. The requirements placed on governance and the success factors vary depending on the production method, the cultivation system, the size of the culture, local circumstances and the political, economic and institutional context.

This section provides an overview of important prerequisites for effective governance, its instruments and the kind of measures that should accompany it – like research and development for a responsible and sustainable development of aquaculture. Important problems, which manifest themselves differently in every country, include the following: the need to reduce negative environmental repercussions; effects on income distribution and poverty reduction; the need to find the right balance between societal benefits and private benefits; and the need to encourage an orientation towards long-term rather than short-term profit maximization (Pullin and Sumaila, 2005).

Aquaculture production is highly dependent on local conditions. But it is also globally linked, for example through international trade and consumer behaviour, information, and cross-border ecological effects. This requires not only regional and national solutions, but also intergovernmental and global ones. For years, non-binding agreements and recommendations have existed at the international and European level, as well as at the level of marine regions, which deal directly or indirectly with aquaculture (Section 4.2.4). And in many countries there has been progress in the development of legislation, regulation and guidelines on aquaculture; however the biggest stumbling block is often implementation, especially in developing countries. Furthermore, in the field of non-state governance, private actors have been trying to fill in existing gaps in state and transnational control (Section 3.5). Examples include stricter certification standards developed by environmental associations (Section 4.2.3.2) or self-management by producer associations (Section 4.2.3.1).

In Section 3.1.4 the WBGU elaborated touchstones for assessing the existing governance of the oceans in the context of sustainability. A sustainable and viable form of aquaculture governance should take its orientation from these touchstones. However, in the context of this report it is impossible to conduct a complete analysis, based on these touchstones, of the many and various approaches to governance and instruments that exist at different levels in aquaculture. In Sections 4.2.3 and 4.2.4, however, it becomes clear that many of the touchstones are regarded as important in the literature on aquaculture governance, or are already reflected and are being applied in existing approaches to governance, as well as in agreements and recommendations.

4.2.3.1
Fundamental prerequisites for a sustainable form of aquaculture

The fundamental prerequisite for sustainable aquaculture is good governance (including elements like the rule of law, accountability, transparency, participation), which allows the formulation and implementation of development strategies and plans (FAO, 2011c). Also essential are transparent and enforceable laws and regulations, which in turn require effective national institutions (NACA and FAO, 2000), as well as economic incentives for producers and voluntary measures by the industry (FAO, 2011c). These three approaches complement each other. They are given different levels of priority and are applied differently in the individual countries, depending on the economic and political context or the level of development in the aquaculture industry. Furthermore, the development of aquaculture should be based on the ecosystem approach. One prerequisite for positive changes here is the collection and provision of reliable data on the development of the industry and the effects of aquaculture on the environment and society (FAO, 2011c).

Strategies and action plans

Sustainable aquaculture requires appropriate overarching strategies that can be implemented by taking corresponding political measures. This includes providing necessary capacity and financial resources, integrating different stakeholder interests, and establishing dispute-settlement mechanisms. Such strategies have already been – and are still being – developed, for example in North America and the EU (EU, 2009a; FAO, 2011c). However, in many countries successful implementation will require capacity-building within the administration, the private sector and among consumers (FAO, 2006).

The ecosystem approach in aquaculture

To date there is neither a universally agreed definition nor a uniform concept of 'sustainable aquaculture'. In recent years, however, the concept of the ecosystem approach has been developed not only in fisheries, but also in aquaculture (Section 4.1.3.1). The FAO

Code of Conduct for Responsible Fisheries emphasizes – in its Article 9 on aquaculture – the need to maintain ecosystem integrity by means of suitable management (FAO, 1995). The Phuket Consensus (Section 4.2.4.1) recommends integrating the approach into the governance of the aquaculture sector (GCA, 2010a). In the context of the ecosystem approach, human beings are seen as an integral part of ecosystems, and a balance is sought between two aspects: to contribute both to the conservation of ecosystem services and biodiversity *and* to the sustainable use of fisheries and aquaculture in order to produce food and secure people's livelihoods. Knowledge and uncertainties about interactions in the entire ecosystem would be taken into account in an integrated and cross-regional approach (Staples and Funge-Smith, 2009). Soto et al. (2008) formulate three principles constituting a systemic approach that transcends the boundaries between ecosystems:

- "Aquaculture should be developed in the context of ecosystem functions and services (including biodiversity) with no degradation of these beyond their resilience capacity."
- "Aquaculture should improve human well-being and equity for all relevant stakeholders."
- "Aquaculture should be developed in the context of other sectors, policies and goals."

According to these principles, farms should be adapted to defined ecosystem limits and to the ecological carrying capacity of ecosystems. Furthermore, the development of aquaculture should not "result in any detriment for any groups of society, especially the poorest" (Soto et al., 2008). Certification can support the ecosystem approach, but is not usually developed parallel to it. However, the approach is difficult to implement due to its complexity and the lack of financial and human resources, especially in developing countries. For some years, however, there have been efforts in several countries to implement the approach at least to some extent (FAO, 2012b).

State regulation of aquaculture

Adequate state governance and its effective implementation are necessary in order to respond to the ecological and social challenges caused by aquaculture (FAO, 2011c). The state should provide stable overall conditions and an investment-friendly climate for businesses. At the same time it should intervene using political means to avoid possible negative repercussions of short-term profit seeking on the environment and society (Hishamunda et al., 2012). Another important element is the application of the precautionary principle, both in politics and in the running of aquaculture farms, because the effects of aquaculture on ecosystems are often insufficiently researched (FAO, 2013c).

In principle, all policy instruments of environmental policy and planning law can be used in the regulation of aquaculture. Government intervention is important, especially to prevent environmental damage and avoid conflicts over land rights (Hishamunda et al., 2012). After aquaculture installations begin operations, regular controls by authorities independent of government are required to ensure that measures are implemented (Howart, 2006). The effective enforcement of political measures requires adequate financial and human resources in order that controls and, where necessary, sanctions can be applied. A lack of capacity, above all in developing countries, is one reason for the often poor implementation of government measures for regulating aquaculture (Hishamunda et al., 2009).

In Myanmar, for example, staff shortages and a resultant lack of controls encouraged the conversion of mangrove forests into shrimp farms. A lack of resources is also one reason for inadequate research and training, which in turn hinders the use and dissemination of new and environment-friendly technologies.

Some forms of state regulation are also unsuitable, inconsistent or too complex, which can make the granting of licenses difficult, for example. Small aquaculture operations often lack the financial and technical means to reach exacting standards, e.g. proving environmental compatibility or the suitability of a location by meeting hygienic criteria (FAO, 2011c). This is problematic because integration into national and international markets requires compliance with certain standards, and for small farms in developing countries this often amounts to exclusion from the markets. Although as little government regulation as possible is desirable from an industry perspective, its absence, or inadequate implementation, can ultimately harm the industry itself, as shown by the example of salmon farming in Chile (Hishamunda et al., 2012; Box 4.2-4). The case example of salmon farming in Norway demonstrates how some environmental hazards have been successfully reduced by governmental action (Box 4.2-5).

Very often there are conflicts between the interests of different sectors, e.g. aquaculture and agriculture, tourism, shipping, wastewater management or nature conservation (Pullin and Sumaila, 2005). To ensure a coordinated development of aquaculture that also takes into account and integrates the interests of other sectors – and in order to establish and coordinate suitable regulations – it is a good idea to set up a central institution to be in charge of such things: either a new government authority or a specialized department within a ministry. These already exist in many countries (Hishamunda et al., 2012: 239). Pooling as much information as possible in one place, e.g. within an 'aquaculture authority', is particularly important for licensing,

Box 4.2-4

Case study I: salmon farming in Chile

Salmon aquaculture in Chile is an example of how inadequate regulation can cause serious long-term damage. Chile is the second-largest salmon producer in the world after Norway (FAO, 2011c). 73% of Chilean aquaculture production focuses on breeding the Atlantic salmon (which is not native to Chile); it is Chile's fourth largest industry. Salmon aquaculture is carried out in open net pens in southern Chile and is now also spreading to the still relatively pristine coastal regions of Patagonia (Buschmann et al., 2006, 2009). Most of production goes to international markets (Gonzáles, 2008).

The salmon-farming industry that developed in Chile in the late 1970s was characterized by a highly flexible private sector and few government regulations or interventions in the 1980s. High growth rates came at the expense of production and environmental protection, mainly due to outbreaks of disease and high mortality rates among the fish. It was not until the 1990s and early 2000s that political measures were taken to improve animal-health and environmental protection and health-and-safety conditions for workers as a reaction to growing internal and public criticism (Barton and Fløysand, 2010).

Many companies began introducing improvements in all three areas as part of integrated management. However, the voluntary measures of the private sector and the public-private regime of governance proved insufficient when the ISA (infectious salmon anaemia) virus broke out in 2007 and 2008 – triggering the worst disease outbreak in the history of salmon aquaculture.

The causes of the outbreak included contaminated production effluent, the sale of infected salmon eggs, and unvaccinated fish. The outbreak reflected the inability of companies and politicians to exclude known risks and to learn from previous epidemics elsewhere (Barton and Fløysand, 2010). The consequences were a fall in output from 386,000 tonnes in 2006 to an estimated 100,000 tonnes in 2010, quarantine restrictions at many farms, many slaughtered fish and mass layoffs (Asche et al., 2010:405; Barton and Fløysand, 2010).

Although a 'National Aquaculture Strategy' oriented towards growth, ecological sustainability and other goals was developed in 2003 (Gonzáles, 2008), and environmental and public-health protection was improved in 2007, both measures were insufficient and not implemented effectively. They were based on a much smaller number of farms than actually existed in reality, and environmental effects were not detected for lack of monitoring. Weak controls encouraged the use of banned substances, and, due to a lack of research, measures were not developed on the basis of empirical research findings (Bushman et al., 2009).

Overall, it can be observed that government intervention was weak in response to real threats up to 2007, which can be explained by the regulatory authorities being acquiescent to the demands of the aquaculture sector. Furthermore, companies themselves did not taken adequate measures to prevent crises.

However, improvements both in environmental-protection and health regulations and in environmental communication have been stimulated by the ISA outbreak, and they can be seen as steps towards improved governance (Barton and Fløysand, 2010).

since it makes decisions and investments easier. This is the case in Norway (Hishamunda et al., 2012).

Economic incentives

Depending on the political and economic context, certain problems caused by aquaculture can be solved with the help of economic incentives, such as subsidized loans and micro-loans, tax breaks, subsidies or payments for ecosystem services (Howart, 2006). This gives aquaculture farms an incentive to invest in exemplary management practices and sustainable aquaculture, which in turn can make it easier for them to access national and international markets (FAO, 2011c).

Sustainable management and entrepreneurial initiative

There are numerous private management initiatives that support and complement state control or international agreements on a voluntary basis. In some cases, ideas like self-management, co-management and best management practices (BMPs) are more suitable for developing countries with inadequate state governance or when the aquaculture units are small. BMPs in particular can promote improvements among producers affecting product quality, product safety and environmental protection (Hishamunda et al., 2012). Producer associations like the aqua clubs in Asia are examples of entrepreneurial initiative (Box 4.2-2). They can provide resources such as technical assistance and information; promote voluntary BMPs and codes of conduct in aquaculture; organize production more efficiently; and influence the development of government regulation (FAO, 2011c). Voluntary measures by farmers have been criticized for being ineffective without additional government measures (FAO, 2008). Even so, there are a growing number of examples of this type of governance in many regions of the world (FAO, 2011c).

Data collection and provision

The rapid and continuing growth of the aquaculture sector increasingly requires data on the economic development of the industry, as well as its effects on the environment and society. This provides the basis for policy adjustments and strategy development and can enable adaptive management. Data and information are also increasingly in demand among the public in order to create transparency. Furthermore, international reporting requirements have been tightened up (FAO, 2011c).

Box 4.2-5

Case study II: salmon farming in Norway

The aquaculture industry, and especially the breeding of Atlantic salmon, holds an important position within the Norwegian fish and seafood sector. 630,000 tonnes were produced in 2006, mainly for export. The fish are bred in cages off the coast (Aarset and Jacobsen, 2009).

Since the 1970s and as late as the early 1980s, the salmon industry, which consisted mainly of spatially distributed small firms, was promoted by the Norwegian government to boost competitiveness in the context of regional development. After a phase starting in the late 1980s that was characterized by massive overproduction, falling prices due to stronger international competition, disease and many bankruptcies, a rethinking of industrial development policies was initiated, and state control of farms was improved from the early 2000s.

The fisheries directorate, the food-safety agency, the coastal directorate and the district councils are responsible for licensing, controls and sanctions. 2004/2005 saw the introduction of technical standards, voluntary accreditation processes for technical quality assurance, an internal control system to monitor farming operations, obligatory contingency plans for the event of diseases or fish escaping, and ceilings on the amounts of biomass allowed. Similarly, there is mandatory reporting from the farmers to the authorities, the main purpose of which is to prevent disease. Since the majority of production is exported to the EU, there is a great need for transparency, data collection, documentation and environmental standards. Comparatively speaking, Norwegian aquaculture is quite strongly regulated by the state in terms of efficiency and compliance with international environmental standards (Aarset and Jacobsen, 2009). However, the local concentration of production has also led to an uneven regional distribution of the income from aquaculture, which is still insufficiently balanced (ICES, 2012b).

Industrial salmon farming is a form of aquaculture that has a considerable influence on marine ecosystems due to the need for feeds in the form of fish meal and fish oil, which come from wild fisheries. However, Norwegian salmon aquaculture has managed to reduce the environmental damage caused by intensive farming. For example, the use of antibiotics has been greatly reduced. After peaking at 48,570 kg to produce 46,000 tonnes of fish in 1987, only 649 kg was used for 822,000 tonnes of fish in 2007 (Asche et al., 2010: 406 ff.; Figure 4.2-3).

The reasons for this included public-private funding, the commercial introduction of high-quality vaccines in the early 1990s, coastal zoning, and the relocation of farms to reduce the spread of pathogens (Asche et al., 2010; Midtlyng et al., 2011). The contamination of water with antibiotics and the spread of disease to wild stocks has been greatly reduced in this way. Marine Harvest, the world's biggest salmon producer, used 732 g of antibiotics per tonne of fish produced in Chile in 2007, while only 0.2 g per tonne of fish was used in Norway (Marine Harvest, 2008: 16).

According to Marine Harvest the difference is mainly due to ineffective inoculants and unvaccinated fish stocks in Chile, which can also be an expression of weaker environmental regulations in Chile. However, continuous vaccinations have reduced the use of antibiotics to about 370 g per tonne of fish there since 2008 (Marine Harvest, 2011: 123). Overall it can be said that the general health situation and disease control is good in Norwegian aquaculture, although outbreaks of disease continue to occur caused by certain pathogens which cannot be controlled, and parasites such as sea lice (Johansen et al., 2011).

According to a comparative life-cycle analysis of salmon aquaculture operations in Norway, Chile, Canada and the UK, which examined factors such as total energy consumption, use of biological resources, greenhouse gases, and emissions that contribute to acidification and eutrophication, Norway also has the lowest total energy consumption and, by comparison, the lowest emissions of CO_2, sulphur oxides, nutrients and phosphates. Furthermore, the country has the best record for the above-mentioned factors per tonne of salmon produced. The exception is feed consumption, since the feeds used in Norway's aquaculture are highly dependent on supplements of fish meal and fish oil. Chile is in second place here in front of Norway, since the feed used in Chile also contains poultry meal. By comparison, however, reduction fishery is very fuel-intensive and the fishmeal and fish-oil yield relatively low (Pelletier et al., 2009).

Despite the measures carried out by the FAO (2011c) to promote the quality and transfer of data, reporting to the FAO is still poor in some producer countries (FAO, 2012b). Improvements are urgently needed here.

4.2.3.2
Selected instruments for promoting sustainable aquaculture

Various instruments are available for ensuring an environmentally and socially acceptable development of aquaculture, and they are already being implemented to varying degrees by many countries. Since the causes of the problems in aquaculture are complex and involve stakeholders at different levels, the instruments often need to be used in combination and must take into account the overall conditions described above.

Certification of aquaculture products

Certification programmes for aquaculture products have been established for several years. They are developed by companies, national and international organizations, and supranational agencies against the background of the strong growth of the aquaculture industry with all its undesired side effects and a rising demand for sustainably produced goods.

Some of the approximately 30 existing certification programmes focus more on product quality and food safety, while others concentrate on environmental and social standards in the production process or on animal welfare (WWF, 2007). Non governmental organizations (NGOs) frequently criticize the standards and labels developed by companies or at the supranational level for being too weak, or for serving their own interests, and have therefore developed more stringent and comprehensive certification programmes and labels of their own. Examples of private stakeholders include the Global Aquaculture Alliance (GAA), GLOBAL G.A.P., the 'Naturland' label and the new Aquaculture Stewardship Council (ASC), which was co-founded by the World Wildlife Fund (WWF).

There are also critical views on the effectiveness of aquaculture labels with respect to achieving sustainability goals and the measurability of the results (Boyd and McNevin, 2011; Kalfagianni and Pattberg, 2013). In a study to assess common certification programs, the WWF identified different criteria that should be examined in the course of certification processes in aquaculture (WWF, 2007): environmental aspects (e.g. feed, energy), social aspects such as labour rights, rights of access to natural resources, animal welfare, animal health, processes for developing standards, the integration of stakeholders, and transparency. None of the programmes analysed meet all the recommended criteria, which is why it would be important to develop them further (WWF, 2007).

Certified aquaculture products currently still concentrate on certain species and certain markets. Products from developing countries are underrepresented, but they are on the increase (FAO, 2010b). Certification can also be a barrier to market entry and competitiveness for developing countries. To ensure that negative environmental effects caused by production are not transferred to other countries by increased imports, however, high environmental standards should apply equally to local production and to imported products (Bostock et al., 2010).

However, the large number of labels makes it more difficult for consumers to make a purchase decision, for example according to ecological criteria. The criteria and certification processes should therefore be standardized at the international level in the future. Since there has as yet been no standardization in the development of aquaculture certification, the FAO has developed recommendations for minimum criteria in the fields of animal health, food safety, environmental integrity and socio-economic aspects (FAO, 2011d).

Integrated coastal-zone management and zoning for aquaculture

Aquaculture farms in coastal areas often compete with other terrestrial and maritime uses such as fishing, tourism, nature conservation or public access to coasts (Tiller et al., 2012). Lack of access to suitable sites, diverging stakeholder and user interests, and low levels of social acceptance in some regions are the main barriers to the further spread of aquaculture (Gibbs, 2009). The aim of integrated coastal zone management (ICZM) and zoning (Sections 3.6.2, 3.6.3) is to integrate mutually compatible ecological requirements and human uses in certain zones and to lay down plans for use. This makes it possible to avoid conflicts over use and harmful environmental effects (Howart, 2006; Hishamunda et al., 2012; Tiller et al., 2012). The integration of stakeholders is essential, especially when vulnerable social groups are affected and such issues as social justice, food security and poverty reduction are involved (Primavera, 2006; Tiller et al., 2012). It is an advantage for zoning if planning powers relating to land use can be transferred to local authorities (Howart, 2006). ICZM and zoning for aquaculture farms are already being applied in several countries (Hishamunda et al., 2012).

Instruments for assessing environmental effects

There are several standardized procedures for analysing and evaluating the environmental effects of aquaculture. These include generic methods such as the ecological footprint, by which the consumption of resources and the waste generated by aquaculture can also be measured (Roth et al., 2000).

Another example is life-cycle analysis (LCA), which considers such parameters as total energy consumption, emissions of phosphorus, nitrogen and carbon dioxide, and water consumption in production, distribution, consumption and the disposal of products (Aubin et al., 2009; Bostock et al., 2010). However, LCA is less suitable for evaluating the dependence of products on natural resources or ecosystem services (Bostock et al., 2010).

In addition, there are evaluation methods that have been specifically developed for aquaculture. These include the EU-funded ECASA toolbox for assessing the environmental impact of fish and crustacean cultivation in European seas. Its aim is to help implement the ecosystem approach and to make it easier to site farms effectively (ECASA, 2013).

The Global Aquaculture Performance Index (GAPI) looks at the cumulative environmental effects of fish farms, as well as the influence per unit of production at the country and species levels. It offers a global comparison of environmental effects and even allows direct comparisons to be made, for example between salmon aquaculture in Chile and Norway, or between the environmental impact of all marine fish farming in Canada and China (GAPI, 2010).

Ecosystem-based carrying-capacity concepts take an expanded view. They evaluate production and ecological limits as well as social acceptance of aquaculture production. They can also be applied beyond an individual farm to ecosystems and catchment areas (Byron and Costa-Pierce, 2012). In order to take into account as many environmental effects as possible, it is not a good idea to consider an individual farm in isolation; rather, the cumulative and regional environmental effects of all the farms in a region should also be taken into account (King and Pushchak, 2008).

4.2.3.3
Research and development for sustainable aquaculture

Research, technology development and knowledge transfer are fundamental measures required for a more environmentally compatible development of aquaculture production and for reducing negative influences on ecosystems. The further development and spread of environment-friendly production systems are examples of implementation of the ecosystem approach in aquaculture. They are also an essential building block towards securing a sustainable form of food production.

Promoting the development of ecologically sustainable production systems

The FAO Code of Conduct calls for the implementation of ecologically sustainable aquaculture (FAO, 1995). The Bangkok Declaration and the Phuket Consensus emphasize the importance of sustainable innovations (NACA and FAO, 2000; GCA, 2010a; Section 4.2.4.1). Depending on the context, laws and regulations, economic incentives and voluntary self-commitments by producers can all promote the further development and spread of environment-friendly production systems.

Sustainable innovations can also be triggered by the demand side, for example by an increase in demand for sustainably produced products or by product boycotts. Improvements are also necessary in farm management, especially in developing and newly industrializing countries, where innovations are feasible in various fields: to reduce water and energy consumption, in feeds and feeding techniques, in wastewater and solid-waste management, and with regard to stocking density and disease control (Primavera, 2006).

At the same time, environment-friendly production systems – such as integrated multitrophic systems, recirculating technologies as closed systems, or mangrove-friendly aquaculture systems – already exist (Section 4.2.2.4). Some of these need to be further developed, e.g. recirculating technologies or industrial-scale multitrophic systems.

Promoting research; knowledge and technology transfer

Research and the transfer of knowledge and technology are crucial to the development of sustainable aquaculture. Their importance is particularly emphasized, for example, in the Bangkok Declaration (NACA and FAO, 2000; Section 4.2.4.1). The EU, too, aims to base its promotion of sustainable aquaculture on 'state-of-the-art research' and 'innovative technologies' (EU, 2009a). In many developing and newly industrializing countries, however, the resources and capacity available for research and development are very limited, which is why international technology transfer should be a key component of international cooperation. Within a country, too, the dissemination of knowledge is key and must be actively supported. Indonesia, for example, has had good experience with the promotion of training and technology transfer, especially for small-scale aquaculture. The ministry responsible for aquaculture is supported by producer organizations in advising farmers and spreading suitable technologies. In addition, national development centres and local centres are given responsibility for technology transfer and training. In this context, farmers are invited as representatives of their villages and trained, thus enabling them to spread the knowledge in their villages. Furthermore, there are courses and degree programmes within the formal training system at numerous fishery-schools, colleges, faculties and a fisheries university (Hishamunda et al., 2009).

4.2.4
International and regional governance in aquaculture

There are many, mostly non-binding treaties and agreements at the international and regional level which relate directly or indirectly to aquaculture. They emphasize the cross-border, and in some respects global, character of aquaculture production as a result of trade and environmental consequences, and highlight the need for international cooperation. Despite a certain amount of progress, the recommendations and guidelines contained in the agreements are often not sufficiently implemented (FAO, 2012e).

Almost all marine aquaculture farms are currently located on coasts or in near-coastal waters, which is why the coastal states are solely responsible for the regulation of aquaculture. Aquaculture is not explicitly mentioned in UNCLOS either. However, as aquaculture increasing moves to regions far from the coasts and possibly onto the high seas – e.g. using free-floating aquaculture installations – international agreements within the framework of UNCLOS could become necessary.

Stringent international standards and effective support with implementation, especially for developing and newly industrializing countries, will be required in order to establish an ecologically and socially responsible aquaculture worldwide. However, an effective, standards-based implementation at national and local levels remains essential.

4.2.4.1 International level

No binding treaties on the regulation of aquaculture exist at the international level. Several quite far-reaching, but non-binding strategies and recommendations have been developed on aquaculture since the first declaration on aquaculture in Kyoto in 1976. Particularly noteworthy is the FAO Code of Conduct for Responsible Fisheries (Section 4.1.4.3), Article 9 of which deals with aquaculture. Later agreements such as the Bangkok Declaration (NACA and FAO, 2000) and the Phuket Consensus (GCA, 2010a) build on this foundation.

Article 9 of the FAO Code of Conduct makes ambitious recommendations and calls for responsible interaction with aquatic ecosystems and the protection of their genetic resources – by means of proper management, effective methods of environmental assessment and monitoring, transparent information, and global and international cooperation. It recommends assessing the possible ecological consequences of aquaculture development in advance and according to the best available scientific information, and establishing development strategies. The Code also emphasizes responsible aquaculture production at farm level and the integration of stakeholders into development processes. Furthermore, it also specifies the needs of developing countries and the interests of local communities, such as secure access to fishing grounds. States are expected to develop national guidelines building on these recommendations (FAO, 1995).

However, little progress has been made up to now in the implementation of this article (Edeson, 2003). Only 13 countries have drawn up aquaculture plans to date, and all of these are industrialized countries (OECD, 2010). According to an evaluation report, there are several reasons for the inadequate implementation of the Code of Conduct. They include, among other things, insufficient resources, lack of knowledge of the FAO recommendations and technical guidelines among government officials and organizations, and insufficient involvement of stakeholders in project-planning processes. According to the report, the FAO should play a more active role in the implementation of the Code of Conduct, improve collaboration with partners, and give the member states more support with the implementation of plans and strategies for sustainable aquaculture development (FAO, 2012e).

The Bangkok Declaration highlights the growth of aquaculture and its importance for "poor sectors of the community", and makes recommendations for a strategy on aquaculture development beyond 2000. Among other things, it emphasizes investment in education, research, modern and environment-friendly technologies, the promotion of food security, integration into rural development, and a strengthening of the institutional, political and administrative framework (NACA and FAO, 2000). It also aims to distribute the costs and benefits of aquaculture fairly and to ensure that society as a whole benefits from the development of the sector (GCA, 2010b). Some countries have been successful in implementing the recommendations, but there are also still many gaps (Hishamunda et al., 2012).

The FAO Code of Conduct also has its weak points. It is non-binding, formulated in broad and general terms, and does not offer any guidelines on transposing its provisions into national law. Nevertheless, the Code can support the establishment of rules for aquaculture, particularly in countries where environmental regulation is weak (Roderburg, 2011). Furthermore, the FAO and the International Council for the Exploration of the Sea (ICES) have developed technical guidelines for refining the FAO Code of Conduct (e.g. see FAO, 1997b, on the responsible development of aquaculture; FAO, 2011d, on the certification of aquaculture products; ICES, 2004, on the ICES's recommendations on the transfer of marine organisms).

In addition, environmental impacts of aquaculture are indirectly affected by other international conventions, e.g. by sections of UNCLOS on marine pollution or the Cartagena Protocol on Biosafety to the Convention on Biological Diversity (CBD; Howart, 2006; Roderburg, 2011).

The Phuket Consensus notes advances in aquaculture development. It identifies seven areas where improvements are most needed, e.g. as regards the effective governance of the sector and suitable development strategies, investment in innovation, and cooperation between regions, institutions and small farmers (GCA, 2010a).

In recent years, the need to strengthen sustainable aquaculture has been emphasized repeatedly at the international level in connection with the protection of biodiversity and ecosystems, for example by the Jakarta Mandate on Marine and Coastal Biological Diversity under the CBD (CBD, 1995) and by decisions of subsequent conferences of the parties. For example, the CBD calls on the states to avoid or reduce negative effects of marine aquaculture on marine and coastal biodiversity, and makes recommendations on relevant methods, techniques and management practices (CBD, 2004a). Target 7 of the Aichi Biodiversity Targets calls on states to manage areas under aquaculture sustainably by 2020, in order to conserve biodiversity. (CBD, 2010a). The resolution of the 'Rio+20 Conference' also calls on states to support sustainable aquaculture for ecological reasons and in order to improve food security and secure livelihoods (UNCSD, 2012). However, the voluntary status of these agreements hinders transposition into national law.

4.2.4.2
European Union

At the European level, no binding legislative acts on environmental protection exist up to now that are directly related to aquaculture, despite the rapid growth of the industry. However, there are directives and regulations that touch indirectly on the environmental effects of aquaculture. These include legislative acts on hygiene in the production of aquaculture products and on the health of animals in aquaculture; on water protection and undesirable substances in animal feed; on the use of alien species; on organic aquaculture and the certification of aquaculture products by the EU organic farming label (EU, 2007).

Various measures of EU environmental policy also affect aquaculture-related issues; these include the Water Framework Directive (WFD), the Marine Strategy Framework Directive (MSFD), the Flora-Fauna-Habitat Directive, the Dangerous Substances Directive, and the legislative acts on environmental impact assessments (EU Commission, 2012d). The WFD aims to achieve a good ecological and chemical status for inland and coastal waters up to 1 nautical mile seaward of the coastal baseline by 2015.

The MSFD calls for a good environmental status of the seas by 2020, the development of environmental targets and monitoring. Inputs of fertilizers and organic matter as a result of aquaculture must therefore be included in the required description of the environmental status and the formulation of environmental targets for the oceans (Schmehl and Wack, 2009). However, since this comes under the responsibility of the member states, the Directive does not create uniform European standards on running aquaculture farms in an environmentally responsible way.

As offshore aquaculture develops, the MSFD could become more important for aquaculture (EU Commission, 2012d). An environmental impact assessment is required for intensive fish farming. However, when the assessment requirement is formulated in greater detail by the member states, this might lead to a weakening of the level of protection, for example if the need for an assessment is made conditional on the size of the farm rather than on the level of emissions (Schmehl and Wack, 2009).

The EU already formulated a strategy for promoting the aquaculture sector in 2002, which was further developed in 2009 by a Communication entitled 'Building a sustainable future for aquaculture' (EU, 2009a). On the subject of environmental protection, the Communication stresses the importance of the existing EU water legislation. It does not contain any measures of its own to reduce negative environmental effects. It states that the extensive use of fish meal and oil as a feed is a problem (EU, 2009a).

In 2009 the EU Regulation on organic production and labelling of organic products was extended to also cover aquaculture products. Implementing provisions for the production of marine algae and animals, and on origin and husbandry, aim to prepare the ground for appropriate labelling of organically produced aquaculture products (EU, 2009a).

The European Fisheries Fund (EFF), which is part of the Common Fisheries Policy of the European Union (CFP), is to promote the sustainable development of European aquaculture and eco-friendly production methods up to 2013. As part of the reform of the CFP, the aim is to further develop the potential of European aquaculture and to integrate it with goals such as sustainability, food security, growth and employment by 2020. In this context, the European Commission has produced, for example, guidelines on integrating aquaculture with nature-conservation issues at Natura 2000 sites (Habitats Directive), since economic activities are not excluded from these protected areas *per se* (EU Commission, 2012d).

4.2.4.3
Regional seas agreements

At the regional level, the environmental effects of aquaculture are touched on indirectly by the OSPAR Convention for the North-East Atlantic and the HELCOM Convention for the Baltic Sea Area. Both treaties are committed to the ecosystem approach and recommend the application of 'best environmental practice' to reduce the input of such contaminants as phosphorus, nitrogen and toxic substances (HELCOM, 2004, 2008, OSPAR, 2010c).

They also recognize the importance of monitoring and assessing the environmental effects of human activities and of the integrated management of these effects (HELCOM, 2007; OSPAR, 2010a). However, the treaties do not contain a comprehensive strategy for regulating the environmental impact of aquaculture.

The Convention for the Protection of the Marine Environment and the Coastal Regions of the Mediterranean (Barcelona Convention) and its protocols refer to aquaculture only as a land-based source of pollution; it recommends that action plans and programmes should be developed to eliminate them and that their discharges and waste treatment should be monitored. The contracting parties are also called upon to regulate invasion by non-indigenous or genetically modified species and to set up an ICZM (UNEP MAP, 2005, 2013), which indirectly affects aquaculture.

4.3 Interactions between fisheries and aquaculture

4.3.1 Forage fisheries and breeding from wild-caught fish

Sustainable aquaculture will be difficult to achieve as long as certain forms of aquaculture production are dependent on fisheries and in this way increase the pressure on wild fish populations (Naylor et al., 2000). Many species that are kept in aquaculture do not reproduce easily in captivity, so breeding farms require spawn from wild populations or wild-caught larvae of fish, shrimp, crabs and other organisms. The number of larvae of non-target species found in bycatch and not used exceeds the number of larvae used for breeding several times over (Ronnback et al., 2002). There are also other forms of aquaculture in which wild-caught juvenile fish, e.g. tuna, are fattened (Tacon and Metian, 2009a). On the other hand, land-based aquaculture in particular can make a contribution to restocking wild fish stocks by breeding larvae (FAO, 2012b).

Predatory fish kept in aquaculture are fed with a protein-rich diet in the form of fish oil or fishmeal. To supply these two kinds of feed, there is a separate form of fishery that specializes in catching small schooling fish. It is called forage fishery – or 'reduction fishery' because it reduces fish to fishmeal and oil (Naylor and Burke, 2005; Bostock et al., 2010). In Asia, fish, primarily from bycatch, is used directly as a feed in aquaculture. On other continents, virtually no fish is used as a feed in aquaculture without being industrially processed, with the exception of farmed bluefin tuna (Wijkström, 2009). Additional pressure on wild fish stocks comes from the addition of fishmeal and fish oil to the diets of herbivorous and omnivorous species. It is not physiologically necessary, but is often done for cost reasons (Bostock et al., 2010).

Reduction fishery, even when practised at MSY levels, can put a strain on food webs and reduce the numbers of commercially interesting predatory fish, as well as seabirds and marine mammals. It impacts on the lower trophic levels, and thus reduces the food supply of species that are higher up in the food chain (Smith et al., 2011; Box 4.3-1). Several stocks of small pelagic fish species in the Pacific and the Atlantic are already being fully exploited or overfished (Tacon and Metian, 2009a).

According to the FAO, yield figures from reduction fisheries have been in the region of 18–30 million tonnes a year for more than 30 years. Yields kept rising until 1994 but have been falling steadily ever since. Today, a total of 5–6 million tonnes of fishmeal per year is made from the fish; the amount of fish oil is just over 1 million tonnes per year. Here, too, changing catch yields initially led to an increase in the quantities produced and then to a decline after 1994 (FAO, 2012b: 174 ff.).

In 2009, 18 million tonnes of fish were not consumed directly by humans, but processed into fishmeal and fish oil; this represents 20% of global landings of fish, shellfish and other marine animals. Most of it is used in aquaculture. In 2008, 61% (3.7 million tonnes) of global fishmeal production and 74% (0.8 million tonnes) of fish-oil production was used to make aquaculture feeds; the figures for fishmeal have been falling since 2005 (FAO, 2012b: 174 ff.; Figure 4.3-1).

The amount of fishmeal used in aquaculture has been growing overall for decades; by contrast, its use in pig and poultry farming has fallen sharply. In 1988, 80% of the world's production of fishmeal was used as feed for pigs and poultry, compared to only 10% in aquaculture (FAO, 2012b: 177). Since the 1970s, there has also been a sharp increase in the amount of landed wild-caught fish used as a direct or freshly processed feed in aquaculture, livestock farming or angling (rising from 0.9 million tonnes in 1970 to 13 million tonnes in 2006; Tacon and Metian, 2009b).

External feed was used in more than 80% of the fish and crab produced in aquaculture worldwide in 2008 (mostly freshwater species; FAO, 2012b: 172 ff.). The extent to which the individual species bred in aquaculture require feeds containing animal protein depends on their position in the food web. Organisms at lower trophic levels (herbivores, omnivores) require little or no animal protein. Filter feeders such as mussels require no external food at all because they feed on plankton from the surrounding sea water. The aquaculture species that require the most fishmeal and fish oil are at a high trophic level and are predators (e.g. salmon, trout, marine fish like sea bass and sea bream) or marine shrimp (FAO, 2012b). In 2008 about two-thirds of the fishmeal used globally in aquaculture, and more than 90% of the fish oil, was consumed by the above-mentioned species groups (Tacon et al., 2011: 51 ff.).

However, depending on the species, the cultivation method and relation between the amount of feed used and the weight of the final product (feed conversion ratio, FCR), the amount of wild fish used in feeds can be several times the final yield of fish (FAO, 2011e, Section 4.3.3). The proportion of fishmeal and oil in the feed also varies with the respective period within the

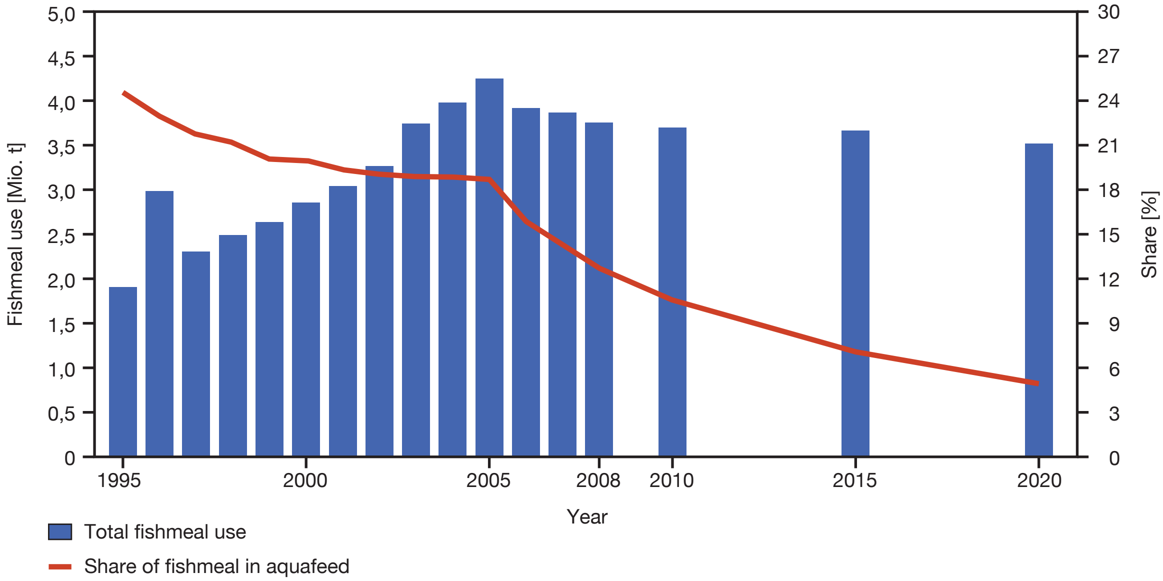


Figure 4.3-1
Actual and predicted reduction in fishmeal use relative to the global production of compound aquaculture feed.
Source: FAO, 2012b: 177

cultivation cycle (Tacon and Metian, 2008; Naylor et al., 2009). Although the aquaculture sector remains the world's biggest consumer of fishmeal, the proportion of fishmeal in aquaculture feeds has been falling sharply in recent years for many species groups (Figure 4.3-1). The FAO estimates that this trend will continue over the next 10 to 12 years (FAO, 2012b; Table 4.3-1).

This decline is being caused by lower yields from reduction fishery and rising demand, especially in the Asian growth regions, which are leading to price increases and more use of lower-cost fishmeal substitutes (Hasan and Halwart, 2009). As regards the consumption of fish oil, although a reduction in the amount used in feed is also expected, due to the rapidly rising production of species of marine fish and crabs and the lack of low-cost substitution options, an increase is expected overall (FAO, 2012b).

As a general rule, it can be said that breeding species at low trophic levels puts no or significantly less pressure on wild populations. However, the production of fish-eating species at a high trophic level is on the increase, so that this form of aquaculture is not easing the pressure on marine fisheries. The pressure on wild fish populations is further exacerbated by the large production quantities of omnivorous species that are given feed containing fishmeal and oil, albeit in declining proportions (FAO, 2012b: 34, 176 ff.).

Considering the dependence of certain aquaculture species on reduction fishery, together with the ecological effects and the growing demand for aquaculture products, the production of mussels and fish species at a lower trophic level (primarily herbivorous and omnivorous freshwater species such as carp and tilapia) should be developed, largely dispensing with the use of fishmeal and oil in the feed, with the aim of stabilizing the stocks of wild fish (Tacon et al., 2010). Demand for these species should be promoted, and the production and consumption of predatory fish species reduced.

4.3.2
Competition between uses

Small marine pelagic schooling fish such as anchovies, herring, sand eel, Norway pout, sardines and sprats are the most frequently caught fish worldwide. They made up just under 30 % of total landings in 2006, weighing 27.3 million tonnes (Tacon and Metian, 2009a). Much of this catch is used to produce feed for aquaculture, livestock production and pets.

Although the fishmeal industry says there is no other demand for 90 % of the fish that is processed into fishmeal, there are large regional differences in the importance of fish in the human diet. These fish might well be missed at the regional level as food for human consumption (Hecht and Jones, 2009). Small pelagic fish, being a relatively inexpensive food on many local markets, are an important source of animal protein and omega-3 fatty acids for poor sections of the population (WFC, 2011a). This applies in particular to populations in Africa and especially in sub-Saharan Africa, where fish accounts for about 18 % of people's consumption of animal protein, and the proportion of marine pelagic fish in the supply of fish protein is around 43 %. In

Box 4.3-1

Sustainable management in forage fisheries

Forage fish play a decisive role in marine ecosystems. They are quite small, pelagic schooling fish species (e.g. sardine, anchovy, herring) that feed on plankton and are an indispensable source of food for predatory fish, sea birds and many marine mammals (Pikitch et al., 2012a). Forage fish also account for over 30% of global fishery yields and are economically very significant, with a value of US$5.6 billion per year. However, forage fish can make a greater economic contribution in the sea than in a fisherman's net. The indirect contribution of forage fish as a source of food in the sea for the stocks of higher-value fish for human consumption is estimated at about US$11.3 billion per annum (Pikitch et al., 2012b). Only 10–20% of the forage fish catches are directly consumed by humans. The rest – in its industrially processed form – is an indispensable food source for marine aquaculture (Section 4.3); it is also used in livestock farming (Alder et al., 2008).

Forage-fish stocks are subject to large and unpredictable natural fluctuations; the uncertainties involved in estimating the size of such stocks and fixing fishing quotas are therefore particularly serious. Applying the ecosystem approach is especially important in their management because of their key role in pelagic food webs. For example, in many ecosystems seabirds need around one third of the maximum forage-fish population size to permanently maintain their populations (Cury et al., 2011). Overall, however, information on the exact structure of marine ecosystems is usually too inadequate to allow the application of the ecosystem approach (Alder et al., 2008). For precautionary reasons, therefore, the biomass in these fisheries should be at least twice the size of what is necessary for the MSY, and when quotas are laid down to protect stocks they should be correspondingly conservative (Pikitch et al., 2012b).

36 countries worldwide the proportion of pelagic fish is over 50%; 14 of these are in Africa. Aquaculture provides only a small proportion of fish consumed in Africa at present (Tacon and Metian, 2009a).

In Asia, the Pacific region and other parts of the world, too, the consumption of small pelagic fish has a very long tradition: e.g. herring in northern Europe, sardines in the Mediterranean, sprats in the Baltic (Tacon and Metian, 2009a). Rising fish prices due to the increased competition for small pelagic fish and the growth of Asian aquaculture are making the sale of forage fish for direct human consumption increasingly profitable (Huntington and Hasan, 2009). Poor sections of the population suffer most from the rising prices (Kent, 2003). In turn, price increases for fishmeal and fish oil encourage producers to reduce locally available, cheap fish to feeds (Wijkström, 2009). Furthermore, compared to other potential users the aquaculture sector is more likely to be prepared to pay higher prices for feed products made from pelagic fish, especially since the demand for high-value carnivorous fish and crabs from large-scale aquaculture is on the increase (Tacon and Metian, 2009a).

There is no unequivocal answer to the question of whether the use of fish from reduction fishery or bycatch to make aquaculture feeds might worsen poor population groups' access to affordable, small pelagic fish and thus worsen their food situation. According to Funge-Smith et al. (2005) there is growing competition between the use of economically inferior fish (often from bycatch) as fresh aquaculture feed and as a food for direct human consumption, especially in Asia, and this is being reflected in rising prices for the fish. De Silva and Turchini (2009) believe, however, that this competition is not so unequivocal, since these fish are often landed in regions where there are plenty of other fish products available for human consumption. Because their quality is often too low for direct human consumption, their use as fish feed is often the most economically sensible alternative. However, processing bycatch to food creates more jobs than processing it to fishmeal. Poor population groups benefit particularly from this food source if the catch can be sold locally without additional transport and refrigeration costs (Wijkström, 2009).

The effects of reduction fishery and fishmeal production on the incomes of the local population vary in a similar way from region to region. If the locally produced fishmeal is used locally and fishmeal-dependent aquaculture generates local employment and income for sections of the population who would otherwise have benefited from the direct consumption of cheaper forage fish, the benefits of reduction fishery can outweigh the disadvantages. One example of positive local income effects is abalone breeding in South Africa. If there are no local employment effects, and an inexpensive source of protein is lost to the reduction fishery, the disadvantages outweigh the advantages for the poor (Hecht and Jones, 2009).

In some regions, there is now a growing trend towards direct human consumption of traditional forage-fish species by local populations (Hasan and Halwart, 2009), and this trend is expected to continue in the future (Huntington and Hasan, 2009). Countries like Chile and Peru are supporting this trend (e.g. in the case of anchovies and mackerel) to improve national food security. A study on Peru also shows that processing a larger percentage of landed anchovy for direct human consumption increases the value of the final product, leading to higher productivity and more jobs

Table 4.3-1
Share of fishmeal in industrially produced feed for several fish species and species groups. The result is a clear trend towards reducing the proportion of fishmeal in feed. * Estimate
Source: FAO, 2012b: 178

Species or species group	Share of fishmeal in aquaculture feed [%]		
	1995	2008	2020*
Carp	10	3	1
Tilapia	10	5	1
Catfish	5	7	2
Milkfish	15	5	2
Various freshwater fish	55	30	8
Salmon	45	25	12
Trout	40	25	12
Eel	65	48	30
Marine fish	50	29	12
Marine shrimp	28	20	8
Freshwater crabs	25	18	8

than in the production of fishmeal (Sánchez Durand and Seminario, 2009).

Overall, it remains a regional, context-dependent question whether the direct consumption of small pelagic fish or the generation of jobs and income in forage fishery and fishmeal-dependent aquaculture has a larger positive influence on the food security of poor sections of the population (Huntington and Hasan, 2009). Further research on ways of reducing conflicts between different resource users seems a good idea (Hecht and Jones, 2009).

4.3.3
Reducing the proportion of fishmeal and fish oil used in aquaculture feeds

For several decades now, efforts have been made to reduce the dependence of aquaculture's feed production on fisheries. Industry and government research have, for example, been trying to increase the feed-conversion ratio among the species farmed, so that the proportion of fishmeal and oil in the feed can be progressively reduced. For example, the ratio of small pelagic fish used per unit of fish and crab produced improved in the period from 1995 to 2006: in the production of salmon from 7.5 to 4.9, trout from 6.0 to 3.4, eel from 5.2 to 3.5 and shrimp from 1.9 to 1.4 (Tacon and Metian, 2008: 156). However, in the cultivation of Australian bluefin tuna fed on fresh fish and fish waste, the best input-output ratio that can be reached is 12:1 (Huntington and Hasan, 2009: 16). The improvements that have been achieved are largely attributed to the rise in the prices of feed, which amounted to 50% for fishmeal and 130% for fish oil between 2005 and 2008 (Naylor et al., 2009).

Over the last 30 years there have been successes in the substitution of the proteins in fishmeal with vegetable proteins, e.g. from cereals, oilseeds, legumes, biomass from bioethanol production, or with proteins from microorganisms. Up to 75% of the fishmeal in the feed for predator species could easily be replaced (Bell and Waagbø, 2008). However, it should be noted that substitution with vegetable proteins is also likely to be limited by increasing competition for agricultural land and fresh water, which could lead to conflicts, especially in the populous regions of Southeast Asia (Olsen et al., 2008).

However, fish waste from the processing industry is also increasingly being used in the production of feed; about 36% of the world's production of fishmeal came from this source in 2010 (FAO, 2012b: 65). Other alternative sources for fishmeal and oil are waste products from livestock production (meal made from meat, bones, feathers, etc.); however, their increased use could be limited a low level of acceptance by the consumers.

Another source is the use of bycatch from fisheries, all of which already has to be landed in some countries today; this rule will also apply in the EU in the future (Section 4.1.3.4). However, the use of bycatch remains controversial because of the risk that it might lead to a softening of regulations on reducing bycatch (Naylor et al., 2009). It could become more important as an alternative source of feed production if accompanied by suitable measures such as a ban on discards and the condition that bycatch may only be used for industrial purposes.

Algae are also used in aquaculture feeds. Feed trials, e.g. with sea grass and blue-green algae, have shown, however, that replacing fishmeal with large amounts of algae has negative effects on most of the farmed fish studied, so that algae do not seem to be very suitable as a fishmeal substitute. As feed additives, algae have positive effects on growth, the feed-conversion ratio, stress tolerance, etc. (Hasan and Chakrabarti, 2009).

The substitution of fish oil, which is rich in polyunsaturated fatty acids and is vital for many marine aquaculture species, has not been very successful up to now. In salmonids like salmon and trout, for example, fish oil remains an important component of their diet because of its metabolic properties, despite the higher proportion of plant lipids. In addition, the complete substitution of fish oil would also reduce the proportion of unsaturated fatty acids in the final product, which is not desirable from the consumer's point of view. Feeds for salmonids, for example, contains more fish oil than is needed in the cultivation of the animals to ensure a certain desired level of omega-3 fatty acids in the fish product (Naylor et al., 2009).

Approaches to reducing fish oil in aquaculture feeds concentrate on almost completely replacing the fish oil during the growth phase and subsequently providing fish-oil-rich feed; as a result, the final product has a similarly high content of unsaturated fatty acids to organisms from the wild (Bostock et al., 2010). Furthermore, organisms such as bacteria and algae could be used as potential sources of unsaturated fatty acids, and genetic modifications in this context are also regarded as promising (Olsen et al., 2008; Bostock et al., 2010). Moreover, studies are being conducted on growing certain species of worm as an additional source of unsaturated fatty acids for integrated systems (Bischoff et al., 2009). Another subject of discussion is the extent to which Antarctic krill might offer a way of substituting fatty acids and proteins. However, it is feared that a significant use of krill could cause considerable negative ecological effects. Since krill is at a low trophic level on the Antarctic marine food web and is a key prey, e.g. for whales, seals and seabirds, very intensive fishing could threaten the food supply of these organisms and change the ecological structure (Constable et al., 2000; Smith et al., 2011). An improved scientific basis with data *inter alia* on distribution and population densities is urgently needed in order to decide to what extent a sustainable form of management of krill fishing might be developed on the basis of the precautionary principle (Naylor et al., 2009).

The substitution of fishmeal and fish oil remains an important issue in industry and in government research. The rising prices due to the growing demand for both feed components could support substitution.

4.4 Systemic effects: land/sea interactions and feedback loops with the Earth system

In addition to the direct effects of fisheries and aquaculture on the environment discussed above, the ecosystems and the sea as a food source are subject to stresses and pressures caused by land-based human activities. The effects of climate change and ocean acidification can threaten the long-term survival of already weakened fish populations (Gruber, 2011); they also make adaptation of aquaculture necessary (de Silva and Soto, 2009). Furthermore, pollutants such as pesticides and heavy metals find their way into the oceans via emissions or direct inputs and can have a negative impact on marine organisms and their consumers.

4.4.1 Climate change

The increased sea temperatures caused by climate change (Section 1.2.4) have direct effects on marine animals. For example, there are physiological limits beyond which the function, growth and reproduction of marine fish are reduced. This is because the oxygen supply is restricted at higher temperatures (Pörtner and Knust, 2007; Pörtner, 2010). Moreover, the temperature can affect the areas and success of reproduction (e.g. bluefin tuna; Muhling et al., 2011). However, temperature is not only a decisive factor for individual organisms; marine ecosystems also react sensitively and quickly to rises in temperature. On large scales, the patterns of marine biodiversity are closely linked to climate change (Worm and Lotze, 2009). Model calculations based on climate scenarios give rise to concerns that significant regional shifts can be expected in marine species, leading to possible disturbances in ecosystem services (Cheung et al., 2009).

Natural changes in the climate can already trigger migrations or major fluctuations in fish populations (e.g. caused by the regional climate phenomenon known as El Niño/Southern Oscillation: Barber, 2001). Anthropogenic global warming has already led to regional shifts of marine populations closer to the poles and into deeper waters (Sumaila et al., 2011; Nicolas et al., 2011). Regional population shifts and changes in species composition can be expected to have far-reaching effects on the food webs of marine ecosystems, although these are difficult to predict in detail (Worm and Lotze, 2009; Burrows et al., 2011). The effects might be less serious than expected if vulnerable species are replaced by others that take on a simi-

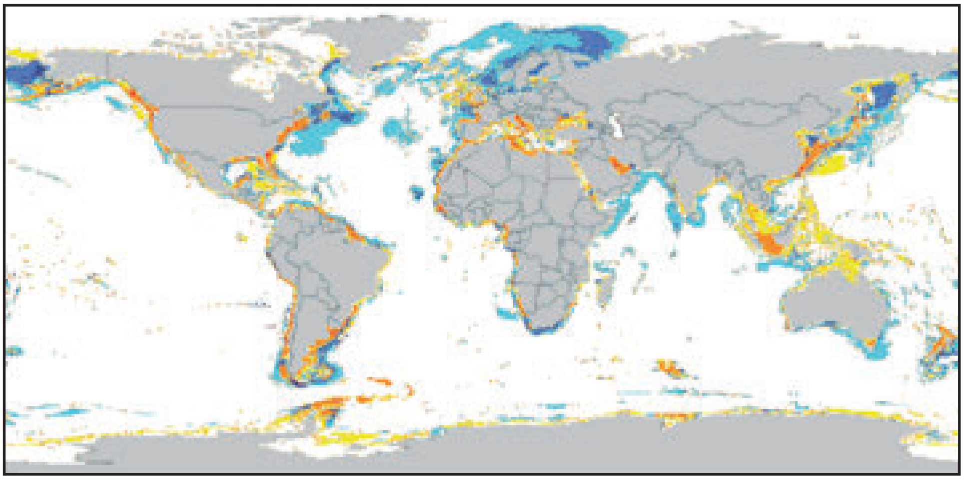


Figure 4.4-1
Absolute change in potential catch sizes (i.e. the maximum possible sustainable catch based on the MSY) between 2005 and 2055 under the A1B climate scenario (based on IPCC, 2000).
Source: Cheung et al., 2010

lar function in the ecosystem structure. But they might also be greater if temporally or functionally linked relationships between species (e.g. predator/prey relationships) are disrupted by population movements (Beaugrand et al., 2003). For example, fundamental regime shifts of marine ecosystems affecting large areas, which also occur without any anthropogenic influence, can have climatic causes (e.g. Chavez et al., 2003).

Climate change impacts are already visible today at all trophic levels (Brander, 2005). Planktonic microalgae (phytoplankton) form the most important basis for the marine food webs, so that significant changes can have a far-reaching indirect effect (Chassot et al., 2010). In the North Pacific, Ware and Thompson (2005) have shown that lower phytoplankton production can correlate with lower fish yields across several trophic levels. This relationship also works in the opposite direction: Brown et al. (2010), for example, expect an increase in primary production – and with it in regional fishery yields – for the waters around Australia as a result of anthropogenic climate change. In general, however, higher surface temperatures lead to an increase in the stratification (i.e. reduced mixing) of the sea water and weaken ocean circulation; taken together with the possible reduction in dust inputs, this is likely to reduce both the supply of nutrients to the productive upper water layers and global primary production (Steinacher et al., 2010). As climate change increases, there is therefore a fear of a global decline in aquatic production, including fish production (Brander, 2007; Chassot et al., 2010). If El Niño conditions occur more frequently or grow in strength in the warmer climate, this could also result in lower global ocean production (Behrenfeld et al., 2006). Boyce et al. (2010) have already postulated a decline in phytoplankton over the past century – both in eight out of ten ocean basins and by global average – and linked this to the higher surface temperatures.

The scientific evidence on the relationship between fisheries and climate change has improved significantly since the WBGU's 2006 Special Report. Large-scale redistribution processes affecting fish stocks were expected as a consequence of climate change (e.g. Perry et al., 2005; Nicolas et al., 2011). According to model results, potential catch sizes on the continental shelves are expected to decline everywhere except for the higher latitudes, while they will tend to increase overall on the high seas (Cheung et al., 2010). These effects will be mainly driven by population shifts and changes in primary production. A marked increase in potential catches by 30–70% can be reckoned with in Arctic and sub-Arctic latitudes (e.g. Norway, Iceland, Greenland, Alaska, Russia), while there could be substantial reductions of up to 40% in the Tropics (e.g. Malaysia, Indonesia, Chile, China, southern USA; Figure 4.4-1).

Especially in tropical regions, where many coastal communities are dependent on fishing, climate change increases people's socio-economic vulnerability and creates additional risks for food security (Allison et al., 2009; Daw et al., 2009; Figure 4.4-2). Two-thirds of the most vulnerable countries are in tropical Africa, and most of them are poor, so that economic pressures and missed development opportunities must be expected as a result. Furthermore, agricultural yields are often also declining in these countries due to climate change, which further exacerbates food insecurity (Cheung et al., 2010).

This will require considerable adaptation by fisher-

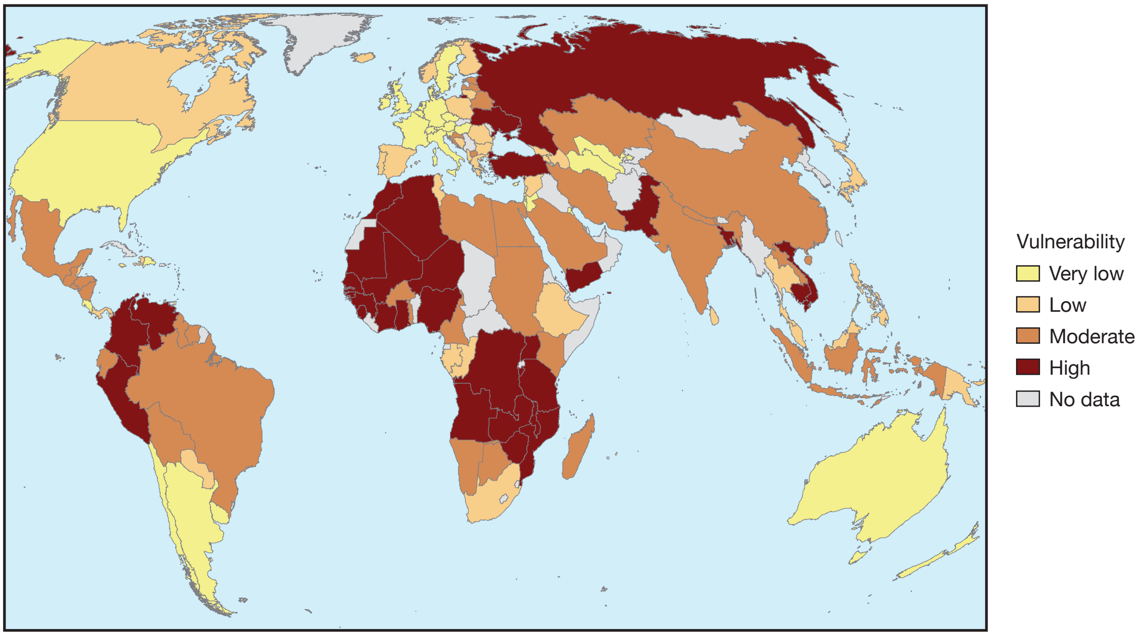


Figure 4.4-2
Vulnerability of national economies to potential climate change impacts on fisheries under the IPCC B2 climate scenario. Exposure, sensitivity and adaptive capacity are integrated and shown as one variable.
Source: Allison et al., 2009: 15

ies, because the synergistic effects of climate change and other stress factors will make fish stocks more vulnerable to fishing in general and thus create additional economic risks (Sumaila et al., 2011). In times of rapid climate change, fisheries must prepare themselves for complex and surprising effects.

Climate change also has implications for aquaculture, which vary in intensity between different climatic zones (de Silva and Soto, 2009). For example, serious restrictions due to higher water temperatures must be reckoned with primarily in temperate zones and especially among more warmth-sensitive species such as salmon (Barange and Perry, 2009). Suitable breeding conditions for these species could shift poleward (Stenevik and Sundby, 2007). The rise in sea levels (Section 1.2.7) may have a negative impact on the aquaculture industry, as it can involve increased saltwater intrusion into coastal ecosystems, greater conflicts with the interests of coastal protection, a greater frequency of extreme weather events, higher risks of disease, oxygen deficiency, increased toxic algal blooms and a growing scarcity of fresh water (Easterling et al., 2007). River deltas are especially vulnerable to extreme weather events and salinization. However, climate change could also have indirect effects on global aquaculture because, for example, the productivity of stocks of small pelagic fish, which are important for the production of fish meal and fish oil, will decline (Merino et al., 2012). In addition, the prices of vegetable feed materials could rise due to increased competition for land use (de Silva and Soto, 2009). Positive effects are also conceivable, for example as a result of an improved feed-conversion ratio and higher growth rates in warmer waters, longer breeding periods or an expansion of breeding regions (Easterling et al., 2007). Adaptation measures have already been developed in some cases and range from adapted technologies to different priorities for site selection and cross-border management (de Silva and Soto, 2009).

Fisheries and aquaculture are not only affected by the impacts of climate change, they also cause emissions, mainly because of their consumption of fossil fuels (Cochrane et al., 2009). The fishing fleet emits 43–134 million tonnes of CO_2 per year by its fuel consumption alone (Daw et al., 2009), so that fisheries account for 1.2% of the world's oil consumption. 1.7 tonnes of CO_2 are released for every tonne of fish live weight landed (Tyedmers et al., 2005).

According to a life-cycle analysis conducted by Pelletier et al. (2009), greenhouse-gas emissions from aquaculture salmon are in the range of 1.8 to 3.3 tonnes of CO_2eq per tonne of live weight – i.e. slightly higher than those of poultry farming in the USA (1.4 tonnes of CO_2eq). The feed supplied to the fish has the biggest influence in this calculation.

In marine fisheries, the phase of catching the fish – as opposed to processing, packaging, transportation, etc. – is the one that impacts most on the environment (Thrane, 2004). The fuel consumption of fishing vessels has an especially large impact, although specific fuel emissions vary considerably depending on stocks and the fishing methods used. For example, trawling is more energy-intensive than fishing with purse seine nets (Driscoll and Tyedmers, 2009; Vázquez-Rowe et al., 2010). Passive methods like hooks or traps are especially energy efficient (Suuronen et al., 2012). High-sea fisheries are particularly emissions-intensive because of the great distances between the fishing grounds and the ports.

LIFE (low-impact, fuel-efficient) fisheries (Suuronen et al., 2012; FAO, 2012b: 205) aims to combine a high yield with low fuel costs and a low impact on marine ecosystems, and thus to develop strategies for a form of fishing that is both climate friendly and sustainable. Phasing out fuel subsidies in the fisheries sector would be a step in the right direction on the road to LIFE fisheries (Sumaila et al., 2008; FAO, 2012b: 205; Section 4.1.4.7). In the long term, however, fisheries – as well as shipping and transport sectors in general – will have to find a way to do without fossil fuels altogether (WBGU, 2011: 151 ff.).

4.4.2 Acidification

Increasing CO_2 emissions are making the oceans more acidic; the sea-water carbonate chemistry is shifting, with growing consequences for the marine ecosystems (Section 1.2.5; Turley et al., 2010; Orr, 2011). Calcifying organisms in particular (corals, mussels, many species of plankton) are directly affected. The acidity of the sea water has increased by 30% in the meantime (rise in the H+ ion concentration, corresponding to a 0.1 fall in the pH). The dynamics of the changes is without parallel since at least 300 million years (Hönisch et al., 2012). An unchecked continuation of ocean acidification would alter the chemistry of the oceans for millennia to come, and many sea organisms and marine ecosystems would most likely be affected (Turley and Gattuso, 2012). Figure 4.4-3 shows the effects of acidification based on physiological responses, and the most vulnerable oceanic regions. The direct and indirect effects of acidification are a major challenge for fisheries and aquaculture.

Direct effects on organisms and populations

Laboratory studies suggest that many calcifying marine organisms are increasingly having difficulties building their skeletal structures under conditions of acidification. Calcifying species in plankton are responsible for about three-quarters of global marine calcification (WBGU, 2006). By exporting calcium carbonate into the deep sea, they not only play a role in the global carbon cycle (Section 1.2.5), but also provide food for other marine animals by forming huge plankton blooms, thus greatly influencing the marine food webs. Decreased calcification and even the dissolving of calcium carbonate structures has been proven as a result of acidification in the three most important groups (e.g. coccolithophorids: Riebesell et al., 2000; Beaufort et al., 2011; pteropods: Comeau et al., 2009, Orr et al., 2005; foraminifera: Bijma et al., 1999; Moy et al., 2009). Reduced calcification impairs the organisms' ability to survive, so that relative competitive advantages look likely to shift in favour of non-calcifying species (Fabry et al., 2008); considerable effects are also expected on the future marine carbon cycle (Beaufort et al., 2011).

Calcifying benthic echinoderms, such as starfish or sea cucumbers, can be locally important factors of food security, even if their global significance is comparatively small. They too are highly vulnerable to increasing acidification, and this is also important for fish stocks because of their role in the food chain (UNEP, 2010b). Calcifying molluscs, especially mussels, account for about three-quarters of aquaculture production in sea water, totalling 13.9 million tonnes per year (FAO, 2012b: 36). Calcification would be significantly reduced in blue mussels (-25%) and Pacific oysters (-10%) at the CO_2 concentrations expected by the end of the century if emissions are not reduced (Gazeau et al., 2007). In some regions, acidification is already causing considerable problems for oyster larvae hatcheries (Service, 2012; Barton et al., 2012).

Adult fish are physiologically able to cushion the expected increases in atmospheric CO_2 concentrations (Pörtner, 2005; Fabry et al., 2008), but juveniles are sensitive. Baumann et al. (2012) found greatly reduced survival rates of fish larvae that hatched where the CO_2 concentration was elevated. Direct damage to the larvae's tissue was even observed among cod, which are very valuable to fisheries (Frommel et al., 2012). Under acidification, fish larvae show changes in their behaviour towards predators; their sense of smell is also disturbed, which could make it difficult for them to find suitable habitats (Munday et al., 2010, 2011). Fish populations, too, therefore can react quite sensitively to acidification.

The rate of acidification is now more than a hundred times faster than in the last 65 million years (Ridgwell and Schmidt, 2010), which makes it seem unlikely that most marine organisms will be able to adapt easily to the new conditions (Munday et al., 2011). Recent studies on the most important coccolithophorid *Emiliania huxleyi*, a unicellular alga with an exoskeleton made of carbonate, report that calcification showed a

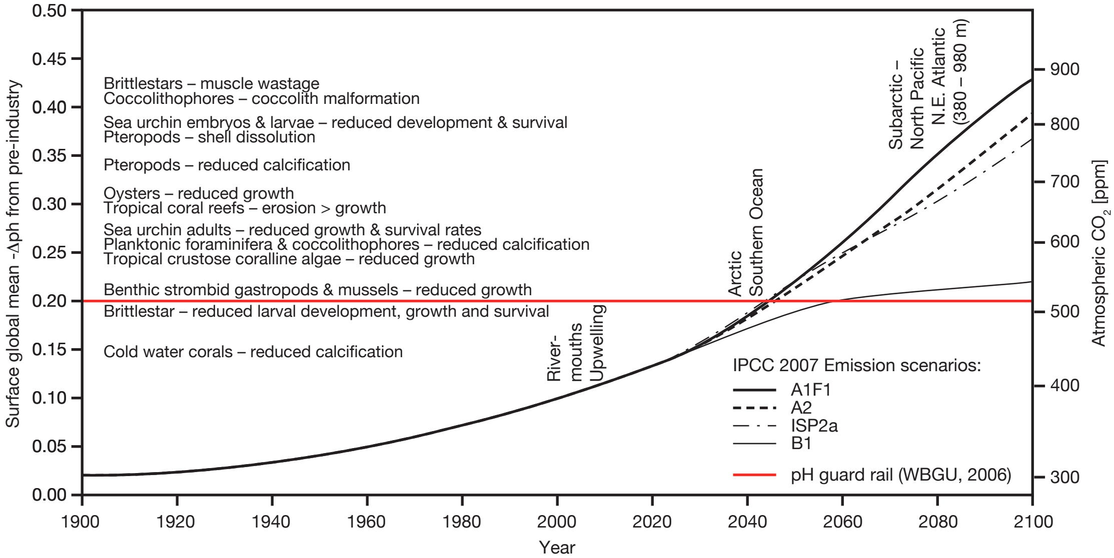


Figure 4.4-3
Projections on atmospheric CO_2 concentration and the surface global mean pH difference for a range of IPCC emission scenarios (B1 to A1F1). On the left, experimentally determined biological impacts on certain species are assigned to the respective pH values. The times and regions where aragonite undersaturation (a critical threshold of marine chemistry) is projected to occur for the first time locally and seasonally are marked on the curve. The red line represents the WBGU's acidification guard rail (Box 1-1).
Sources: Turley et al., 2010 (modified); WBGU, 2006 (guard rail)

certain degree of adaptability to acidification (Lohbeck et al., 2012). Adaptability probably varies from one species to another, so that the relative competitive advantages between species could shift dramatically, which will generate winners and losers. The resultant structural changes in the marine food web are highly unpredictable.

Indirect effects on ecosystems, fisheries and aquaculture

Planktonic pteropods offer an example of a possible indirect effect of acidification that can be traced to impacts on fisheries. These animals are particularly sensitive to acidification and are of major importance to the food webs in the higher latitudes (Hunt et al., 2008). If CO_2 emissions are not limited, it is likely to result in the aragonite undersaturation of the surface water over large areas in the North Pacific, North Atlantic and the Southern Ocean in the course of this century (Orr et al., 2005; Steinacher et al., 2009). Some of these areas are highly productive and rated among the most economically important fishery zones. For example, in the North Pacific pteropods are an important food source for juvenile salmon, which form stocks that are valuable to fisheries (Fabry et al., 2008). According to model calculations, a reduction in pteropod production could lead to a considerable reduction in the body weight of adult salmon (Aydin et al., 2005). Parts of the Southern Ocean might even become uninhabitable for pteropods as early as 2050 (Hunt et al., 2008). At higher latitudes the first occurrences of aragonite undersaturation are already being measured today (Yamamoto-Kawai et al., 2009); for the coastal waters off California they are expected within the next 30 years (Gruber et al., 2012). Increasing acidification is likely to lead to dramatic changes in the structure, function and services of polar ecosystems (Comeau et al., 2009), with corresponding impacts on fisheries (Guinotte and Fabry, 2008). It is very difficult to detect and prove such coupled effects in the ecosystem and it is only achieved in individual cases.

Coral reefs are another example (Box 1.2-4). They contribute indirectly to ensuring food security for about 500 million people, because they form the habitat for many species that are important to fisheries (UNEP, 2010b). At the same time, however, they are particularly affected by acidification, because the reef structures consist of aragonite, which dissolves rapidly when pH values fall. Hardly any reef locations (including both hot- and cold-water corals) will be able to support coral growth by the middle of the century if CO_2 emissions continue without restriction (Guinotte et al., 2006; Turley et al., 2007; Cao and Caldeira, 2008). The synergistic damage done by rising temperatures, acidification, pollution and overuse could increasingly drive reef ecosystems to functional collapse, with serious consequences for fisheries, tourism and coastal communities (Hoegh-Guldberg et al., 2007).

Overall, studies conducted to date show that uncontrolled acidification poses a considerable risk of far-reaching and irreversible changes to marine ecosystems, which is also likely to affect fisheries, aquaculture and food security (Fabry et al., 2008; Guinotte and Fabry, 2008; Doney et al., 2009; Turley et al., 2010; UNEP, 2010b; Turley and Gattuso, 2012). The potential economic cost is difficult to assess. Cooley and Doney (2011) give an example: shellfish account for about half of the USA's domestic fisheries' profits of US$4 billion, so considerable losses would ensue if, say, revenues fell by 10–25 % as a result of reduced calcification.

4.4.3
Low-oxygen zones and eutrophication

The physiological performance and distribution of many marine organisms, especially fish and shellfish, are highly dependent on the oxygen content of the water. They cannot survive below a certain threshold, so low-oxygen and anoxic zones in deep water are also called 'dead zones' (Diaz and Rosenberg, 2008; Section 1.2.6). In such regions, fundamental changes happen to benthic communities, including demersal fish and above all shellfish (e.g. Gulf of Mexico: Rabalais et al., 2002, Zhang et al., 2010). The number and extent of low-oxygen zones have increased over the last few decades (Rabalais et al., 2010; Figure 4.4-4). Their effects on marine ecosystems have tended to be underestimated (Vaquer-Sunyer and Duarte, 2008; Keeling et al., 2010).

Anthropogenic inputs of sewage and nutrients (nitrogen, phosphorus) are widespread in coastal waters and their effects well studied (eutrophication). The increased primary production caused by these inputs and the subsequent oxygen depletion when biomass decomposes favours the formation or expansion of low-oxygen zones near the ocean floor (Breitburg et al., 2009; Rabalais et al., 2010). In particular, the discharge of untreated sewage can cause severe oxygen depletion in estuaries. Increasing numbers of dead zones have formed (and naturally present dead zones have increased considerably in size) in semi-enclosed and marginal seas like the Baltic, the Black Sea or the Gulf of Mexico, where the level of water exchange with the ocean is reduced. They typically develop in the summer after the decomposition of the sinking spring phytoplankton bloom and disappear again in the autumn. There are also permanent low-oxygen zones, e.g. in the Baltic Sea. Dead zones have been found in more than 400 marine regions in the meantime, with a total area of over 245,000 km² (Diaz and Rosenberg, 2008). The longer the process of oxygen depletion continues, the

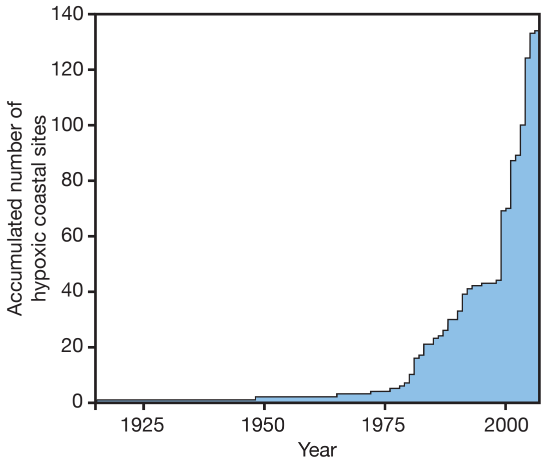


Figure 4.4-4
Accumulated number through time of coastal sites where hypoxia has been reported.
Source: Vaquer-Sunyer and Duarte, 2008

longer the benthic habitats take to recover and be re-colonized (Diaz and Rosenberg, 2008). The simplest and most effective means of addressing eutrophication is sewage treatment and reducing nutrient discharges from agriculture.

In addition to eutrophication, model calculations suggest that the oxygen content of sea water in the oceans decreases with climate change (Rabalais et al., 2010). This is not only due to the warmer water, which cannot dissolve as much oxygen, but also to thermal stratification, which is increased by a warmer climate and reduces the supply of oxygen to the deeper layers. Analyses of geological strata show that in the past the oceans formed large areas with reduced oxygen content during warmer periods. There are already signs of a reduced oxygen content in the oxygen minimum zones of the North Pacific and the Tropics (Keeling et al., 2010). In the tropical North Atlantic, the expansion of the oxygen minimum zones, together with overfishing, can become a threat to the valuable stocks of tuna and swordfish (Stramma et al., 2011).

Direct effects on fisheries have already been observed. Rosenberg (1985) reports that lobster fishing in the Norwegian Kattegat has suffered from the formation of low-oxygen deep-water zones. In the Black Sea, nutrient input, low-oxygen zones, and the falling yields of bottom fishing are all closely linked and seem to be reversible (Mee, 2006). However, the growth of low-oxygen zones can also reduce predator pressure on certain anoxia-tolerant species (e.g. the clam *Mercenaria mercenaria*), so that their yields increase (Altieri, 2008). After analysing 30 estuaries and marginal seas, Breitburg et al. (2009) come to the conclusion that to date fishing yields are typically not being reduced to the extent that would be expected given the high nitrogen inputs. In the Gulf of Mexico, too, which regularly has large low-oxygen zones, no statistical correlations with fishing yields are recognizable (Rabalais et al., 2002). Not infrequently, fisheries can be observed to switch from demersal to pelagic species.

Overall, however, it is not advisable to sound the all-clear, since low-oxygen zones cause fundamental changes in marine ecosystem structures and functions. These regime shifts in marine ecosystems can have unforeseen effects which, at least locally, can have a negative impact on biodiversity and indirectly also on fisheries (Zhang et al., 2010).

4.4.4
Anthropogenic pollution

Substances like plastics, chemicals, heavy metals and radioactive compounds have long-since been entering the marine environment both from land- and sea-based sources and via inputs from the atmosphere (Section 1.1.4). For example, rivers transport chemicals and waste into the seas from industry, households and agriculture; pollutants and waste enter the oceans from offshore oil and gas installations, marine aquaculture and shipping traffic. Residues from combustion processes, for example, are transferred into the seas from the atmosphere (OSPAR, 2010c). Historical deposits in sediments or the Arctic ice sheet can become secondary sources of pollution when disturbed, e.g. by floods or melting (Ma et al., 2011). Since there are several hundred substances that can be harmful to the marine environment, the following section focuses on specific examples: persistent (i.e. long-lived) organic pollutants (POPs), mercury (a heavy metal), radioactive compounds and plastics.

There are several international conventions and numerous other initiatives regulating the production, use and emission into the environment of hazardous substances. For example, the Stockholm Convention of 2001 now prohibits or restricts the production of 22 POPs (Stockholm Convention, 2013a, b, c). This covers industrial chemicals such as the banned polychlorinated biphenyls (PCBs), pesticides like DDT, and by-products of industrial processes like chlorofluorocarbons. The International Convention for the Prevention of Pollution from Ships (MARPOL), for example, prohibits the dumping of plastic waste at sea (IMO, 2013b). Since the mid-1990s, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention) has prohibited the dumping of industrial wastes and solid radioactive waste at sea (IMO, 2013d). Under the Hazardous Substances Strategy, the OSPAR member governments have set themselves the target of terminating the production of 26 'chemicals for priority action' by 2020. OSPAR itself says this target will be reached for a third of the substances, including six pesticides and tributyltin hydride (OSPAR, 2010a). The OSPAR governments aim to reduce the input of radioactive substances into the north-east Atlantic by means of the Radioactive Substances Strategy, which has had some success with nuclear reprocessing plants, for example (OSPAR, 2010a). In January 2013 the international community adopted the Minamata Convention aimed at reducing and controlling the use and emission of mercury (UNEP, 2013c).

Studies show that concentrations of the regulated pollutants in marine organisms are currently declining (Bustnes et al., 2010). Nevertheless, traces of DDT, for example, were still detected in roundnose grenadier fish at a depth of 3,000 m a long time after its use had been greatly restricted (Islam and Tanaka, 2004). Studies of organisms in the north-east Atlantic also continue to show in some cases high concentrations of anthropogenic pollutants, although the situation has improved in some regions (OSPAR, 2010c; Figure 1.2-1 on the example of PCBs). Although the efforts to regulate and reduce the input of chemical and radioactive substances and waste into the oceans are showing individual successes, they often fall short of the mark, especially in the case of plastic waste.

Persistent organic pollutants and mercury

Substances like POPs and heavy metals can be found in sea water, sediments and marine organisms (OSPAR, 2010c). Their toxic properties, combined with the fact that they accumulate in the tissues of marine organisms (bioconcentration) and therefore in the food chain (bioaccumulation), make them especially dangerous. Concentrations of both classes of substances increase two- to seven-fold at each higher level in the food chain; they are therefore often highest in predatory fish (Islam and Tanaka, 2004; UNEP-AMAP, 2011).

The effects of anthropogenic pollutants on marine fauna have been analysed in various laboratory studies, e.g. on fish and invertebrates; it was found that the sensitivity of response varied from one species to another (e.g. Foekema et al., 2008; Anselmo et al., 2011). Foekema et al. (2008) found that PCB 126 caused higher death rates and morphological disorders; exposure at the egg stage, e.g. in sole larvae, caused damage that did not appear until later, as well as mortalities. Laboratory studies often do not capture the full extent of the impact of pollutants on organisms, since they consider pollutants individually. In the open sea the investigated substances do not occur in isolation but in combination, and this can have much more damaging effects. Nakayama et al. (2005), for example, have shown the stronger effect of combinations of pollutants on Japanese rice fish. Since there is currently no comprehensive monitoring of biological reactions to chemicals, to date it has not yet been possible to assess the effects of these substances on ecosystems on a regional scale (OSPAR, 2010c).

The effects of mercury on humans are well documented. It is harmful to the nervous system and to development. Consumption during pregnancy is associated with malformations of the foetus (WHO, 2007b). By contrast, the health effects of POPs have only been known since the 1980s and have not yet been exhaustively analysed (Bowen and Depledge, 2006; Dewailly et al., 2008). Animal experiments, individual studies of long-term exposure by ingestion, and acute exposure to POPs as a result of chemical accidents show a range of carcinogenic effects, neurodevelopmental disorders, hormonal disorders, obesity, diabetes and disorders of the immune system. Children and foetuses are considered particularly sensitive (UNEP-AMAP, 2011).

Humans are affected by the accumulation of anthropogenic contaminants in marine organisms when they eat fish and seafood. For example, studies conducted in Spain show that fish can be humans' main source of mercury, PCBs and a number of other pollutants. Domingo et al. (2007) studied the 14 most frequently consumed fish species and came to the conclusion, on the basis of the average amounts of mercury they contained, that people should not eat tuna or swordfish. The US environmental organization EPA recommends that pregnant and breastfeeding women and children should refrain from eating species with a high mercury content – such as painted mackerel, shark and swordfish (EPA, 2012). Similarly, the Norwegian health authority has recommended that people in the Faroe Islands stop their traditional consumption of pilot whales (Weihe and Joensen, 2008).

Plastic and microplastics

The amount of plastic waste circulating in the oceans is estimated at about 100 million tonnes in the meantime (UNEP, 2011c), and its distribution varies considerably in the different marine regions. For example, up to 100,000 pieces of plastic waste are visible to the eye per km^2 on the seabed in European waters, compared to up to 690,000 in Indonesia (Maribus, 2010:86ff.). About 80% of the waste comes from the land and enters the sea via rivers, from poorly secured rubbish dumps near the coast, or from beaches (Andrady, 2011; Cole et al., 2011). The rest comes from ships, oil rigs, aquaculture installations and fishing operations (UNEP, 2011c). Plastic waste can travel for hundreds of kilometres via ocean currents. It then accumulates in uninhabited regions, e.g. in the Arctic or Antarctic (Barnes et al., 2010; UNEP, 2011c) or sinks into the deep sea, where it is degraded even more slowly due to the lower temperatures and the lack of UV radiation (UNEP, 2011c). In several oceanic regions such as the North Pacific and the North Atlantic, however, the waste collects because of the ocean currents and rotates on or near the surface in eddies hundreds of kilometres wide (Law et al., 2010; Maribus, 2010; van Sebille et al., 2012).

The effects and dangers of larger pieces of plastic waste on marine organisms and ecosystems are well documented. Marine mammals, seabirds, fish, crabs and reptiles can be injured; some drown as a result of getting entangled in pieces of plastic or drifting 'ghost nets' (Gregory, 2009; Katsanevakis, 2008). If pieces of plastic are mistaken for food and ingested, this can cause constipation, malnutrition and death and has been documented above all in seabirds (Young et al., 2009). Another problem is the dispersal over long distances of non-native species such as barnacles, mussels and tube worms into other marine ecosystems on pieces of plastic (Barnes, 2002; Gregory, 2009), where they can cause ecosystem damage as invasive alien species. Pieces of plastic on the seabed can furthermore attract organisms dependent on hard substrate and thus lead to changes in benthic communities (Katsanevakis, 2008).

However, plastic waste in the sea not only burdens the marine environment, it can sometimes also cause high costs for the fishing and tourism industry, the marine transport sector, local onshore communities and governments. Considerable costs are caused when beaches, mainly for aesthetic reasons, need to be cleaned and ships repaired, or catches are contaminated with waste. The corresponding costs to the British fishing industry alone are estimated at €33 million (ten Brink et al., 2009). Solutions aimed at reducing marine plastic waste include material reduction, re-use, recycling and improved waste management. Moreover, there are numerous international treaties and national initiatives aimed at reducing waste; even so, no effective global approach to containing the problem is in sight (STAP 2011).

When pieces of plastic are decomposed by the action of UV radiation, waves or biological processes, small particles are formed. The term microplastic is used for such particles below a certain size, which varies, depending on the author or study, between <10 mm, <5 mm, 2–6 mm, <2 mm and <1 mm (Cole et al., 2011). Microplastic also refers to small, plastic granules used in industry, and microscopic particles used for example in cosmetics, medicine or for sandblasting (UNEP, 2011c; Cole et al., 2011). Another source of microplastic is washing-machine wastewater, which contains miniscule fibres of synthetic clothing (Browne et al., 2011).

Microplastic has already been detected in the guts and tissues of various marine animals, including whales, fish and invertebrates (Maribus, 2010). Of particular concern are research findings from the last ten years showing that microplastics give off plasticizers and other ingredient substances into the environment; they can also bind substances such as POPs, which are carcinogenic and harmful to the hormone system. These substances can then be spread by being transported by the plastic particles, finding their way into organisms and accumulating in the food chain (Islam and Tanaka, 2004; Teuten et al., 2009; Andrady, 2011).

Radioactive substances

Radioactive substances of anthropogenic origin have entered – and are still entering – the marine environment in three main ways: as radioactive fallout from past nuclear weapon tests in the atmosphere (decreasing inputs), from the accidents that happened at the nuclear power plants in Chernobyl in 1986 and Fukushima in March 2011, and as radioactive effluent from nuclear reprocessing plants that is legally discharged into the sea to this day, primarily at Sellafield (north-west coast of England) and La Hague (north-west coast of France; Livingston and Povinec, 2000). In addition, inputs have been and are still being caused by the dumping of nuclear waste, the use of radioactive materials in research, industry (e.g. offshore oil and gas industry) and medicine, and more minor accidents in nuclear power stations (Aarkrog, 2003; UNEP and GPA, 2006; OSPAR, 2010c).

The Arctic and north-east Atlantic are particularly affected by anthropogenic radioactive inputs (UNEP and GPA, 2006). Among other issues the storage of spent nuclear fuel and reactors and the dismantling of nuclear-powered ships, mainly in north-west Russia, remain problematic (AMAP, 2010). Dangers from sunk submarines and waste cannot be assessed as yet. However, a study of the Barents Sea shows only a small burden on the marine environment by anthropogenic radionuclides and classifies the consumption of seafood from this region as safe (Gwynn et al., 2012). AMAP (2010), however, points to increased concentrations of radionuclides in sea birds and whales in the Arctic. The EU's ERICA project to assess environmental risks posed by radioactive substances in the north-east Atlantic found that marine ecosystems were exposed to small doses. Negative consequences were considered unlikely (OSPAR, 2010c). However, reducing inputs of anthropogenic radioactive materials should remain an objective of international and national efforts.

The reactor accident in Fukushima is the biggest source of radionuclides in the ocean caused by an accident to date. The impact on marine ecosystems has been spread over a wide area by dilution effects, as indicated by the rapid fall in radioactivity levels in the sea water off Japan one month after the highest level of activity was measured. So although radionuclides from the nuclear accident at Fukushima have been indentified in Pacific bluefin tuna caught off the coast of California, the concentrations measured were more than one order of magnitude below the Japanese thresholds for the consumption of fish and seafood (Madigan et al., 2012). Due to the expected local radioactivity levels in marine sediments, in benthic organisms and along the food chain via bioaccumulation, however, threats to humans cannot be excluded. This is especially true for Japan, where consumption levels of fish, shellfish and algae are very high. Continuous monitoring, the collection of more data, and a ban on fishing in waters polluted by Fukushima are necessary measures (Buesseler et al., 2011).

However, the highest exposure to radioactivity comes from natural sources. Naturally occurring radioactive polonium (^{210}Po) accounts for the biggest proportion of the dose to which marine organisms are exposed, and thus also for most of the background dose of a population that lives on fish and shellfish (Livingston and Povinec, 2000; UNEP and GPA, 2006). Thus, the annual dose of anthropogenic radioactive caesium (^{137}Cs) for a hypothetical population living on the north-east Atlantic that consumes 100 kg fish and 10 kg of shellfish per year, is estimated at 3 µSv, while ^{210}Po contributes 160 µSv. These figures are still way below the figure of 1,000 µSv that is still considered acceptable for humans (Livingston and Povinec, 2000).

4.4.5
Synergistic effects

There are a number of mutually influencing interactions between the global environmental changes examined here and their effects on marine ecosystems. These interactions often reinforce, rather than weaken, each other (Rogers and Laffoley, 2011). The complex effects of greenhouse-gas emissions on marine ecosystems, fisheries and aquaculture are particularly important in this context (Sections 4.4.1, 4.4.2; Figure 4.4-5). Furthermore, there are reinforcing relationships between acidification and anoxic zones (Hofmann and Schellnhuber, 2009), between oxygen supply and thermal tolerance in organisms (Pörtner, 2010), and between warming, oxygen supply, stratification, nutrient cycling (N, P) and emissions of N_2O relevant for climate change (Keeling et al., 2010). Furthermore, acidification can have the effect of making phytoplankton

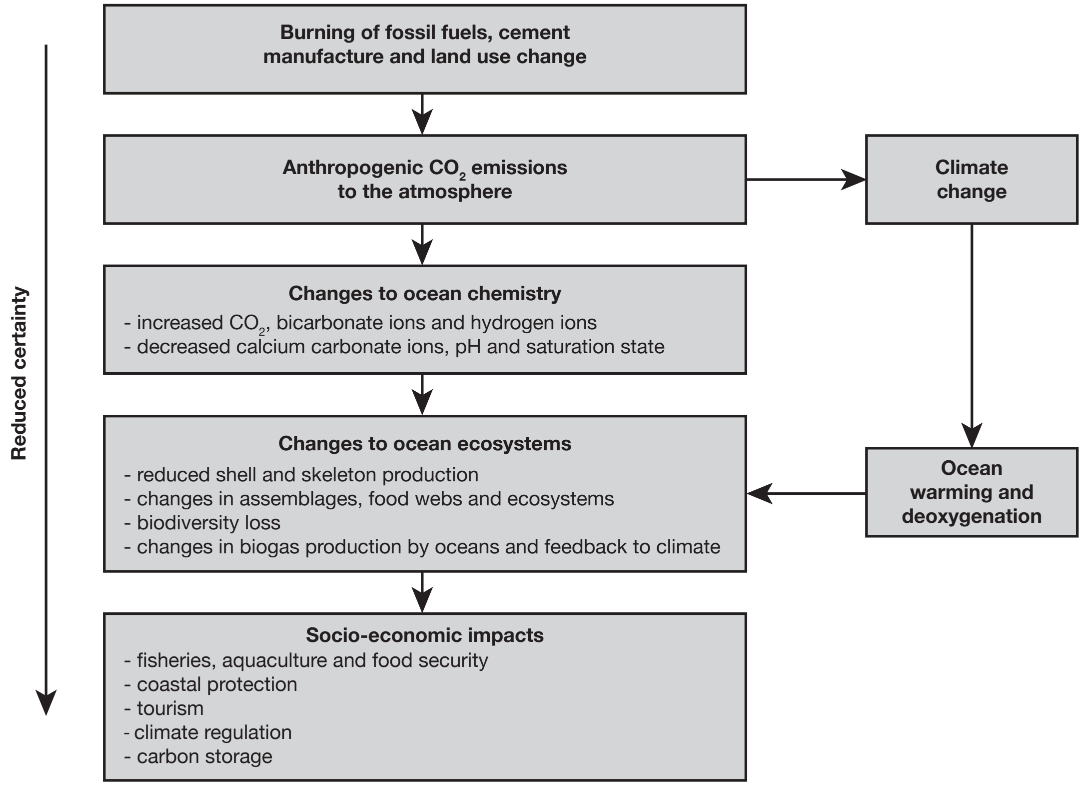


Figure 4.4-5
The flow chart shows the direct causes of ocean acidification, the impacts on ocean chemistry, marine ecosystems and society, as well as the interaction with climate change as a result of ocean warming and oxygen loss. Note the decreasing certainty from top to bottom.
Source: based on Turley und Gattuso, 2012, modified

more sensitive to light, which could reduce production (Gao et al., 2012). The negative influence on eutrophication and anoxic zones of increasing nutrient inputs into the sea has already been discussed in Section 4.4.3. In addition to this, a link can be shown to have existed between a warmer climate and anoxic zones in the Baltic Sea for many centuries (Kabel et al., 2012).

It is almost impossible to predict such cumulative or synergistic effects of different anthropogenic stress factors working in parallel (e.g. rising temperatures, acidification, pollution, overuse; Doney et al., 2009; Boyd et al., 2010). In combination with overfishing they have considerable potential for unexpected reactions which could lead to tipping points being reached in marine ecosystems (Scheffer et al., 2001). Overall marine degradation appears to be greater than the sum of its parts, and the degradation process is advancing more quickly than predicted (Rogers and Laffoley, 2011).

Global environmental changes and their interactions with overuse and degradation represent major challenges for the future of the oceans (Section 1.2.8). The effects of climate change and acidification on fisheries are growing in this context, and resilience will be lower where stocks are already damaged by overfishing: healthy, sustainably managed stocks are more robust vis-à-vis environmental effects. The systemic relationships, the uncertainties and the possible non-linear dynamics (e.g. when tipping points are triggered) highlight the need to move away from analysing individual stocks towards a holistic, adaptive, ecosystem approach and towards the precautionary approach in fisheries management (Section 4.5). However, most of the emissions reductions in greenhouse gases and nutrients will have to be achieved on land – in the energy, transport and land-use systems – since this is where by far the biggest share of emissions comes from.

The combination of acidification, warming and oxygen loss, its effects on marine ecosystems and fisheries, and their feedback effects on the climate system are insufficiently understood. Increasingly, therefore, multidisciplinary approaches in research are recommended in order to address these complex issues (Turley and Gattuso, 2012).

4.5 Conclusions

Fisheries

- *From an economic perspective, humanity's current way of interacting with marine living resources is ill-advised:* In practice, unregulated access to fish stocks, in which every fisherman primarily seeks to maximize his own personal yield, is still widespread. This way of thinking in short-term yields leads to overfishing and will continue to run stocks down until they collapse. In many regions, too little action is being taken to enact and implement rules for sustainable management based on a long-term perspective. Seen from a global viewpoint, therefore, marine fish stocks are being poorly managed, thus costing national economies billions (World Bank and FAO, 2009).
- *From an ecological perspective, humanity's current way of interacting with marine living resources is unsustainable:* Many marine ecosystems are suffering from the extreme interventions of fisheries. Overfishing, high bycatch levels, illegal and destructive fishing methods threaten the ecological basis of marine ecosystems, the preservation of biological diversity and the ocean's ecosystem services.
- *The demand for fish is on the increase:* The demand pressure on fish resources will grow. Fish is in demand not only as a high-quality product in industrialized countries and among the more wealthy sections of the population in emerging economies, but also as a vital source of protein for the growing populations in developing countries. It will not be possible to satisfy this demand from the wild stocks, and this will make it even more difficult for policy makers to quickly and consistently implement a shift towards sustainability (Mora et al., 2009).
- *The transformation towards sustainable fishing is necessary:* There is an urgent and fundamental need for transformation in the world's marine fisheries. If stocks are not given an opportunity to recover, and if the pressure from fishing remains constant, then the yields will decline, more and more stocks will become endangered, and the important contribution that the seas can make to food security, especially in developing countries, will be put at risk. A transformation towards sustainability would also be positive for food security, for national economies, and for the marine ecosystems. The goal should be to secure the following threefold benefit: larger stocks, higher yields and greater resilience, e.g. vis-à-vis systemic effects like climate change – and all this at lower operating costs (Section 7.4.1). The need for such a transformation of fisheries towards sustainability is widely recognized among scientists and politicians.
- *The transformation towards sustainability is possible:* The technical and policy instruments for sustainable stocks management are available (Beddington et al., 2007). There is considerable potential for achieving a sustainable form of ocean use – by applying technical solutions and by agreeing and implementing better management rules. To achieve this, the primary task would have to be to implement long-agreed principles (especially the ecosystem approach and the precautionary principle) and policy targets, and to apply already existing instruments (Section 7.4.1). Above all, significantly more should be invested in conserving and rebuilding stocks. However, the existing instruments would have to be tailored to the respective local ecosystem and societal conditions and combined to form a suitable mix. This applies not only to stocks management itself, but also to its integration into overarching ocean-conservation strategies (e.g. marine spatial planning, systems of marine protected areas).
- *The transition to sustainable fishing will involve temporary losses of yield:* Pressure from fisheries will have to be temporarily reduced in order to consolidate and rebuild stocks. This means that average global yields will temporarily decline. This will involve considerable short-term political, social and economic costs, although these would be offset by long-term advantages (World Bank and FAO, 2009). Catch restrictions will be inevitable, especially in regions where there have been years of overfishing; measures might range from dramatic reductions in quotas to the closure of fisheries altogether for a certain number of years, so it will be difficult to convince players in the fishing sector to agree. This situation means that mobilizing the political will among a broad cross-section of society will be crucial to implementing this transformation. However, yields can be expected to return to the old level – or even be higher worldwide and in many regions – after the transformation, without endangering the stocks or using destructive methods (UNEP, 2011b; EU: Froese and Quaas, 2013). The duration of the necessary transition periods will depend on the particular stock and the environmental situation. It is difficult to predict and could take years or even decades.
- *The trend has already started to turn in some regions:* In the scientifically well-studied stocks in industrialized countries, the tide is already beginning to turn in the direction of sustainability (Worm et al., 2009). The targeted EU reform also points in the right direction (Section 7.4.1.7). Overall, the situation in indus-

trialized countries is gradually moving onto a slow road towards improvement (e.g. Australia; Box 4.1-6). On the other hand, the poorly studied, 'data-poor' stocks, most of which are in developing or newly industrializing countries, are in a much worse condition. There is no turning point in sight yet here (Costello et al., 2012b). The challenge in these regions is also much greater, partly because there is serious lack of capacity in many areas. Nevertheless, there are also some developing countries that are regarded as positive case examples (e.g. Namibia; Box 4.1-7).

- *The implementation and enforcement of regulations is decisive:* The basis of a form of fisheries governance that serves sustainability already exists, even though there are regulatory gaps that need to be closed immediately (e.g. relating to fishing on the high seas). International regulations, such as the FAO Code of Conduct for Responsible Fisheries and the UN Fish Stocks Agreement, provide good guidance for sustainable stocks management. However, a sustainable governance of fisheries has failed so far, mostly from a lack of national regulation combined with weak implementation. One example is the continuing subsidization of fishing industries, leading to excess capacity. It is crucial for the sustainability of fisheries that the recommendations put forward by scientists (e.g. quotas, management plans) are implemented into practical policy by means of a transparent and participatory process – wherever possible without getting watered down in the process (Mora et al., 2009). As a rule, such implementation is the task of public authorities, such as fisheries ministries, and since they operate in the political arena they are exposed to many other factors and interests in addition to the assessments of scientists. Not least, there is a considerable and widespread lack of enforcement, so that adopted regulations can often be undermined with impunity.
- *Global coordination is necessary:* One side effect of sustainable fisheries management in a region of the world can be that catch sizes there decline and the demand is then met by imports from other regions of the world, where political pressure to allow overfishing increases accordingly. To avoid such a shift, a globally coordinated transition to sustainable management would be desirable, although it is politically very difficult to implement (Worm and Branch, 2012).
- *Systemic effects of global environmental changes should be taken into account:* Climate change puts considerable pressure on fisheries to adapt, because the vulnerability of fish stocks can be expected to increase, and fisheries will have to react to complex and surprising effects. If ocean acidification were to continue unchecked, this would alter ocean chemistry for millennia to come and involve a further significant risk of far-reaching and irreversible changes to marine ecosystems. Anoxic zones also cause fundamental changes in the structure and function of the marine ecosystem. Overall, this is also likely to affect fisheries and aquaculture, although the likely economic losses are difficult to estimate.
- *Continue research and development:* Even if the current problems caused by overfishing have their roots not so much in inadequate knowledge about the sustainable management of fish stocks as in the inadequate application of existing knowledge, the present gaps in knowledge should nevertheless be filled. This applies in particular to a better understanding of the structures of the managed marine ecosystems, the development of more environment-friendly fishing methods, the management of data-poor stocks, research into governance, and research into the effects of global environmental changes (Section 8.3.3.1).

Aquaculture

- *Aquaculture is a key component in supplying humanity with fish products:* Aquaculture today has a very important role worldwide in supplying people with fish and seafood. Its importance will grow further in view of stagnating fishing yields, growing populations and a growing demand, especially from the developing middle classes in emerging and developing countries: aquaculture is the fastest-growing food sector in the world. Aquaculture's contribution to supplying people with animal aquatic products is expected to overtake that of fishing in the near future.
- *Much of aquaculture is not sustainable:* The intensive forms of aquaculture can cause considerable environmental problems such as pollution, disease transmission and risks to the gene pool of wild populations. The growing production of economically high-value, fish-eating species such as salmon further increases pressure on wild fish stocks because of its dependence on fish meal and fish oil. These forms of aquaculture will not, therefore, take any pressure off fish stocks until the fish meal and fish oil in the feed are substituted.
- *Aquaculture is inadequately regulated internationally:* The international governance of aquaculture is inadequate. Only vaguely formulated recommendations, guidelines and strategies for promoting sustainable aquaculture exist at the international and EU level. The non-binding FAO Code of Conduct for Responsible Fisheries (Article 9; FAO, 1995) plays a leading role in this context. In addition, several of aquaculture's concerns and environmental effects are touched on by specific conventions (e.g.

rules on hygiene, management of invasive alien species).

- *State regulation of aquaculture is often unsatisfactory:* In most countries there are regulations governing aquaculture. However, these are often weak and inadequately enforced, especially in developing and newly industrializing countries, which opens the door to non-sustainable practices and conflicts over use. Topical and reliable data are often lacking, which makes policy-making and strategy implementation even more difficult. When strict quality and environmental standards are implemented, however, there is a danger that small aquaculture farmers in developing countries will be unable to meet them for lack of financial or technical resources; this can then make it more difficult for them to access supraregional markets.
- *Transformation of aquaculture towards sustainability is necessary:* Parallel to fisheries there should also be a shift towards sustainability in aquaculture (Section 7.4.2). Many of the above-mentioned environmental problems can already be mitigated today by introducing sustainable management principles, improved production systems and different feeds. The dependence of certain aquaculture systems on forage fish, too, can be further reduced and the proportion of plant-based food increased. It is important to bear in mind the diversity of aquaculture: in its different forms, species are also to be found whose cultivation only impacts slightly on the environment. These include herbivorous fish and shellfish, mussels and snails.
- *Develop and implement rules on sustainable aquaculture:* If aquaculture is to be made sustainable, effective approaches to governance will be needed at all levels to encourage a development towards ecologically and socially responsible forms of aquaculture production and consumption in producer and consumer countries (Section 7.4.2). The ecosystem approach and the precautionary principle should form the basis, and the systemic relationships (e.g. socio-economic impacts of aquaculture, impacts of climate change on aquaculture) should also be considered. The development of sustainable aquaculture requires the cooperation of many players across national borders and a wide range of measures. Above all, the focus should be on further developing existing international regulation, stepping up its implementation in national law, and ensuring effective enforcement. Alongside state policy, environmental-protection measures taken by the farmers on their own initiative can promote the implementation of sustainable aquaculture, e.g. environment-friendly production methods.
- *Promote research and development for sustainable aquaculture:* Support should be given to developing new, environment-friendly production methods, as well as to improving conventional systems, e.g. by more effective vaccination of breeding animals and effective management (Section 8.3.3.2). At the same time, the development and marketing of herbivorous and omnivorous freshwater fish, as well as mussels and snails, should be promoted, as their cultivation is preferable to predatory fish from an ecological point of view. Other important approaches include improving and standardizing the certification of sustainably produced products, and providing better information for traders and consumers on the effects of certain forms of production. The integration of aquaculture into offshore wind farms is a promising approach to sharing the use of infrastructure and reducing spatial competition between different uses. The relevant technologies are in their infancy and should be further supported.
- *Sustainable aquaculture is an opportunity for developing and newly industrializing countries:* The vast majority of aquaculture production occurs in developing and newly industrializing countries, some of which suffer from serious food insecurity. A stronger commitment from governments and civil society in a critical dialogue with the producers should be encouraged to ensure that the potential of aquaculture is wisely used and damage prevented wherever possible. Industrialized countries in particular, as important importers of aquaculture products, should – in the context of their development cooperation – support producers in the developing and newly industrializing countries in their transition to a ecologically sustainable and socially just aquaculture.
- *Regulate conflicts over use:* The dynamic development of aquaculture often leads to conflicts with competition over the use of space. The integration of conflict-regulation mechanisms into processes is therefore of great importance (Section 7.4.2.5); examples include approval procedures with environmental impact assessments in the context of marine spatial planning, and the promotion of dialogue processes within an integrated system of coastal-zone management.
- *Follow developments in offshore aquaculture:* As result of the strong growth of the aquaculture industry, increasing competition for the use of coastal regions, and technological development, aquaculture installations are expected to be built further and further away from the coast, possibly even on the high seas, in future. The existing international agreements, recommendations and principles, however, are insufficient to meet the challenges involved, so that there is a lack of regulation here (FAO, 2010b).

Energy from the sea

5

Energy systems play an important role in the transformation towards sustainable development. While the report 'A Social Contract for Sustainability' (WBGU, 2011) focused mainly on terrestrial aspects of energy generation, the present report takes a closer look at the potential for generating energy from and on the sea. In the extraction of oil and gas there is already a clear trend towards offshore exploration. This development seems to be continuing in the field of renewable energy; the use of offshore wind energy, for example, is growing much faster than onshore use in European countries.

Technologies for generating electricity are playing an important role in the offshore expansion of renewable energy because they enable considerable increases in technical efficiency for all downstream processes of energy use. The improvement in efficiency along energy-conversion chains makes it attractive to use more electrical energy. Important examples include electromobility and the increased use of electric heat pumps for heating or air-conditioning buildings. In this context electricity from renewable energy displaces fossil fuels such as petrol, diesel, heating oil and gas. These developments then make a massive contribution to the decarbonization of the energy systems. Another possible method of low-CO_2 energy generation is to use fossil fuels, but to separate and store the resulting CO_2 (CCS) – if the CO_2 can be stored safely over geological timescales. The oceans can make a decisive contribution to both alternatives in the future.

In general, wind and solar energy could make the most important contribution towards power generation using renewable energy. Both technologies produce electricity without heat losses. The biggest wind-energy potential is seen in offshore use, because it allows a relatively balanced energy supply and could be a good option for supplying near-coastal metropolitan areas (WBGU, 2011). CCS is a necessary climate-protection option for countries that do not wish to stop using fossil fuels. From a safety and acceptability viewpoint, the best options for storing the CO_2 separated from fossil combustion processes are to be found beneath the seabed (WBGU, 2006). In the long run another use of the seas might be added in which the high productivity of aquacultures is used for bioenergy production. If the CO_2 generated in the process is deposited beneath the seabed, CO_2 is actively removed from the atmosphere.

The oceans themselves are becoming increasingly interesting for energy storage, too. Marine pumped-storage power plants open up new possibilities for a cost-effective and environment-friendly short-term storage of electrical energy. Further possible uses of the seas include the production of hydrogen or methane from wind power or from aquaculture-based biomass for the long-term storage of energy and the provision of chemical raw materials. In addition, the oceans are increasingly being used for energy infrastructures and transporting electricity and energy gases. The seas can therefore develop into an indispensable component of future sustainable energy systems. Global agreements on the governance of the oceans and the seabed must therefore be developed and put into place in good time to avoid foreseeable conflicts involving this type of use (Chapter 3).

5.1 Fossil energy carriers from the sea

The following section gives a brief overview of current estimates of global deposits of fossil energy resources, the technologies and costs of mining them at sea, and the interactions with sustainability goals that can arise as a result of their extraction. This appraisal lays the foundation for a description of the future role of fossil energy carriers in a visionary form of marine, sustainable energy generation (Section 5.3).

The following analysis distinguishes between conventional and unconventional fossil energy sources (oil, gas, marine methane hydrates). The expansion of mineral-oil and natural-gas production into the sea has already taken place, so that a wealth of experience is available in this field. This does not apply to the extraction of marine methane hydrates, which are not yet commercially mined.

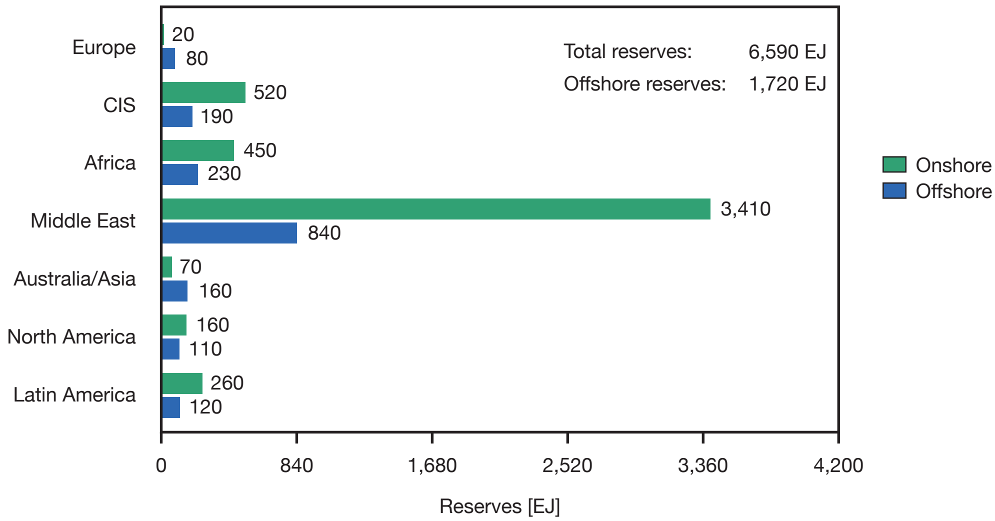


Figure 5.1-1
Onshore and offshore distribution of reserves of conventional mineral oil in 2007 by region. The figures on reserves shown here lie within the range given in Table 5.1-1a.
Source: BGR, 2009

5.1.1 Resource availability of fossil energy carriers

Deposits of fossil hydrocarbons are limited and varyingly distributed from region to region (Figure 5.1-1, Box 5.1-1). Hydrocarbons are usually to be found in pores in sedimentary rock within the earth's crust. There are a number of different conventions for classifying reserves and resources. The WBGU uses the following definitions: *reserves* are known deposits that have been quantified very precisely; it is technically and economically feasible to extract them today. *Resources* also include deposits that have been proven with a certain amount of uncertainty but are not extractable at present for technical or economic reasons. A distinction is also made between conventional and unconventional deposits; the latter refers to deposits whose extraction is technically very complex and could potentially become economically viable in the future (WBGU, 2011). Sustainability criteria are not considered in this classification. However, as will be shown in the following, it can be preferable not to tap all deposits that are financially feasible – for environmental, economic or social reasons.

Updated international estimates of reserves, resources and other deposits are made regularly by public organizations such as Germany's Federal Institute for Geosciences and Natural Resources (BGR) and the U.S. Geological Survey (USGS), and private companies such as BP (British Petroleum). Table 5.1-1a shows the historical production of fossil energy carriers, production in 2010, and estimates of reserves, resources and other deposits. It also shows the reserve/production ratio, which indicates how many years the reserves would last if the present level of annual consumption were to continue. Unconventional natural gas is by far the biggest resource. Marine methane hydrates are categorized under other deposits of unconventional gas; estimates on the size of methane hydrate deposits vary greatly. In addition to the usual approach of energy content, Table 5.1-1b shows the amounts of CO_2 that would be released if the fossil fuels were used.

It should be emphasized that the carbon dioxide that can be released by the use of fossil fuels is several times the amount of carbon dioxide currently contained in the atmosphere. The right column of Table 5.1-1b shows that every individual energy carrier alone already exceeds the CO_2 budget that would be compatible with a 2 °C rise in the mean global temperature over pre-industrial levels. All fossil deposits together exceed the CO_2 budget by more than two orders of magnitude (WBGU, 2009).

The values given in Table 5.1-1 represent a 'snapshot' taken at a certain moment in time. It is clear from the above definition that the distinction between reserves and resources is a dynamic concept, and that it is influenced by many factors – especially technological and energy-price developments, but also regulations, for example. Estimates of resources provide an indication of the quantities of hydrocarbons that could be developed.

Mineral oil and natural gas

The total amount of crude oil and natural gas that can be ultimately extracted is made up of produced and available reserves, reserve growth (for example an increase

Table 5.1-1
Global fossil reserves and resources. The ranges show (a) the lowest and highest estimate respectively, and (b) the potential CO_2 emissions as a result of their use. The table also shows their potential for endangering the 2 °C guard rail. This risk is expressed as the factor by which, assuming complete exhaustion of the respective reserves and resources, the resultant CO_2 emissions would exceed the emissions budget allowed up to 2050 of 750 Gt of CO_2 from fossil sources. The figures refer solely to CO_2; other greenhouse gases have not been taken into account. Marine methane hydrates are shown in the category 'Other deposits'.
Source: WBGU, 2011; GEA, 2012; own calculations

a

	Historical production up to 2010	Production in 2010	Reserves	Resources	Other deposits	Total: reserves, resource and other deposits	Statistical range (reserves/production)
	[EJ]	[EJ]	[EJ]	[EJ]	[EJ]	[EJ]	[years]
Conventional oil	6,788	141	4,900–7,610	4,170–6,150		9.070–13,760	35–54
Unconventional oil	629	23	3,750–5,600	11,280–14,800	>40,000	>55,000	165–247
Conventional gas	3,572	106	5,000–7,100	7,200–8,900		12,200–16,000	47–67
Unconventional gas	173	15	20,100–67,100	40,200–121,900	>1,000,000	>1,060,000	1,331–4,444
Coal	7,426	156	17,300–21,000	291,000–435,000		308,300–456,000	111–134
Total	18,588	441	51,050–108,410	353,850–586,750	>1,040,000	>1,444,000	1,689–4,946

b

	Historical production up to 2010	Production in 2010	Reserves	Resources	Other deposits	Total: reserves, resource and other deposits	The factor by which these emissions exceed the 2 °C emissions budget
	[Gt CO_2]	[Gt CO_2]	[Gt CO_2]	[Gt CO_2]	[Gt CO_2]	[Gt CO_2]	
Conventional oil	498	10	359–558	306–451	–	665–1,009	>1
Unconventional oil	46	2	275–410	827–1,085	>3,000	>4,100	>5
Conventional gas	200	6	281–398	404–499	–	684–898	>1
Unconventional gas	10	1	1,128–3,764	2,255–6,839	>56,000	>59,000	>79
Coal	1,758	42	4,829–10,256	33,474–55,507	–	38,304–65,762	>51
Total	2,512	60	6,871–15,386	37,266–64,380	>59,000	>103,000	>137

in a field's level of production), and supposed resources that are yet to be discovered. It is likely that this will also lead to increases in reserves in the future. The statistical range (reserves/production) of oil and gas at least has in the past remained constant at 40 to 50 or 70 years in this way, with consumption and new discoveries approximately balancing each other out. There are therefore still controversial discussions on whether global oil production has already peaked. It is generally agreed, however, that the peak has been reached in some traditional producing regions, and this poses great challenges especially for private oil and gas companies. Since access to the remaining producing regions that are relatively easy to develop is often reserved for state mining companies, oil-producing companies have increasingly been developing technical skills which enable them to advance into new frontier regions in search of oil and gas. In this context the focus has moved in particular to the deep sea and to the Arctic (Box 5.1-2), where a large proportion of future discov-

Box 5.1-1

Conflicts over resources in the Pacific

In the Western Pacific there are a number of long-running conflicts between the countries bordering the East China Sea, the South China Sea and the Gulf of Thailand. They stem from competing territorial and maritime claims. Prominent examples include the recent disputes between China and Japan over the Diaoyutai or Senkaku Islands in the East China Sea, and between China, Vietnam and the Philippines over the Paracel and Spratly Islands in the South China Sea. With the exception of Cambodia and Taiwan (a non-UN state), the countries bordering these regions have signed the UN Convention on the Law of the Sea, which provides the legal framework for resolving competing claims (NBR, 2011; Section 3.2). The disputed island groups are often little more than tiny rocky outcrops. There are primarily three main reasons for the increased interest (Richter, 2012a; Fabi and Aizhu, 2012):

- Important world-trade shipping routes run along the island groups connecting Europe, Africa, the Middle East and South Asia with the urban centres of East Asia. At least a third of the world's shipping freight traffic uses these routes, and much of it consists of Asian imports of raw materials.
- The region harbours very rich fish stocks. The South China Sea alone provides 10% of the world's annual fish yields.
- Major oil and gas reserves are suspected in the region (Fabi and Aizhu, 2012). Resource estimates for oil in the South China Sea range between 164 EJ and 1,250 EJ; gas deposits are put at 130 EJ (EIA, 2013). Taking the average of these figures, they would cover China's current consumption for more than 30 years. In view of the growing demand for energy in the East Asian countries and their growing dependence on imports, this explains the strategic importance of these local resources. However, some of these estimates are quite speculative, and only a small percentage of the suspected resources have actually been confirmed. Up to now, companies have carried out little exploration in this area due to the ongoing territorial conflicts and the uncertainty they bring.

The islands' key strategic significance is matched by a military build-up in the region (Richter, 2012b). For example, the Western Pacific is simultaneously the arena where the 21st century's two military superpowers meet: the USA and China. This is also illustrated by the growing number of military manoeuvres in this region. In 2010 Beijing claimed military jurisdiction over the entire East and South China Sea for the first time. For its part, the USA – a kind of Hegemon in the South Pacific since the end of the Second World War – is increasingly turning its strategic attention away from the Atlantic and towards the Western Pacific. Since Beijing often settles its territorial conflicts bilaterally, the smaller nations in the area feel cornered and have therefore been turning more and more to the USA. In turn, China feels hemmed in by this growing USA presence.

Military build-ups and concerns about energy security are mutually reinforcing factors, so that it is difficult to find starting points for resolving the conflicts. An extended perspective on the problem can reveal further causes, which could at the same time become part of the solution. The lack of an integrated energy-supply system in the region and the absence of an electric 'supergrid' or a transnational pipeline system (Section 5.3) means that much of the international energy trade in the region takes place by ship. As a result, the risks associated with transporting energy have on the one hand further exacerbated concerns about the security of supply; on the other, the risks are delaying the changeover to more modern, on-grid energy sources like gas from different sources or locally available renewable energies, which would have the potential to defuse the tense situation surrounding the supply-security issue. The Eurasian electricity and pipeline network can serve as a positive example in this context, since to a certain extent it creates a 'peace dividend' by generating both interdependencies and strong incentives for cooperative behaviour on the supply and demand sides. The possible establishment of a pan-Asian energy infrastructure could improve the tense situation surrounding supply security in the region and furthermore help to sustainably integrate the marine energy resources into the energy system. In the WBGU's view, a transformation of the primarily fossil-fuel-based energy systems of the countries bordering on the Western Pacific towards renewable energy, incorporating their marine potential, would help to transform what is currently a very conflict-ridden situation into an environment focusing more on collaboration.

eries are expected according to IEA (2005). In 2007 offshore areas accounted for about 27% of mineral oil reserves (17,000 EJ or 400 GTOE; Figure 5.1-1; BGR, 2009). 460 EJ (or 11 GTOE) of these reserves were in fields at water depths in excess of 500m.

Almost half of the offshore reserves are located in the Middle East. On the one hand, it can be expected that offshore reserves will grow as a result of new exploration in deepwater regions of the Gulf of Mexico, the Atlantic Ocean off Brazil, on the west coast of Africa, the Caspian Sea, in Southeast Asia and the Arctic regions of Russia and North America (Figure 5.1-3). On the other hand, the relative weights of the geographical distribution of reserves look likely to shift further.

Methane hydrates

Methane hydrates are ice-like compounds in which a crystal lattice consisting of water molecules encapsulates gas molecules; they are classed as unconventional gas deposits. They are combustible and store large quantities of methane within a very small space: when the methane enters the gas phase as a result of heating, its volume increases 170 times (WBGU, 2006; Krey et al., 2009). Methane hydrates in the oceans are found mainly in the sediments of continental margins at depths of at least 150–200m at high latitudes, and 500m at low to middle latitudes (Figure 5.1-2; GEA, 2012). Deposits at water depths of up to 4,000m are also considered possible (Ruppel, 2011). On land, gas hydrates are found in the Arctic permafrost.

The conditions needed for the formation and stability of methane hydrates are high pressure and low temperatures. Marine gas hydrates form primarily when methane rises from sediment at greater depths and is fixed in the higher, colder layers of sediment. Depending on the pressure, the temperature and the geochemical conditions, gas hydrates remain stable in what is known as a methane-hydrate stability zone, which can extend up to several hundred metres below the sea floor. The gas-hydrate content in the sediment is variable. High concentrations occur mostly in porous, highly permeable sediments such as sand. Fine-grained sediments such as shales have the lowest concentrations (Figure 5.1-2; Milkov, 2004; Trehu et al., 2006; Wallmann et al., 2011; GEA, 2012).

The amount of gas trapped in hydrates far exceeds the known resources of conventional gas (Table 5.1-1a). Scientists suspect that the amount of methane hydrates also exceeds the quantities of other unconventional gas deposits (MIT, 2011). The deposits of gas hydrates can be categorized according to their size and how they are geologically embedded; this is illustrated using a resource pyramid (Figure 5.1-2). The smallest proportion of the deposits is located in Arctic sandy soils on land. Larger deposits are suspected in sandy sediments on the seabed. The largest deposits lie encapsulated in fine-grained clay and slate sediments in the ocean floor.

Mining marine methane hydrates is most practicable in sandy sediments. They have a high concentration of gas and are distributed over distinct, well-defined reservoirs. The permeability of the sediments within the reservoirs makes extraction possible using mining technologies which, for the most part, already exist. In addition, the reservoirs are usually trapped in a matrix of impermeable sediments, which can reduce the accidental release of methane during drilling. In the case of deposits in non-sandy sediments, which make up the vast majority of the deposits, extraction is very unlikely in the foreseeable future due to the low gas concentration, since completely new drilling technologies would have to be developed for the purpose (Boswell, 2009; GEA, 2012).

Estimates on the size of the methane hydrate deposits vary greatly and, according to Wallmann et al. (2011), range from at least 6,700 EJ to 747,000 EJ. According to the Global Energy Assessment (GEA), the theoretical resource potential lies between 2,500 and 2,773,000 EJ, the technical potential between 1,200 and 238,400 EJ, and the economic potential between 0 and 12,600 EJ (GEA, 2012:458). According to Boswell and Collet (2011) methane hydrate reserves are currently practically zero.

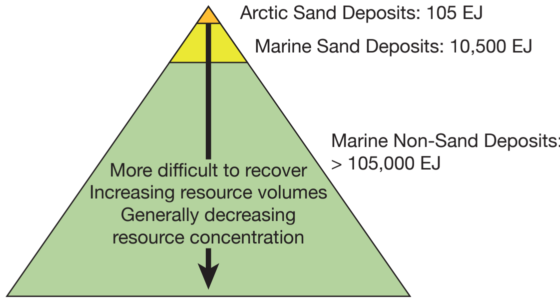


Figure 5.1-2
Size of methane hydrate deposits by deposit type.
Source: Boswell, 2009, modified by WBGU

5.1.2 Technologies of offshore extraction

Mineral oil and natural gas

Humans have known about mineral oil for several thousands of years, since it occurs in small quantities on the surface in some places. For the most part, however, it is held back on its way to the surface by a natural barrier in the form of an impermeable layer of earth. Targeted prospecting began in the 19th century as a result of the commercial use of mineral oil as a fuel, initially for petroleum lamps and later for the emerging automobile. The first place in Germany where people drilled for oil was north of Hanover, in Diethmarschen and Wieze. But the first really famous oil well was the one drilled by Edwin Drake in 1859, who developed the first major oil field in Pennsylvania, USA, at a depth of some 20m. Soon afterwards the first oil fields that stretched out to sea were discovered on beaches. The first offshore oil well was drilled from piers in 1896 – in Summerland Field, California (USA). The first platforms were used soon afterwards. They were initially made of wood and operated in inland waters, but even before the Second World War oil was extracted using steel oil platforms in the Gulf of Mexico.

The development and the most important concepts of offshore production are briefly described in the following. Development up to the present day has been a process of continuous technological innovation, starting with the first offshore platforms, working in just a few metres of water, to drilling rigs – floating structures comparable to a small town in type and size operating in water that is several thousands of metres deep. Drilling in the Arctic (Box 5.1-2) and in the deep sea, where companies face similar technical challenges, represents the current limit of technical feasibility.

Much of the mineral-oil and natural-gas deposits that are worked in the sea (Figure 5.1-1) lie in the shallow, coastal areas of the continental shelves, e.g.

Box 5.1-2

Oil and gas extraction in the Arctic

The current level of oil and gas production from fields situated north of the Arctic Circle is very low compared to global production of hydrocarbons. However, this could change significantly in the future (Box 1.2-3). Oil and gas have been extracted onshore since 1920 and offshore since 1970 in the Arctic (Economist, 2012; Lloyd's, 2012). Current estimates on the availability of oil and gas in the Arctic are largely based on studies conducted by the U.S. Geological Survey (USGS, 2008; IEA, 2008; Lloyd's, 2012), according to which about 25% of all as-yet undiscovered fossil resources are located in the Arctic. Furthermore, the chances of discovering especially large fields there are better than in other regions because little exploration activity has been carried out to date (Figure 5.1-1). Natural gas accounts for about two-thirds of hydrocarbon resources in the Arctic, with deposits totalling approximately 1,460 EJ (35 GTOE). Oil deposits are thought to amount to about 530 EJ (13 GTOE; USGS, 2008). A large proportion of the deposits is believed to be in the region of the coastal continental slopes.

Accordingly all the countries bordering the Arctic (Canada, Russia, Norway, Greenland/Denmark and the USA) have prospected for oil and gas in their territorial seas and EEZs (Section 3.2; Economist, 2012; Koivurova and Hossain, 2008). Interest in these supposed resource deposits is growing as the Arctic sea ice melts (Box 1.2-3). The commercial extraction of these fossil raw materials depends on the development of marine and transport technologies, as well as on global oil and gas prices. To date the infrastructure for transporting oil and gas from the sea in the Arctic is underdeveloped, partly because of the climatic conditions (Lloyd's, 2012).

The following factors have been driving the growing interest in using the Arctic for energy-related purposes (Lloyd's, 2012):

- *Technological feasibility:* technological progress makes it possible to assess the technical and economic practicability of an increasing number of projects; geological risks are also easier to control.
- *Economic attractiveness:* projects in the Arctic appear increasingly attractive to countries and investors when commodity prices stabilize at a relatively high level and there is uncertainty over access to resources in other parts of the world.
- *Access:* shrinking ice sheets within the Arctic Circle make access to production fields and the related logistics easier, thus also leading to lower costs.

Nevertheless, drilling for oil and gas in the Arctic is still a great challenge and in some cases fraught with similar difficulties to those of deep-sea drilling. According to the IEA (2008), these include the remoteness of the drilling fields, more severe safety risks for workers, greater environmental risks and ecosystem sensitivity, and high costs. Additional problems are posed by the extreme climatic conditions and storms, short time windows when access is possible, and the dangers caused by ice and icebergs (PEG, 2010). The prospects for production depend on technological developments such as the development of special drill ships and, in particular, semi-autonomous underwater technology systems for drilling in ice-covered waters (IEA, 2005).

The possibility of using non-conventional fossil energy carriers, especially shale gas in the USA, has greatly changed the international energy market. At present the risks of investing in opening up the resource deposits in the Arctic are estimated to be higher than the returns on these investments (DG, 2010; Humrich, 2011; Economist, 2012; Lloyd's, 2012). Furthermore, mining the Arctic's mineral resources involves considerable environmental risks. Due to the climatic conditions it is even more difficult to deal with oil or gas accidents during extraction or transport in the Arctic than in other regions. Because of the large distances involved, salvage ships are not available as quickly as elsewhere. Moreover, it is almost completely dark for half of the year (Welt Online, 6.9.2011; Lloyd's, 2012).

The framework for the governance of the Arctic is currently provided by UNCLOS, the Arctic Council and multilateral conventions (Chapter 3, Box 3.4-1). The Arctic Council encourages the participation of the Arctic's population (Box 3.4-1; Humrich, 2011). The countries bordering the Arctic (USA, Canada, Norway, Greenland/Denmark, Russia) have already staked their territorial claims and claims for rights of use in accordance with UNCLOS (Box 3.2-3). The countries have jointly filed applications to have their continental shelf boundaries determined by the UN Commission on the Limits of the Continental Shelf (Section 3.2; Humrich, 2011). Since most oil and gas deposits are located in the Exclusive Economic Zones (EEZs) of the respective countries, i.e. not in disputed regions, national law applies to the exploitation of the fossil fuel deposits. Figure 5.1-3 shows that a large proportion of the gas is to be found on Russian territory or in Russian waters, and most of the oil is in the USA, Canada and Greenland/Denmark, or in their waters.

Oil and gas leaks can happen at every stage of production and can be caused by a large number of factors (e.g. human error, equipment failure, sabotage). The Arctic conditions, such as sea ice, low temperatures, constant darkness, and violent storms and waves increase the overall likelihood of accidents. In literature, the possible environmental consequences of oil and gas leaks are considered to be far more serious in the case of oil than for gas. It should be noted in this context that oil leaks are in principle also possible as by-product of gas production.

The Arctic is home to a unique ecosystem, providing habitats for, among others, walruses, polar bears, whales, sea birds, fish and a large number of smaller creatures (Box 7.3-1). These species are well adapted to the Arctic conditions and only exist there. An oil spill would put this unique ecosystem at great risk. Due to interaction with the ice, oil spreads more slowly in this region than in open water, and the natural decomposition process is slowed down by the low temperatures. This could mean that oil will remain in the Arctic environment for decades to come and have toxic effects long after the original leak. Certain characteristics of Arctic species make them appear particularly vulnerable. Many of these animals have long life spans and slow reproduction rates. Especially animals at the top of the food chain are affected by the accumulation of toxic substances. Altogether a large number of Arctic species are already on the list of endangered species, and for some of them large-scale oil spills could have very serious consequences.

The multilateral conventions that currently apply in the Arctic do not sufficiently regulate either shipping or oil-and-gas extraction. In this region there is little regulation of either the risks or the consequences of use in the event of cross-border damage; the same applies to liability obligations when accidents occur (Section 3.6.5; Humrich, 2011). The Arctic Council says it aims to support sustainable development in the Arctic: five working groups have been set up to examine

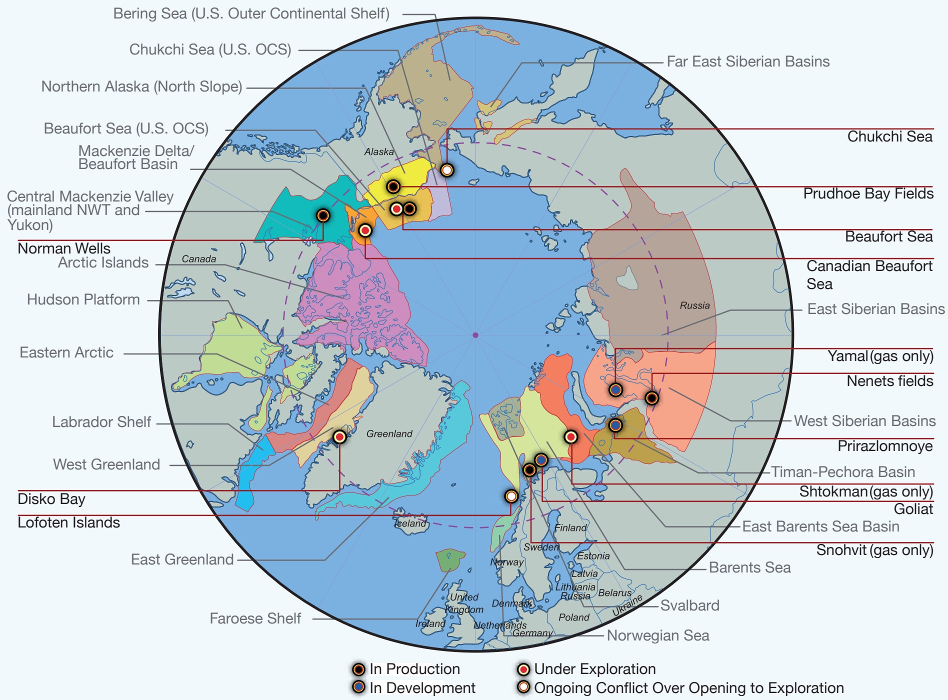


Figure 5.1-3
National onshore and offshore oil and gas reserves and their production in the Arctic.
Source: PEG, 2010

the development of standards and overall regulation (nature conservation, ocean protection, disaster prevention, environmental monitoring and the control of environmental toxins). The Arctic Council's guidelines on oil and gas production aim to ensure that the precautionary principle and the polluter-pays principle are followed, sustainability is promoted, and policies are adjusted to new findings of scientific research. Environmental protection takes top priority (Koivurova and Hossain, 2008). Although there are many initiatives, governance is still incomplete when it comes to the sustainable use of the Arctic (Box 3.4-1).

in the North Sea, the Caribbean, the Western Pacific and the Gulf of Mexico. Most wells are drilled vertically downwards using what is known as the rotary method. From a certain depth, steel pipes are cemented in to permanently stabilize the well. Another important method in addition to the rotary process is directional drilling, because this allows a vertical well to be diverted horizontally, so that several oil and gas fields can be accessed from one platform (BP Europe SE, 2008). Offshore drilling is carried out from platforms, and various types are used depending on how deep the sea is (Figure 5.1-4). A common classification distinguishes between reef water (up to 300m), shallow water (300–1,000m), the deep sea (1,000–1,500m) and the ultra-deep sea (from 1,500m). As far as types of drilling rig are concerned, four basic concepts can be distinguished (Figure 5.1-4). Jack-up rigs stand on vertically adjustable steel stilts; they are used in coastal areas in water depths of up to about 100m. In the case of fixed platforms, which are used in up to 600m of water, a steel or concrete base extending to the sea floor carries the facilities that are above the surface of the water. Floating structures are generally used at greater water depths. Semi-submersibles are the most common type of platform and vary considerably in design. They are supported by floats and stabilized by ballast tanks and steel cables anchored to the seabed. In addition to semi-submersibles, drillships are used in the deep and ultra-deep sea. More and more new components of underwater technology were developed as fields were tapped at ever-greater depths that were no longer accessible for divers. These enable, for example, several wells to be connected to one platform. Future underwater technology systems will increasingly be capable of operating autonomously, as well as processing and separating the oil and gas underwater.

Overall, technological advances in offshore technology development have made it possible to advance

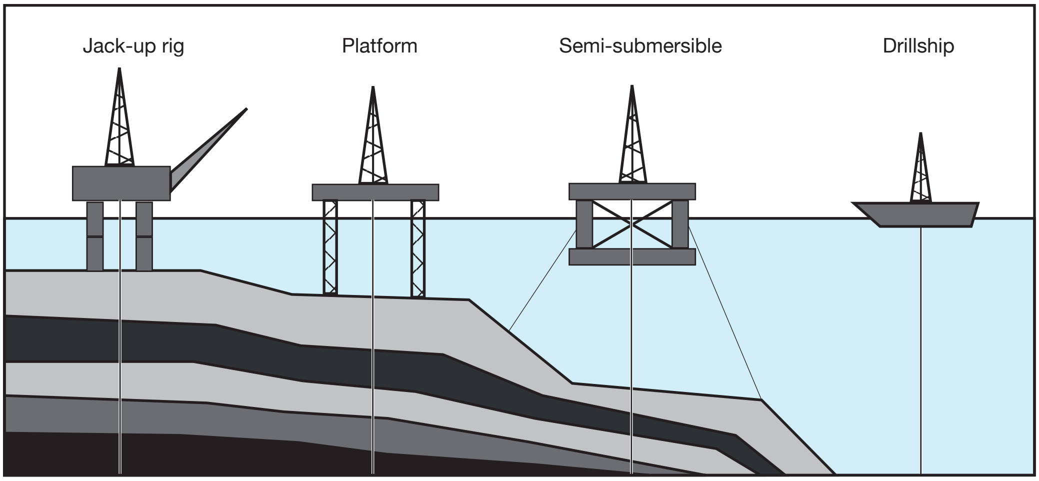


Figure 5.1-4
Different offshore extraction methods for different water depths and types of oil rig.
Source: WBGU, based on BP Europe SE, 2008

to ever-greater depths and ever-more remote regions. Furthermore, there has been a development away from firmly anchored structures to floating, mobile ones that can be used at several locations. Advances in underwater technology make it possible to develop a larger area from one platform, so that the extracted oil and gas can be transported directly from there to the coast by pipeline.

Marine methane hydrates

Three methods can be distinguished for extracting marine methane hydrates in sandy sediments, and they can be used either individually or in combination. Since methane hydrates form at high pressures and low temperatures, the solid, trapped methane components of the methane hydrate can be converted into gas by reducing the pressure or raising the temperature. The pressure is lowered primarily by extracting conventional methane deposited below the methane hydrate stability zone. The extraction of the gas reduces the pressure from below, the hydrates break down and the released methane can be extracted using conventional marine mining technology. The extraction of the released methane reduces the pressure further, so that the hydrates at higher levels break down. The other method is extraction by raising the temperatures. Here, water steam or a heated liquid is injected directly into the methane hydrate stability zone. The released methane can then be extracted via a second borehole. The third possibility is to inject inhibitors such as methanol, glycol or salt. The destabilization is caused by a brief change in temperature as the chemical conditions are simultaneously changed to counteract any re-stabilization of the hydrates (Demirbas, 2010). Research is currently being conducted into the idea of combining the extraction of methane hydrates with CO_2 storage by injecting liquid CO_2 (Kvamme et al., 2007).

Scientists expect to be able to mine marine methane hydrates in sandy sediments by making incremental advances in marine extraction technologies for conventional methane. These deposits are also the only ones that can be mined commercially in the near future. This is primarily due to the permeability of the sediment prior to the formation of methane hydrates. As a result of this permeability, the level of saturation is relatively high there, changes in the pressure or temperature can be easily transferred from the borehole into the sediment, and released gas can flow back along the pressure gradient back to the drill head and be collected there.

Major technological advances will be necessary before deposits can be extracted from sediments that are not sandy, but exhibit a high level of permeability. According to the current state of research, a paradigm shift in extraction technology will be necessary if marine methane hydrates are to be mined in reservoirs with low levels of permeability (Boswell and Collet, 2006; Moridis et al., 2009). The extent to which existing mining technologies will have to be further developed will depend on the characteristics of the deposits, e.g. the nature of the ground in which methane hydrates are trapped, the level of saturation with hydrates, the water depth and the proximity to infrastructure. Since there is still a lack of comprehensive mining experience, however, these assumptions are provisional. The relevant literature (US DOE, 2006; Council of Canadian Academies, 2008; Boswell, 2009; Ruppel, 2011) agrees that, despite the initial practical experience that has been gained, long-term demonstration projects will be necessary to determine the optimum processes and conditions for production and to demonstrate safety with regard to environmental hazards. Since the problems involved in extracting marine methane hydrates are to some extent comparable with the marine extraction of conventional gas and oil, synergies are expected when technologies are further developed (US DOE, 2006; Council of Canadian Academies, 2008; Boswell, 2009; Ruppel, 2011).The fact that methane hydrates can also be mined by injecting liquid CO_2 raises the possibility of combining methane-hydrate extraction with CO_2 storage (Figure 5.1-5). Under suitable pressure and temperature conditions, the injected CO_2 could be stored in the former methane hydrate beds as carbon dioxide hydrate. The development of the technology is still in its infancy (Groth, 2010). The first successful field test was conducted on land in early 2012 at Prudhoe Bay, Alaska.

Marine methane hydrate is not currently being mined commercially, but a number of extraction plants and test boreholes do exist as part of government research projects. Assessments as to when commercial mining might become possible vary considerably. According to Moridis et al. (2009), Japan is running the most advanced mining plants which could begin commercial production in 2016. The Japanese test plants operate in highly saturated, sandy sediments. The authors assess the development in the Gulf of Mexico as similarly well advanced, since this region has access to the existing infrastructure for oil and gas production. Krey et al. (2009) and Walsh et al. (2009) estimate that small-scale commercial production could begin in 2020. Because of the experimental stage of research, the IEA does not expect significant amounts of methane to be extracted from marine methane hydrates before 2035 (IEA, 2011a).

Japan runs the world's largest methane-hydrate research programme and plans to carry out its first mining tests in 2014. China and Korea have drilled exploratory boreholes in their coastal waters and the adjacent EEZs, and have found methane hydrate. In 2014 South Korea will conduct a production test at a depth of 2,000 m with the participation of the German methane hydrate programme SUGAR (Wallmann et al., 2011). The aim is to recover natural gas from gas hydrates by pressure release. The Indian government is also promoting a large research programme on methane hydrates, as there are methane hydrate deposits in its waters. Canada and the USA, too, are funding research and exploratory drilling (Moridis et al., 2009). Furthermore, Chile, Russia, New Zealand, Taiwan and Germany all have methane hydrate research programmes.

5.1.3
Environmental impact of fossil energy use

Mineral oil

The public usually takes note of the pollution of the seas by oil when an oil tanker breaks up in heavy seas or a platform suffers a serious accident, as in the case of the Deepwater Horizon in the Gulf of Mexico in the spring of 2010. In such cases, oil slicks often drift towards the coasts, killing many marine animals and seabirds. However, spectacular tanker accidents only account for about 10% of the global oil pollution of the seas (Section 1.1.5). Most of the oil enters the sea in different, less striking ways, such as leaks, combustion processes or through natural seepage (Maribus, 2010). Nature has adapted to low seepage rates in the form of specialized bacteria that break down the oil naturally (The Future Ocean, 2010). For this reason it does tend to be the major accidents that overwhelm and destroy marine ecosystems (Section 1; Box 5.1-2).

When estimating the consequences, a distinction must first be made between coastal ecosystems and those in deeper waters. Since oil is lighter than water, it rises to the surface and forms films and slicks. Depending on the winds and currents, these accumulations can then drift towards the coast, where the oil accumulates and impacts directly on the benthic ecosystems (i.e. ecosystems on and in the seabed). It is still very difficult to specifically assess the consequences of oil spills on marine coastal ecosystems. To date the information available on possible effects come mainly from studies of specific spills, and these are difficult to generalize because the ecosystems in different locations differ greatly from each other (The Future Ocean, 2010).

However, some basic points can nevertheless be made. For example, one decisive factor is how fast the oil is broken down or sinks from the surface to the sea floor. Decomposition is influenced by physical, chemical and biological processes. The time it takes for bacteria to break down mineral-oil hydrocarbons varies, depending on environmental conditions such as temperature, the water's nutrient content and wave action. Processes like sedimentation and bacterial decomposition can take months or even years. Under favourable conditions, however, they can be completed within as little as a few days. This discrepancy stems from the differences in the speed at which the different groups of substances that make up mineral oil are biologically decomposed. The decomposition process rate depends primarily on the molecular structure of the oil components. The more complex the hydrocarbon molecules, the longer microorganisms need to break them down. Another important distinguishing feature for damage assessment in coastal areas is what type of habitat they represent.

Regeneration periods between a few months and decades can be assumed depending on the coastal form and the ecosystem (Maribus, 2010).

Natural gas

Methane is the most environment-friendly fossil energy source because its combustion releases neither dust nor heavy metals. However, burning fossil fuels generates CO_2 emissions, and if possible their use should be avoided for this reason (Table 5.1-1b). Combustion of methane generates only half as much CO_2 emissions per unit of energy as burning coal. The output of gas power stations can essentially be regulated without any loss of efficiency. Because methane has these advantages over other fossil fuels, it represents a potential bridging technology in the transformation of the energy systems. The vision of a marine energy system of the future outlined in Section 5.3 includes such a transformation towards climate-friendly energy systems, which in addition also focuses increasingly on synthetic hydrogen or synthetic methane that is produced offshore using renewable energy sources.

Marine methane hydrates

Possible environmental hazards of extracting marine methane hydrates can be caused by the unplanned release of methane hydrates into the sea, the destabilization of the sediments surrounding the deposits or the injection of inhibitors during mining. In addition, the extraction of methane hydrates may remove the basis of life of specific ecosystems (Smith et al., 2008).

When methane hydrates are formed in sediments, gas and ice solidify and limit the pore space between the sediments' constituents. If the pressure or the temperature in the sediments is changed by drilling, this can lead to release of the trapped methane; the associated excess pressure can cause the uncontrolled release of methane, damage to the drilling equipment, local submarine landslides in steep terrain, and the subsidence of the well (Kvenvolden, 1993; Wallmann et al., 2011).

If the sediment destabilizes, methane can escape directly at the well or through cracks that form on the ocean floor. In addition, methane can escape if the drilling technology fails. If the methane released into the sea were to enter the atmosphere, it would contribute to global warming, since it is a highly effective greenhouse gas. However, methane released during production at a depth of 400–2,000 m is very unlikely to reach the atmosphere, since it is almost completely oxidized to CO_2 by bacteria in the water column. Methane released on the seabed only enters the atmosphere if the sea is less than 200 m deep.

Ruppel (2011) points out that the injection of inhibitors such as methanol, glycol or brine during extraction can cause as-yet-unknown environmental hazards. In areas where gas hydrates are located at or near the seabed, the escaping methane serves as a source of energy for specific benthic ecosystems. Removing the methane would withdraw their basis of life (Wallmann et al., 2011).

Authors differ in their assessments of the possibility of the sediments being destabilized by extraction. Archer (2005) comes to the conclusion that the likelihood of destabilization is quite speculative. Representatives of the Japanese gas industry conclude that the deformation and subsistence of the sea floor may be inevitable, but that it does not constitute a danger. Potential landslides could be avoided by a careful selection of the drilling site and good knowledge of the terrain. However, they do stress that their assessments only relate to the deposits in the eastern Nankai Trough (Yamamoto and Nagakubo, 2009). On the basis of models and laboratory experiments, Grozic (2010) arrives at the assessment that the release of even a small amount of methane hydrates can lead to significant loss of sediment strength and to landslides.

5.1.4 Infrastructure

The oil and gas value chain is made up of a large number of steps that require a complex infrastructure. This section only describes one part of it: the marine system. This relates primarily to transporting the hydrocarbons and the related processes of storage and landing. The most important producing and consuming regions for both mineral oil and natural gas are geographically very distant from each other, so that both energy carriers have to be transported over long distances. Whereas a global market has developed for mineral oil, the natural-gas markets are mainly regional, although global transport is possible with liquefied natural gas (LNG), which is increasingly used. Carbon dioxide is another important element in the oil and gas value chain. It forms both during extraction and as a combustion product during energy conversion. In addition, carbon dioxide is used to increase the level of production of deposits by being pressure-injected into the deposit. Carbon dioxide thus represents an important component in an integrated marine fossil-energy system; this will also apply in the long term in a marine energy system based on renewable energy (Section 5.3).

5.1.4.1
Mineral oil

Because of the great distances involved, crude oil is transported globally either by tanker or by pipeline; transport by tanker is the more dominant method with a share of 75% (BGR, 2009). The demand for capacity to transport mineral oil and conversion products like petrol and heating oil rose consistently in the past, requiring ever larger tankers. Tankers in service today often have a lightweight tonnage of 500,000 tonnes and can be up to 300 m in length. To ensure the stability of a ship when transporting large amounts of liquid cargo, the cargo bay is divided into several cell-like bulkheads; this also makes it possible to transport different products at once (BP Europe SE, 2008). Like the tanker hull's double wall structure, subdivision into the bulkhead structure improves the tankers' safety. However, these higher safety standards are by no means the rule, due to the freighters' long lifetime or to a lack of regulation or commitment by the owners. Apart from safety, the second important issue in oil transport is the continuous increase in the size of the tankers. This has fundamentally disadvantageous effects on manoeuvrability, and the increased draft when the ships are fully loaded means that the number of ports they can call at is declining all the time. It is often unprofitable to retrofit existing ports or build new ones with the necessary capacity. Many terminals are therefore being built offshore these days, where the water is deep enough and the ships' poor manoeuvrability presents much less of a problem. Such systems exist for different water depths and tanker sizes.

5.1.4.2
Natural gas

As in the case of mineral oil, the distances between producing and consuming regions for natural gas are often very large. Because gaseous natural gas has a lower energy content per unit of volume, its transport costs are about one order of magnitude higher than those of crude oil and coal, so that natural-gas markets have tended to develop in a regional way. Since natural gas in its gaseous form is also on principle more difficult to handle during transport, more transport methods have been tested and developed than for oil. Some methods represent a combination of transport and storage. Since methane hydrates pass into the gas phase during extraction, all the procedures mentioned in the following are basically also suitable for the methane mined in this way.

In the case of natural gas, too, the two dominant transport options are by pipeline or LNG tanker. The gas is generally transported from the platform by pipeline. However, since gas, too, is being extracted in ever remoter regions or as a complementary product of mineral oil, procedures have also become established to already convert – and if necessary liquefy – the natural gas on the platform for transportation purposes. Pipelines also dominate long-distance transport, although here, too, an increase has been observed in the LNG trade.

The relevant processes for this are briefly described in the following. Both of the two transportation options for natural gas (pipelines, LNG) initially discussed are very capital intensive. Other transport methods can be used when only short distances need to be covered or volumes are lower (compressed natural gas (CNG), gas to liquid (GTL), gas hydrates in the form of pellets).

Pipelines

Pipeline systems are required to transport natural gas. The North Sea, for example, is criss-crossed by a meshed network of pipelines. Installing them can be very complicated due to large tidal differences, strong currents and jagged rocks on the seabed. Specially built pipelay barges are used for the purpose. The concrete-coated pipes are welded together on board and lowered to the sea floor from an adjustable stern ramp. The pipeline is subsequently buried in a ditch. Another option is using offshore pipelines for the long-distance transport of gas. This technique is very expensive, but can be appropriate from the investors' point of view when further criteria, such as security of supply, are taken into account. To date the largest completed project of this kind is the Nordstream pipeline between Russia and Germany, with a total length of 1,224 km.

Liquefied natural gas (LNG)

One advantage of liquid energy carriers over gaseous ones is that they are easier to handle during transport. When natural gas is cooled to -162 °C it changes from the gaseous to the liquid state; the result is liquefied natural gas (LNG). Such a system essentially consists of three components: (1) a liquefaction plant, including a gas-storage facility and a loading station, (2) transport tankers and (3) a re-gasification plant including facilities for storage and further distribution. Each of these components is very capital intensive, and about 20% of the energy content of the gas is needed for the liquefaction and continuous cooling of the gas. LNG facilities have been increasingly expanded because they offer the option of connecting isolated markets (e.g. Japan), transporting gas over great distances by ship, and responding flexibly to spot markets. But it remains to be seen how additional construction will develop in the future, especially after it recently emerged that the USA in particular is increasingly turning to the domestic production of shale gas. This will make it unprofitable to invest in import terminals there and encourage some of the existing capacity to be converted into export terminals. A gas liquefaction terminal usually brings together gas from several fields in order to achieve the necessary economies of scale. Particularly for smaller or remote fields, it can be advantageous to already liquefy the gas offshore instead of transporting it to the shore by pipeline and liquefying it on land. One of the largest floating structures is currently being built off the north-west coast of Australia; it has an annual LNG production capacity of 187 PJ. Such systems could also be used as an important component in an integrated marine energy system based on renewable energy (Section 5.3).

Compressed natural gas

In this method the gas is not liquefied, but put under high pressure by compressors. The energy content per unit of volume is far below that of liquid natural gas, but the investment costs are lower.

Gas to liquids

In this option the gas is converted into a liquid energy carrier, often a fuel, using a variant of the Fischer-Tropsch process. This is an option when gas is recovered as a by-product of offshore mineral-oil production.

Gas hydrates in the form of pellets

A novel option that is interesting for different volumes is forming hydrates in the shape of pellets. As soon as ice crystals form, the methane is trapped in a kind of cage structure. This even remains stable when the ambient pressure decreases, making it possible to also transport methane – at suitable temperatures – at atmospheric pressure, as long as it remains frozen. The snow-like hydrate can be shaped into pellets and transported in special refrigerated ships that can guarantee a temperature of -10 °C (compared to -162 °C for LNG). This is the same temperature as that prescribed for food transport. Moreover, there is no risk of explosion, because although methane hydrate can burn, the gas is released so slowly that it is not explosive. On arrival at the destination the methane can be re-gasified by warming it to room temperature.

5.1.4.3
Carbon dioxide

As a technical option to gain time for the transformation of the energy system to emissions-free energy sources while utilizing at least some of the large reserves of fossil energy carriers, possible ways of technically separating CO_2 from the emissions of stationary plants are under discussion, as are options for the subsequent storage of compressed CO_2 in geological formations (carbon dioxide capture and storage, CCS). For countries that continue to use fossil energies, CCS is a necessary mitigation option if anthropogenic global warming of more than 2 °C is to be avoided. Beyond this, combining bioenergy with CCS is also under discussion as an option for withdrawing CO_2 from the atmosphere in the long term (WBGU, 2011).

The three steps of a CCS system consist of capture, transport and storage. After capture, the CO_2 is initially compressed, resulting in liquefaction. The liquid CO_2 is then transported to the storage site by pipeline or ship. There are already about 5,000 km of pipelines being used for transporting CO_2 worldwide. Relatively small, specialized vessels for transporting CO_2 are already in operation. Large ships with a capacity of about 40,000 tonnes of CO_2 are currently being built (Wallmann et al., 2011; Maersk Group, 2013).

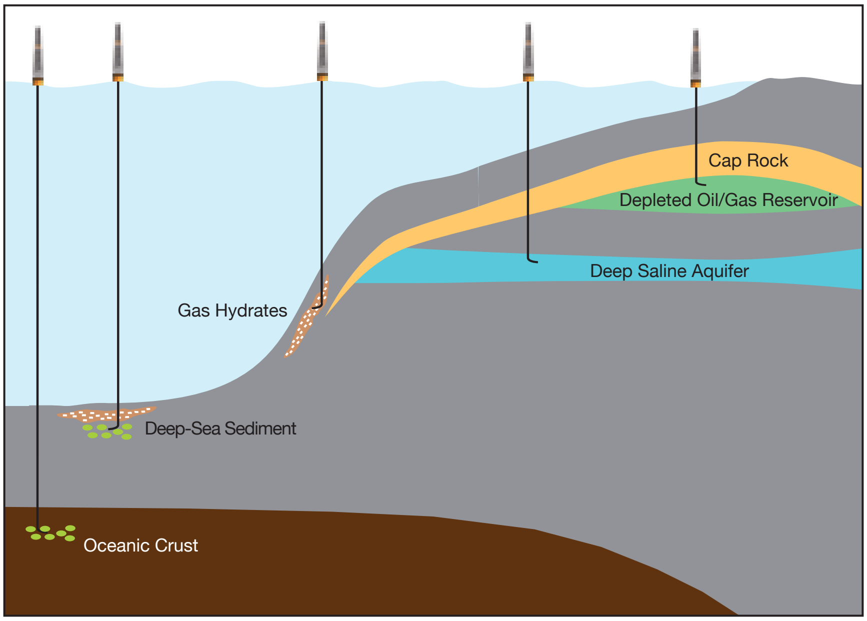
The liquid CO_2 is stored underground, i.e. in deep geological formations in a process that can be carried out both on land and under the seabed. Potential reservoir rocks include salt-water-bearing sandstone formations (saline aquifers), depleted mineral-oil and natural-gas deposits, deposits where the production rate can be increased by injecting CO_2 (enhanced oil recovery), gas hydrate deposits and deep-sea sediments (Figure 5.1-5). CO_2 has been stored in the Utsira sand formation in the Norwegian sector of the North Sea for many years. Up to now the CO_2 used has not come from power stations, but from natural gas that is extracted and cleaned on site at the Sleipner platform (Wallmann et al., 2011).

But doubts have also been formulated about the suitability for long-term storage of the site used by the Sleipner CO_2 project. A 2009 Greenpeace publication, for instance, refers to discrepancies between the behaviour of the CO_2 injected into the Utsira formation and the expectations of geologists; this suggests that there might be limits to the reliability of predictions on the permanence of the storage. However, these doubts have never been substantiated or verified and no escaping CO_2 has actually been documented to date.

Jacobson (2008) points out that, although selected storage sites have a theoretical retention capacity of 99% after 1,000 years according to IPCC (2005), the storage properties can be adversely affected by tectonic movements that cannot be predicted. His conclusion is that it is therefore impossible on principle to guarantee the permanence of storage. Practical operations have shown that increasing experience with the injection process and precise knowledge of both the subsurface and the specific geology are critical factors for minimizing the risk of leakage.

Combining the storage of CO_2 with the extraction of methane hydrates is referred to in many publica-

Figure 5.1-5
Geological locations for storing carbon dioxide under the seabed.
Source: WBGU, based on Haeckel und Suess, 2011



tions on methane hydrates as a possible contribution to climate protection. It has also been investigated in a few studies. The underlying idea is to pump the carbon dioxide under pressure into the methane-hydrate-bearing sediments while methane is being released. The CO_2 could then be stored as a hydrate under the seabed for a long time without escaping.

The combination of storing CO_2 as a hydrate and methane recovery is theoretically possible because the pressure required to form methane hydrates is higher at the same temperature than the pressure needed to form CO_2 hydrates. The temperature and pressure required to form hydrates change when the CO_2 content in the hydrate-bearing sediment is higher; these temperatures and pressures depend in detail on the nature of the sediment (e.g. pore size; Goel, 2006). Researchers are currently using simulations and experiments to try to gain a better understanding of the kinetic properties and mechanisms of CO_2 and methane exchange. Furthermore, the first successful onshore field test has been completed in Alaska (Long et al., 2009; White and McGrail, 2009).

5.1.5 Costs

Mineral oil and natural gas

According to a study conducted by Germany's Federal Institute for Geosciences and Natural Resources, the following four cost types can be distinguished in mineral-oil production: exploration costs, prospecting costs, development costs and operating costs (BGR, 2009).

Because the conditions are similar, this cost structure can also be transferred to gas production. The total cost of a project can be calculated by adding these individual factors together. Literature uses different terms in this context – e.g. technical costs, production costs or extraction costs – and authors often do not make it clear what costs types are included. In general, the finding and development costs and the production costs are allocated to the supply costs, while the exploration costs cannot be directly allocated to a project (BGR, 2009). The individual cost types can vary a great deal depending on the specific circumstances of each project. In addition, the respective volume of investment must also be assessed in relation to the volume of the storage site. The specific total upstream costs expressed in US$ per GJ are therefore useful (Table 5.1-2).

Table 5.1-2 shows cost estimates by the Federal Institute for Geosciences and Natural Resources (2009) based on data from the US Energy Information Administration (EIA, 2008). A breakdown of costs between onshore and offshore extraction is only available for the USA. The data shown in Table 5.1-2 only show part of the cost structure of global extraction conditions. One striking statistic is that the costs of offshore projects in the USA are two to three times higher than those of onshore projects. If it is assumed that this cost structure also applies in the other producing regions (Figure 5.1-1), it is more expensive to produce mineral oil from the sea than on land.

Figure 5.1-6 shows the IEA cost estimates (2008) for the production of global conventional and unconventional oil reserves and resources. It can be seen that

Table 5.1-2
Production costs of oil. Specific finding and development costs and total upstream costs for companies with a financial reporting system for the 2004-2006 and 2005-2007 three-year averages by regions in 2007. The distinction between the costs of onshore and offshore extraction is only made for the USA.
Source: BGR, 2009, based on EIA, 2008

Region	Finding and development costs [US$/GJ]		Total upstream costs [US$/GJ]	
	2004–2006	2005–2007	2004–2006	2005–2007
USA total	**3**	**3**	**4**	**5**
Onshore	2	2	3	4
Offshore	11	8	12	10
Non-US total	**3**	**4**	**5**	**5**
Canada	3	2	5	4
Europe	4	5	5	7
CIS	not specified	not specified	not specified	not specified
Africa	4	7	6	8
Middle East	1	1	3	3
Other eastern hemisphere	2	4	3	5
Other western hemisphere	7	3	8	6
Worldwide	**3**	**3**	**4**	**5**

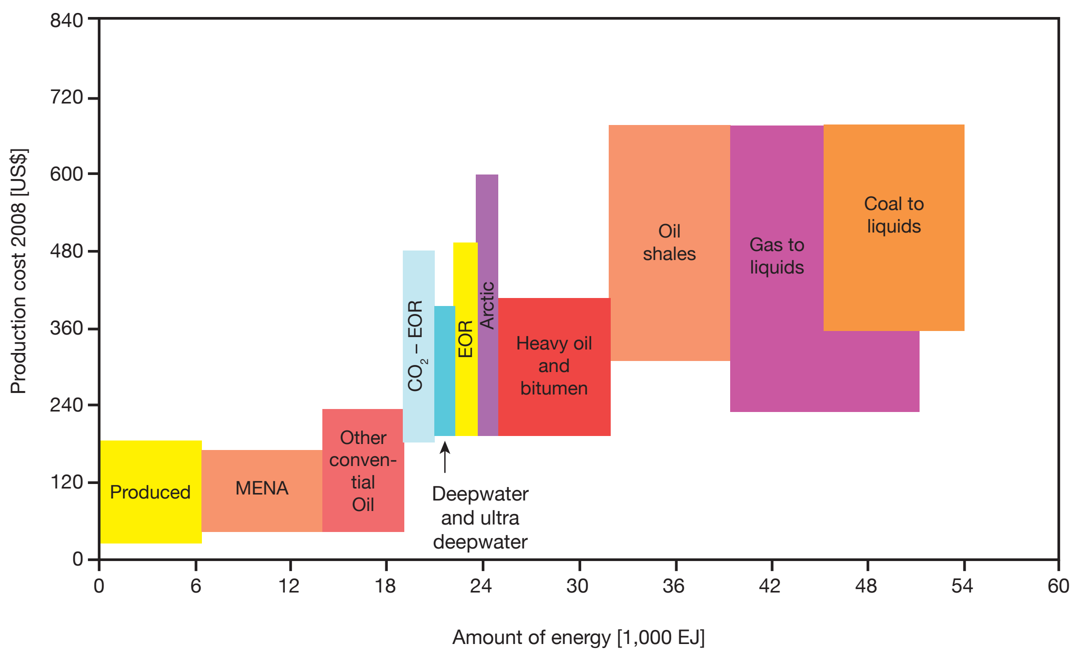


Figure 5.1-6
Estimate of 2008 production costs for the global oil supply with conventional and unconventional reserves and resources. The techniques for unconventional oil reserves and resources include enhanced oil recovery (EOR) with and without CO_2, gas-to-liquid, in which gas is converted by a chemical process into inflammable liquids, and coal-to-liquid, i.e. coal liquefaction.
Source: IEA, 2008

the maximum production costs of the 960 EJ of oil that can potentially be extracted from the deep sea could be around US$11 per GJ, and the production costs of oil from the Arctic, totalling 530 EJ, a maximum of US$18 per GJ (IEA, 2008).

Since the specific transport costs relative to the energy content are considerably higher for natural gas than for mineral oil, particularly due to the markedly lower energy density, hardly any global trade in natural gas has developed to date (BGR, 2009; Figure 5.1-7). As a rule it is cheaper to transport crude oil by tanker than by pipeline. In the case of natural gas, the relative cost advantage of transporting by tanker only comes into play at a distance of more than 3,000 km due to the high capital intensity of the LNG plants (Figure 5.1-7). In some cases, transportation by tanker can even be the preferred alternative when there is a relative cost disadvantage, in order to be able to respond better to regionally fluctuating spot-market prices for gas. However, the costs shown in Figure 5.1-7 should only be regarded as average figures because the transport costs depend on the size of the vessels and the capacity of the pipelines.

So-called multi-core pipelines, which transport several products simultaneously, might be one way to improve the earnings situation or reduce specific costs on some routes. One possible option, for example, would be the simultaneous transport of CO_2, hydrogen and natural gas (IEA, 2005).

Marine methane hydrates

There are currently only few, highly speculative cost estimates for the extraction of marine methane hydrates. Basically it can be assumed that the extraction of gas from methane hydrates is currently more cost-intensive than it is for conventional natural gas (Walsh et al., 2009). The Energy Technology Systems Analysis Program of the International Energy Agency estimates the cost at between US$4.4 and US$8.6 per GJ (IEA ETSAP, 2010).

CO_2 storage costs

Information on the costs of storing carbon dioxide are still subject to a certain degree of uncertainty due to

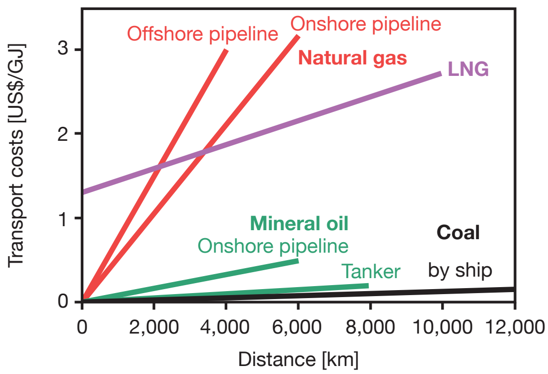


Figure 5.1-7
Transport costs of mineral oil and natural gas, depending on the distance and the type of transport (ship, pipeline).
Source: BGR, 2009

the small number of ongoing projects (Benson et al., 2012; GEA, 2012; Table 5.1-3). Furthermore, the natural conditions at the respective sites also have an influence on the costs.

5.1.6
Prospects of fossil-fuel extraction in the oceans

The current use of the seas for energy generation is dominated by the production of mineral oil and natural gas, and several trends suggest that these forms of use will continue in the future (Boxes 5.1-1, 5.1-2). However, the transformation to a marine energy system based on renewable energy, as outlined in Section 5.3, could contribute to making fossil-fuel extraction from the sea obsolescent.

Against this background, the question arises as to whether marine methane hydrates – i.e. unconventional reserves and resources of gas – should be developed, thus extending the present range of fossil energy carriers. The implications at the technology level have been discussed in Sections 5.1.2 and 5.1.3. From a systemic point of view, however, possible lock-in effects must also be taken into account. On the one hand, this affects the future orientation of the (infra-)structure of the energy systems; on the other, economic resources

Table 5.1-3
Cost estimates of geological carbon dioxide storage in the seabed on the basis of four studies; in US$ per tonne of CO_2 stored.
Source: Benson et al., 2012

Geologischer Speicher im Meeresboden	Hendriks et al., 2004	IPCC, 2005	Blesl und Kober, 2010	McKinsey, 2008
	[US-$/t of CO_2]	[US-$/t of CO_2]	[US-$/t of CO_2]	[US-$/t of CO_2]
Depleted oil and gas deposits	5–11	4–9	4–12	16
Saline aquifers	7–14	1–33	3–35	18

Table 5.1-4
Current and projected gas consumption in 2010, 2035, 2040, 2050. The table shows the range of estimated consumption on the basis of 41 development paths of the Global Energy Assessment (GEA, 2012), in EJ per year and cumulative figures. The development paths are based on a main scenario with two goals: the global average temperature must not rise to more than 2 °C above pre-industrial levels, and universal access to clean energy services must be provided worldwide. The business-as-usual (BAU) scenario is shown separately. The figures on accumulated consumption for 2035, 2040, 2050 include only consumption from 2011.
Source: Riahi et al., 2012; GEA, 2012; WBGU, own calculations

Scenarios	Gas consumption			
	2010	2035	2040	2050
All scenarios: min. and max. consumption (EJ/year)	100.5	112–196	113–233	106–287
All scenarios: min. and max. consumption cumulated until 2010 and from 2011 (EJ)	2,726	2,784–4,127	3,418–5,344	4,600–8,300
BAU (EJ/year)	100.5	169	180	215
BAU cumulative (EJ)	2,726	3,844	4,790	7,057

would be tied up in the development of a new technology option that would no longer be available for alternative options.

The extraction of marine methane hydrates has sometimes been referred to as a ‘bridging technology’ on the road to fully decarbonized energy systems (Section 5.1.3; Boswell, 2009; Krey et al., 2009). The idea here is that in the course of this development towards decarbonized energy systems, coal and oil are first replaced as energy sources by a higher proportion of gas, before the gas, too, is substituted as far as possible by renewable energy sources (Section 5.3). Burning methane is undoubtedly more climate-friendly than burning mineral oil and coal, and a whole range of energy scenarios against the background of the climate issue highlight the importance of gas in the future energy supply (WBGU, 2011; Riahi et al., 2012). Despite the importance of natural gas in a sustainable, climate-friendly energy system, the fundamental question arises as to whether the extraction of marine methane hydrates is actually necessary in view of the existing, dynamically changing reserves of conventional methane.

It can be seen from Table 5.1-1a that the reserves of conventional gas already documented today are in the range of 5,000 to 7,100 EJ and the resources of conventional gas lie between approximately 7,200 and 8,900 EJ. At the same time it can be assumed that at least a certain amount of these resources can be transferred to reserves in the future.

In order to be better able to assess whether marine methane hydrates will be needed, the potential supply of conventional methane must be compared to projections on future demand and future consumption (Table 5.1-4). The global energy study *Global Energy Assessment. Toward a Sustainable Future* (GEA, 2012) calculates 41 development paths, including future levels of energy consumption, on the basis of a main scenario. Two normative goals are laid down for the main scenario: first, the global average temperature must not rise by more than 2 °C compared to pre-industrial levels; second, almost universal access to clean energy services must be provided worldwide. The simulated development paths for different development options on the supply and demand side show that the stated goals still allow many degrees of freedom when it comes to the specific energy mix. These 41 development paths provide reliable indications of the future demand for gas.

Table 5.1-4 shows respectively the minimum and maximum estimated annual gas consumption levels of all GEA development paths for 2035, 2040 and 2050. Starting from an initial value of about 100 EJ in 2010, gas consumption by 2050 ranges between 106 EJ and 287 EJ per year depending on the development path. However, cumulative gas consumption is a more meaningful indicator in relation to the question posed. According to calculations of the GEA development paths, cumulative global gas consumption in 2050 will be between 4,600 and 8,300 EJ. As a comparative figure the GEA Baseline scenario (business as usual) calculates a cumulative gas consumption of about 7,000 EJ for 2050 (GEA, 2012). This shows that the transformative development paths do not deviate from a business-as-usual world in a certain direction.

None of the GEA development paths predicts a cumulative gas consumption in line with today’s conventional gas reserves of approximately 5,000 to 7,100 EJ before 2040 (Table 5.1-1a). In the GEA development paths that assume a gas consumption at the higher end, a level of gas consumption corresponding to the reserves is not reached before the 2040–2050 decade. In the GEA development paths that assume a lower gas consumption, this is not the case until the 2050–2060 decade (GEA, 2012). Moreover, it can be assumed that part of conventional gas resources can be developed into reserves within this period.

As regards the use of natural-gas reserves, it can be inferred from this estimate that it would take at least 30 years before the question arose as to whether there were enough conventional gas resources – or whether unconventional gas resources such as methane hydrates should be developed from permafrost regions or marine methane hydrates. According to this (purely theoretical) approach, the necessary technologies for extracting and transporting marine methane hydrates are also unlikely to be mature and competitive in less than 30 years. If humanity were to get by without extracting marine methane hydrates, people would still have the option of mining them in the future; from a systemic point of view this would prevent an unnecessary lock-in effect and avoid the related risk of becoming committed to technologies that might be harmful to the environment and are extremely difficult or impossible to revise. At the same time it becomes clear that there is sufficient time to develop and test extraction technologies in order to avoid negative environmental effects (Sections 5.4.3, 8.3.4).

If, during the next 30 years, the extraction of other unconventional gas resources proves to be cheaper and more environment-friendly than the extraction of marine methane hydrates, there will be no need to mine marine methane hydrates for even longer. The exact timing would depend on the percentage share natural gas makes up in a future, climate-friendly energy system and on the size of existing unconventional gas resources (Section 5.3). Depending on the costs and the environmental impact of the mining methods, methane hydrates from permafrost regions and other unconventional gas resources might be used before marine methane hydrates. From a global point of view, in this case the extraction of marine methane hydrates would be postponed for much longer than the next 30 years.

5.1.7 Conclusions

- From a global perspective, hydrocarbons are still abundant; resources in offshore deposits play a key role in this context. However, the geographical positions of the main producing regions are changing, which in some cases is leading to new conflicts (Arctic, Pacific).
- Rising development and production costs can be expected, albeit not on the scale that would mean that offshore oil and gas were no longer economically attractive; this is also confirmed by the investments currently being made in new offshore capacity.
- Technical advances, combined with the price development of fossil energy carriers, are one of the most important drivers of this industry. Resources can become reserves with the help of new technologies. Although technological progress can help to improve the safety of production for people and for the environment, it simultaneously poses new risks. The risk of major oil spills rises on principle as operations move into the deep sea or Arctic waters.
- From today's perspective, marine methane hydrates are not needed to meet the demand for gas. Nor does the supply side justify a rapid development of this energy source from the point of view of economic viability. However, regional considerations (security of supply, local gas prices, climate targets) could contribute to an accelerated development of this energy source. This would relate primarily to regions where access to natural gas is difficult or expensive, e.g. Japan.
- Any technology assessment should be based on a systemic view; such an assessment is carried out in Section 5.3. This takes into account the view that the cumulative total amount of emissions from fossil sources should not exceed 750 Gt of CO_2 by 2050 (WBGU, 2011). It can therefore already be noted at this point that a continuation of the current trend in the use of marine hydrocarbons cannot be sustainable.

5.2 Renewable energy

In addition to offshore wind energy, the technologies of marine renewable-energy generation comprise ocean-wave energy, tidal-barrage, tidal-stream and ocean-current power stations, thermal-gradient and salinity-gradient power plants, and growing algae for energy production. The term 'marine energies' encompasses all the above forms of energy with the exception of offshore wind energy.

5.2.1 Technological possibilities of offshore wind energy and marine energies

5.2.1.1 Development status of offshore wind energy

The development of offshore wind energy is being stepped up because wind conditions are more favourable at sea, and wind turbines on land are facing increasing problems of acceptance and space. In principle, the technology used offshore is comparable to the kind of turbines generally used today onshore. However, very

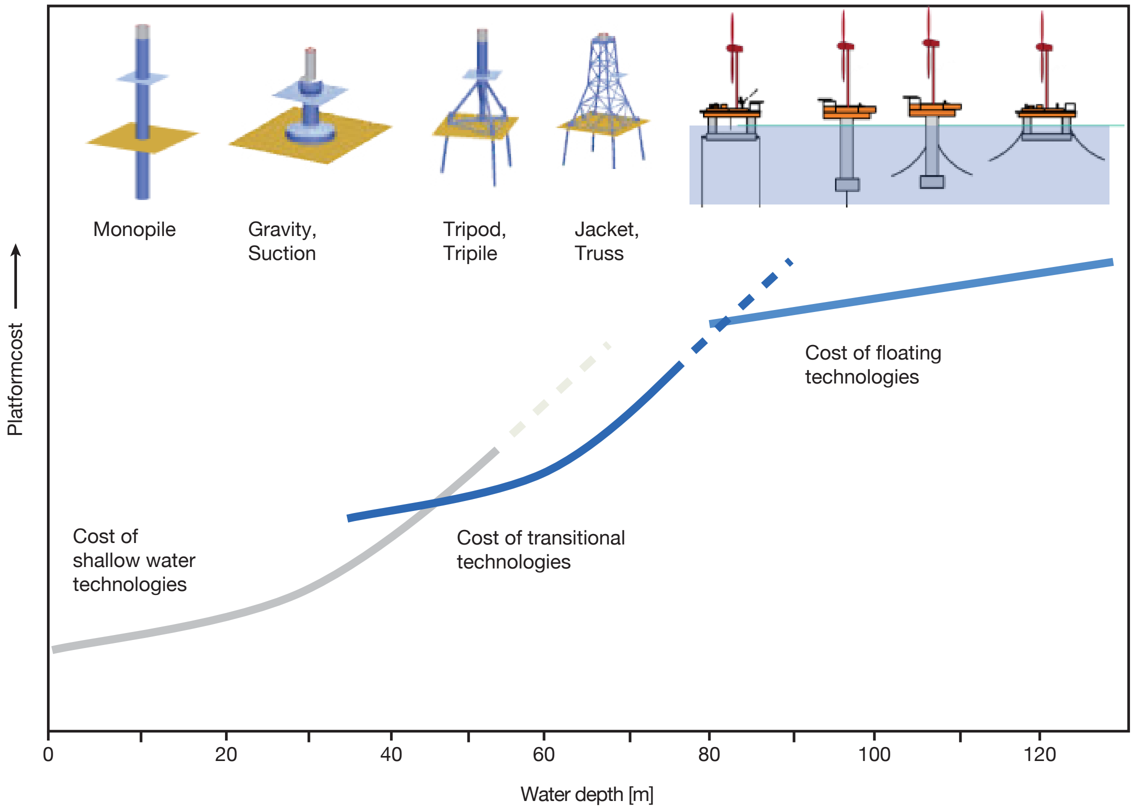


Figure 5.2-1
Various anchoring systems for offshore wind turbines and their costs, depending on the water depth.
Source: Bard, 2013

high demands are made on the reliability of the systems, because maintenance is more complex, the installations can sometimes not be reached due to poor weather, and storms and the salty air cause more extraordinary burden (physical stress). To reduce the amount of maintenance and installation work required, the trend is moving towards larger installations at sea. Wind turbines with a capacity of up to 6 MW are now being used commercially offshore. Furthermore, offshore plants differ fundamentally in terms of how they are anchored or fixed to the seafloor. A range of different technologies are used here, depending on the water depth and the geological topography of the seabed. Offshore wind turbines are currently built with fixed foundations up to a depth of about 50 m. The following types of fixed foundations are used (Figure 5.2-1):

- *Monopile:* A monopile is a cylindrical tube pile which can be driven into sandy sediment by drilling or pile driving in water depths of up to about 20 m. Monopiles are only slightly affected by scouring, i.e. gradual uncovering by water currents.
- *Tripod/tripile:* The tripod is a three-legged design that supports the main pile of the wind turbine. The tripod is anchored with small piles that are driven into the seabed. A tripod structure that carries the wind turbine is placed on top of the tripod above the water surface. Tripile foundations can be used at depths of between 25 and 50 m.
- *Jacket:* The jacket is a steel truss structure with three or four feet which are anchored to the seabed by piles. It is a very common type of foundation for a wide variety of offshore activities (Figure 5.1-4). Jackets can also be used at greater water depths. In the North Sea they are used in the oil and gas industry at depths of 150 to 180 m and in calmer waters at much greater depths.
- *Bucket foundation:* The bucket foundation uses not only the foundation's own weight, but also the pressure of the surrounding water to secure the wind turbine. It is shaped rather like an inverted bucket, inside which a vacuum is created, so that the foundation adheres to the seabed by suction.
- *Gravity foundation:* Gravity foundations are also used mostly in shallower water. They consist of a large block of concrete which supports the wind turbine and stabilizes it by its weight. Gravity foundations are quite vulnerable to scouring, which can cause a loss of stability.

At depths greater than 60–80 m, floating installations anchored to the seabed represent a more cost-efficient option than fixed foundations (Figure 5.2-1); at present, however, floating wind turbines are still at the (advanced) prototype stage, although individual plants with a capacity of 2 MW are already operating off the coasts of Norway and Portugal.

Floating structures anchored to the seabed are already used in the offshore mineral-oil and natural-gas industry (Figure 5.1-4). Several different anchoring systems are possible (Figure 5.2-1):

- *Spar platform:* In this type, a greatly elongated main cylinder functions as the buoyancy tank. At its bottom end, the cylinder is weighted by ballasting material to lower the system's centre of gravity as far as possible. The buoyancy body below the surface is moored to the seabed. This design is used by the Norwegian Hywind installation, for example.
- *Tension-leg platform:* A tension-leg platform consists of a buoyancy tank onto which the platform is mounted and which is constantly moored under tension to the seabed. The mooring keeps the platform at a position slightly below the one it would otherwise occupy as a result of its buoyancy; this is what generates the tension. The buoyancy tank can also be completely immersed.
- *Semi-submersible platform:* Another option is to moor a buoyant hull designed as a semi-submersible to the seabed.

The offshore use of wind energy is currently at the early commercial phase, which is characterized by almost exponential growth rates (Figure 5.2-2). However, from the investors' point of view it is still subject to considerable uncertainties. At the end of 2012 offshore wind turbines made up 4.7% of installed wind-power capacity in Europe. A total of 4,993 MW of offshore wind-power capacity was installed and connected to the power grid within the European Union (EU-27); the figure for land-based power plants was 101,048 MW (EWEA, 2013: 13).

The large number of applied-for or already approved projects indicates dynamic offshore expansion – in Europe alone almost 6 GW of capacity was under construction in 2011, and at the end of 2012 permits had been issued for a further 10 GW for the German Baltic and North Sea (Offshore-Windenergie.net, 2013). According to the roadmap of the European Wind Energy Agency (EWEA), the installed offshore wind-energy capacity in Europe is expected to rise to 40 GW by 2020 and 150 GW by 2030 (EWEA, 2011).

5.2.1.2 Development status of marine-energy technologies

Although the majority of research and development of marine-energy use (Figure 5.2-3) has taken place in Europe over the past 15 years, global interest is now on the increase. This is also reflected in the rising number of member countries of the Implementing Agreement on Marine Energy Systems of the International Energy

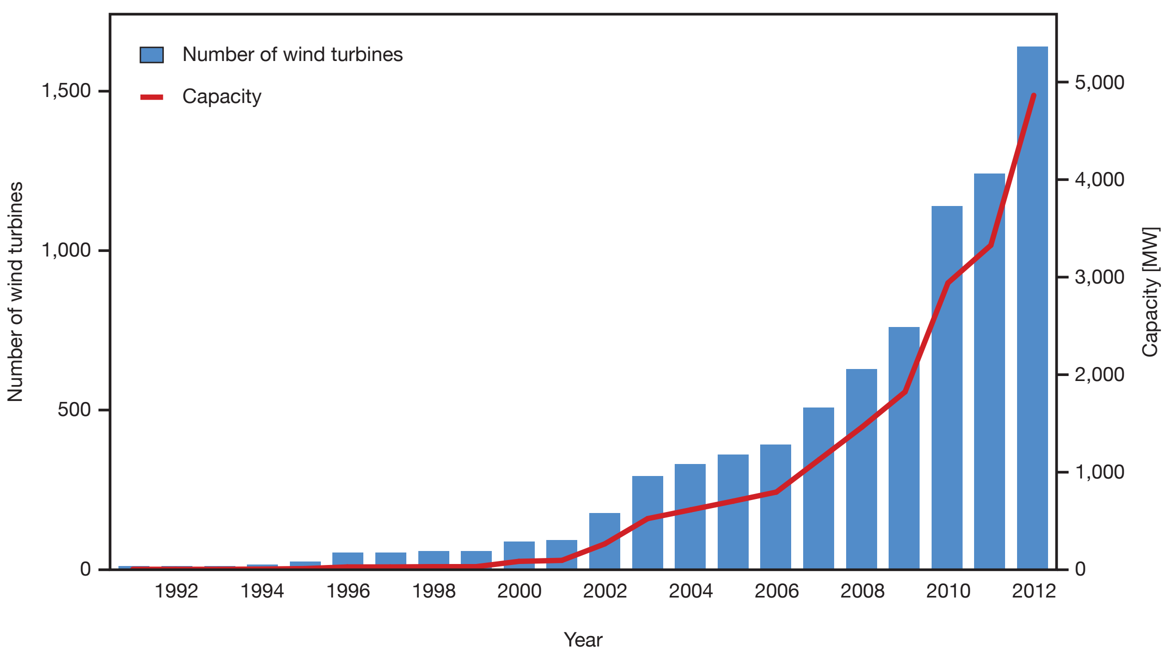


Figure 5.2-2
Development of the number of installed offshore wind turbines and their cumulated capacity in Europe (in MW). The blue bars indicate the number of installations; the red line shows the cumulated capacity.
Source: IWES based on www.4coffshore.com

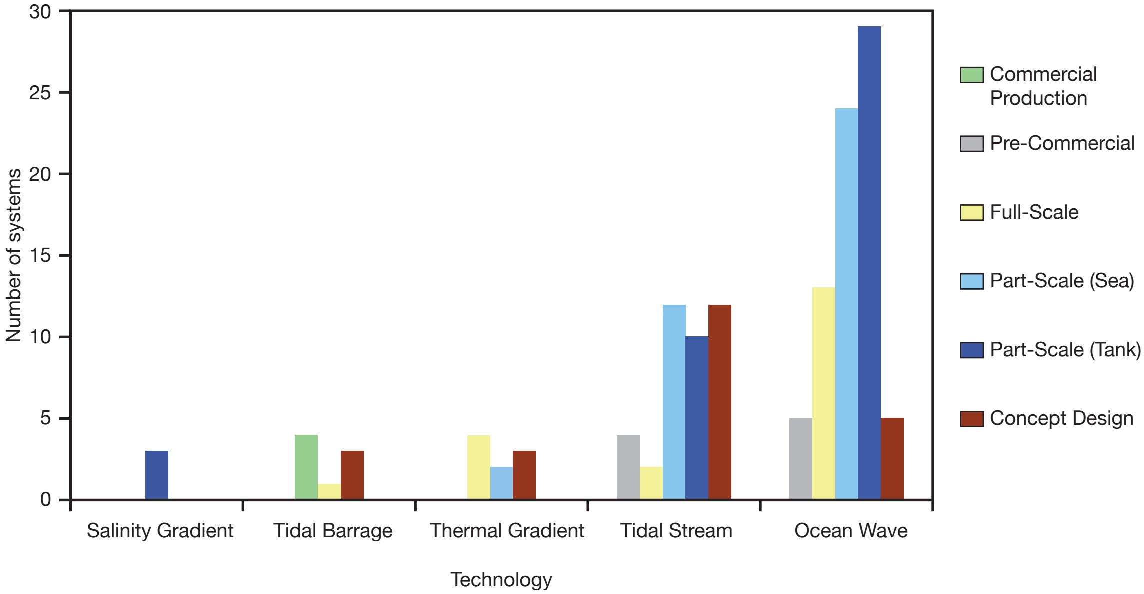


Figure 5.2-3
Different technologies of marine-energy generation and their level of development. Tidal-barrage power plants are already being used commercially. All the other technologies are either at an early stage of development without a dominant operating principle or at the full-scale stage.
Source: Khan and Bhuyan, 2009

Agency (IEA; IEA, 2010).

Overall – with the exception of tidal-barrage power plants – all marine-energy technologies are at a very early stage of development. To date, no dominant operating principle has become established in ocean-wave or tidal-stream technology. Most of the systems are still prototypes or at a pre-commercial stage of development (IEA RETD, 2011). The IEA reckons with commercial systems between 2015 and 2025 (IEA ETSAP, 2010).

Ocean-wave energy

In contrast to the use of wind energy, there are more than 100 different concepts for harnessing ocean-wave energy. One example is to make the waves' oscillating water column (OWC) drive an air turbine. Another method is to use wave-induced motion (oscillating body system), while a third option consists in converting the potential energy of the waves (de Falcão, 2010).

Disadvantages of the generally weaker wave energy near the coasts are partially offset by a frequently natural concentration of waves and lower costs of installation and connection to the grid. OWC systems consist of a partially submerged, air-filled steel or concrete structure with an opening below the water line. The trapped air mass, which moves with the oscillating water column, drives a generator via an air turbine (de Falcão, 2010).

Wave-induced motion is used to convert the movements of buoyancy bodies relative to each other (or to the coast or the sea-floor) into electrical energy. Point absorbers can be used in coastal areas where the water is shallow. They consist of an air-filled telescopic cylinder whose lower part, which acts as a stator, is firmly anchored to the seabed. The upper part follows the vertical movement of the waves and in this way produces electricity using linear generators (Clément et al., 2002; Kerr, 2007). Linear generators are also used in a number of other concepts using buoyancy bodies (Drew et al., 2009; de Falcão, 2010). The Pelamis device uses wave motion with four flexibly interconnected cylindrical sections floating on the surface of the sea; as the sections move relative to one another, high-pressure oil is pumped through hydraulic motors by piston pumps, thereby producing electricity using generators. Another interesting approach to using wave energy is CETO technology. Here, water is first pumped onto land at a pressure of 70 bar using point absorbers; there it is used either to generate electricity using a Pelton turbine or to produce drinking water by reverse osmosis (Carnegie, 2013). The concept is currently being tested in various projects.

The idea behind the Wave Dragon uses the potential energy of the waves. It consists of a floating, V-shaped structure, which makes the waves rise higher when they arrive at the apex of the enclosed sea surface. They flow into an elevated pool, and a turbine generates electricity when the seawater flows back into the sea (de Falcão, 2010).

No single dominant design has yet emerged among

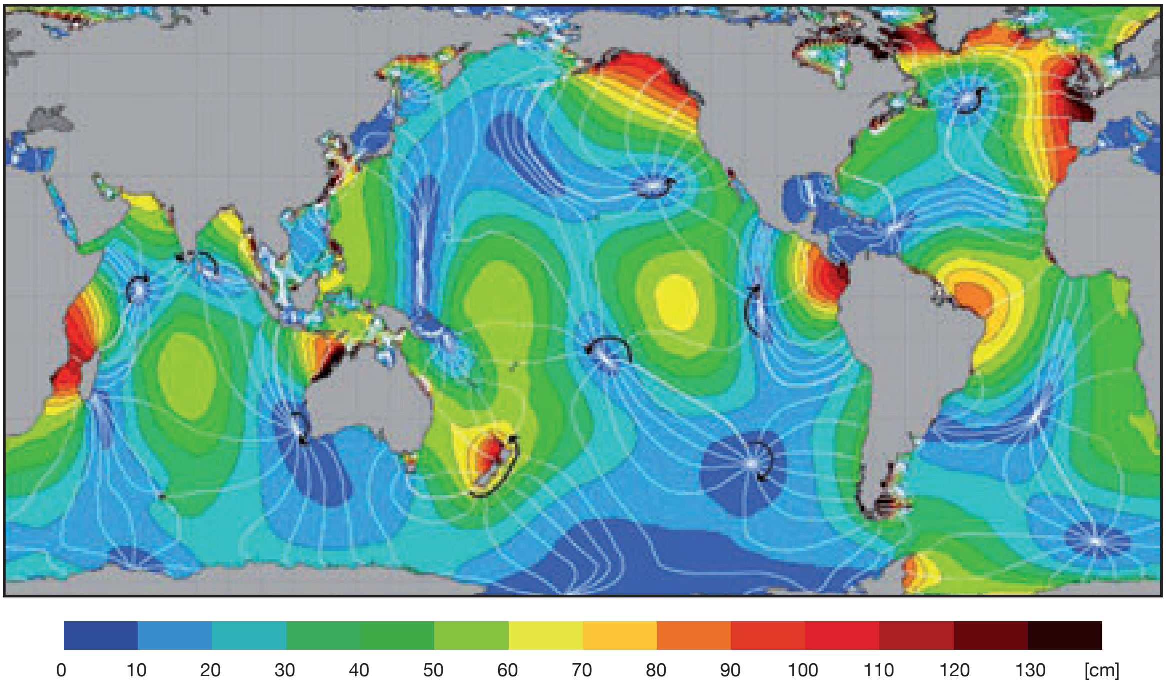


Figure 5.2-4
Worldwide distribution of the half-daily main moon tide M2. A tidal range of at least 4 m is required to be able to build tidal-barrage power plants; certain coastal formations are also required.
Source: NASA, 2006

the different kinds of wave-energy power plants. Only a few concepts have been tested in the form of large-scale prototypes under real conditions. The only commercially used wave power station – a 300 kW plant using the oscillating water column principle – was commissioned in 2011 in Mutriku, Spain. The design is integrated into a harbour pier and is thus directly on the coast. Other commercial projects are planned for the short to medium term, e.g. the erection of several wave-energy farms, each with a capacity of 10 MW and consisting of 14 Pelamis wave-energy converters off the Scottish coast (Pelamis Wave Power, 2011).

Tidal power plants

Unlike all other marine renewable-energy sources, generating power from tidal forces is not based on radiation from the Sun as the primary energy source. The tides are caused by gravitational and rotational forces acting between the Earth, the Moon and the Sun. The interaction of centrifugal and inertial forces, the Earth's daily rotation (24 hours) and the Moon's monthly orbit around the Earth (27.3 days) results in a period of 24 hours 50 min. Since both the attraction of the Moon and the opposite centrifugal force on the side of the Earth facing away from the Moon lead to a rise in sea levels in most regions, the result is a high and low tide that occurs about twice a day (Figure 5.2-4). The effect of the Sun's gravity (which on Earth is about half as strong as the Moon's) is superimposed on the tides caused by the Moon. Depending on the relative positions of the Sun and the Moon vis-à-vis the Earth, the tides are either weakened (neap tide) or strengthened (spring tide). The period of this superimposed cycle is 29.5 days.

- *Tidal rise and fall:* Tidal-barrage power plants convert the potential energy resulting from the periodic rise and fall of the sea level into electrical energy. Examples of places with a particularly pronounced tidal rise and fall are the Bay of Fundy in Canada (17 m), the Severn Estuary in the UK (15 m) and the Bay of Mont Saint Michel in France (13.5 m; Kerr, 2007). Here, the sea and the estuary region can be separated off by dams (barrages); the water then passes through turbines and generates electricity as it flows through the barrier. The periodicity of the tides means that the power generated in this way is intermittent, although it can be predicted very precisely. Research is being conducted into multi-basin concepts, for example, in order to make the intermittent generation more stable and flexible. The concepts discussed in the past have visualized building a dam separating the open sea from the river mouth, and since this idea has been facing growing criticism from the point of view of nature conservation, tidal lagoons are now being pursued as a possible alternative. By building closed, usually circular pools in

areas with a large tidal rise and fall, the power is generated by water passing through turbines integrated into the dams. The advantage lies in the fact that the estuary's brackish water ecosystem remains largely unaffected by the installations.
The Sihwa-ho tidal power plant in South Korea came into service in August 2011 with a nominal capacity of 254 MW, taking over as the world's largest tidal-barrage power station (after 40 years) from the 240 MW power plant, which was commissioned in 1967 in La Rance, France. A number of other tidal power plants are currently planned, especially in South Korea. Many other, in some cases quite large-scale projects are at the planning stage, although some of these have stalled because of environmental concerns and rising costs. As already mentioned, in future the concept of tidal lagoons could be a more environment-friendly alternative to conventional tidal-barrage power plants.

- *Tidal stream:* Tidal currents are a consequence of the upward and downward movements of the water masses. The resulting horizontal equalization currents are amplified in many places by coastal and seabed geometry, so that, for example, currents between the mainland and offshore islands or in estuaries can frequently reach high flow velocities. Since these are caused by the tides, they are subject to the same, usually half-day periodicity as the tidal rise and fall. The periodic reversal of the flow direction makes high demands on the turbines. Many of these tidal-stream turbines are similar in design to wind turbines – both the horizontal-axis and vertical-axis types. However, the turbines must be designed for the demanding marine underwater conditions. Because water has a higher density than air, the medium's energy density is also considerably higher than in the case of air turbines (wind power), so that the rotors can be much smaller and still achieve the same output – despite the slower flow velocity of the water. Different technologies enable the rotors to be raised to the surface for maintenance purposes (Figure 5.2-5).

About 50 concepts for using the currents caused by tides are at an early stage of development. Tests on prototypes of several plants are being conducted mainly in Europe, but also in Canada and China (Bedard et al., 2010). A detailed presentation of some of these techniques and their level of development can be found in O'Rourke et al. (2010). Experience from the field of wind power and shipbuilding can be used here because of the similarities between the technologies. The reliability of the systems is of great importance in view of the difficulties of underwater maintenance. If tests continue to be successful, commercial-scale tidal-stream power farms can be reckoned with in the coming decade (O'Rourke et al., 2010).

Figure 5.2-5
Ocean-current power plant (SeaGen). The turbines can be raised out of the sea for maintenance purposes.
Source: The image was made available by Marine Current Turbines, a subsidiary of Siemens AG

Ocean-current power plants

The flow velocities of marine currents are usually considerably slower than those of tidal currents; however, they are continuous and do not reverse their direction of flow, thus enabling continuous power generation. Circulations with flow velocities of approximately 2 m/s over large areas are found east of Africa in the Indian Ocean (Agulhas Current) and west of Africa in the Atlantic Ocean (Gulf Stream; Leaman et al., 1987).

Due to the slower flow velocities and therefore lower energy density, this technology is still far from commercial implementation. Basically, the technology is broadly comparable with that of the tidal turbines.

Ocean thermal energy conversion

Ocean thermal energy conversion (OTEC) plants use the differences in seawater temperature between the zone near the surface and the zone at a depth of approximately 1,000 m to run a heat engine. This requires a thermal gradient of at least 20 °C (Binger, 2004); the regions where this technology can be used are therefore limited to the seas to the north and south of the equator (Figure 5.2-6).

In practice the efficiency of such a heat engine is about 3 % (Nihous, 2010) and a large proportion of the mechanical energy generated in this way (about 30 % of the rated value of the turbine; Nihous, 2010) needs to be used to operate the pump in order to supply the cold or warm sea water to the heat exchangers. Open-cycle OTEC plants use the sea water directly as the working medium, which is evaporated at reduced pressure. In addition to power generation, this variant can be used to produce drinking water. Since the availability of the

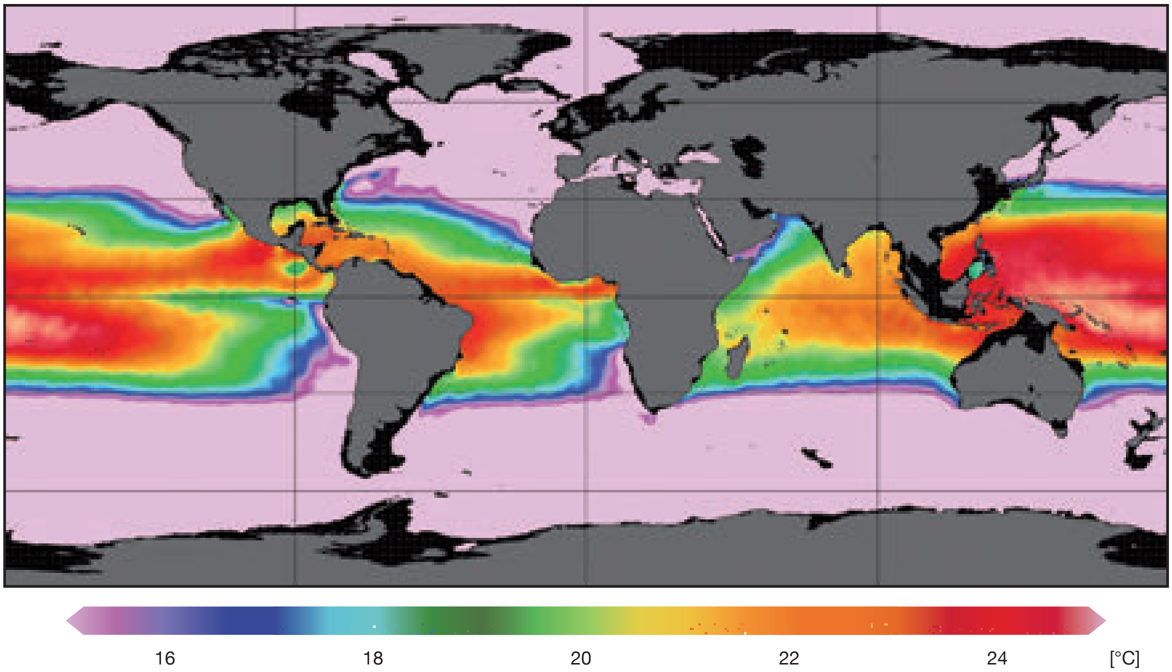


Figure 5.2-6
Global distribution of average ocean-temperature differences between the near surface and a depth of 1,000 m. Since a temperature difference of at least 20 °C can be found only near the equator, OTEC plants can only be used in this region.
Source: Nihous, 2010, based on data from NODC, 2005

resource is subject to few seasonal fluctuations, OTEC plants enable continuous power generation.

The first attempts to use OTEC plants to generate electricity date back to the 1930s, when Claude (1930) constructed the first plant in Cuba. However, the unfavourable local conditions made net electricity generation impossible. Another attempt by the scientist in the form of a ship-based system for making ice also failed – this time when installing the cold water pipe that reached down into the depths. Subsequent installations of OTEC plants in Hawaii and Nauru have achieved a net capacity of up to approximately 100 kW (Vega, 2002). Despite these successes, no commercial OTEC plants have been built to date. Some projects with plants of about 10 MW are currently planned. The challenges that need to be overcome before large-scale use becomes possible include the fouling of the heat exchangers, the leak-tightness of the fluid cycle and the large amount of energy required to run the plant, especially the pumps.

Salinity-gradient or osmotic power stations

When fluids with different (sea) salt concentrations are mixed, there is an increase in entropy (Scråmestø et al., 2009). Two different methods are followed to use this to generate energy (Post et al., 2007; Lewis et al., 2011).

In reversed electrodialysis (RED), anion and cation exchange membranes are alternately exposed to salt water and fresh water, thereby creating a voltage across the membrane (van den Ende and Groeman, 2007).

Pressure-retarded osmosis (PRO) is used in osmotic power plants. When liquids with different levels of salinity come into contact with each other through a semi-permeable membrane, water diffuses through the membrane to the side with the higher salt concentration, until an equilibrium of osmotic and static pressure is reached. In a closed container, the osmotic pressure of sea water amounts to approximately 24-26 bar (Lewis et al., 2011), which corresponds to a water column of about 240–260 m. Since in an open container, the incoming water dilutes and therefore reduces the salt content, the (technical) potential useable by osmosis is estimated at 120 m (Lübbert, 2005). In order to reduce the extent to which the salt concentration on the seawater side is lowered, a higher volume flow must be circulated.

Both approaches are currently being studied on an experimental scale. One unit for examining reversed electrodialysis with a capacity of 1 kW is currently being studied in the Netherlands, and a 4 kW prototype osmotic power plant is being run and researched in Norway (Scråmestø et al., 2009). The primary challenge in the case of osmotic power plants is to develop efficient membranes. Economically feasible operation is possible from a capacity of about 5W per m² (Lübbert, 2005); the current capacity per m² lies at about 2 to 3W (Scråmestø et al., 2009; Skilhagen, 2010). Other challenges include the long-term durability of the membranes, fouling by bacteria and algae, and other forms of contaminants that reduce the permeability of the membranes.

Using algae as an energy source

Like higher plants on land, algae are also suitable for use in energy generation. In general, a distinction needs to be made between the use of multicellular algae (macroalgae) and small single-cell and protist algae (microalgae). Seawater, brackish or fresh water can be used as a medium for cultivating microalgae, depending on the type of algae. While macroalgae are cultivated directly in the sea, microalgae are bred mainly in large land-based photobioreactors or shallow, open ponds called raceways. However, there are also concepts for cultivating microalgae directly in the sea. The microalgae suspension is isolated from the surrounding seawater using plastic membranes. Such approaches are being studied in ongoing research projects (OMEGA Project, NASA; TROPOS Project, EU). Macroalgae aquaculture is now carried out primarily in Asian countries, where algae are of great importance as a source of food. The cultivation takes place in coastal waters, usually using lines.

The lines are seeded with cells at a suitable stage of their life cycle and spread out in the sea, where the macroalgae continue to develop until they are ready for harvest. Another possible approach is 'ocean farming', in which free-floating macroalgae are cultivated for energy production in regions far from the coast (Florentinus et al., 2008; Reith et al., 2012). Research is currently being conducted into ideas such as cultivating macroalgae by taking advantage of the fixed structures of offshore wind turbines (Buck et al., 2004; Buck and Buchholz, 2005), or using concentric rings around fish-mariculture installations (integrated aquaculture). The latter method would have the advantage that the nutrients that are released by the fish aquaculture can be used by the algae, thereby reducing the negative environmental impact while simultaneously achieving higher growth rates for the algae (Section 4.2). Such an integrated aquaculture is also being discussed for land-based systems in conjunction with fish aquaculture, although a considerable amount of development work still needs to be done before profitability can be reached (Friedlander, 2008).

The extraction of nutrient-rich deep water is also being considered to provide nutrients for offshore macroalgae cultures (Roesijadi et al., 2010). Synergies in combination with OTEC plants might well be possible here (Box 4.1-2).

Since macroalgae are characterized by a low lipid content (compared to microalgae) of usually less than 5% of the dry weight, the use of the biomass as an energy source in particular exploits anaerobic fermentation/digestion to produce biogas or biomethane. However, in principle it is also possible to produce lipid-based fuels from macroalgae (Hossain and Salleh, 2008). Macroalgae are characterized by a higher ash content, and the calorific value is 11–12 MJ/kg lower than in terrestrial biomass (17–18 MJ/kg). The high nitrogen and sulphur content may prove to be a problem if they are used as an energy source. On the other hand, macroalgae are characterized by a low cellulose and lignin content – both substances that are difficult to use in anaerobic fermentation. The economic feasibility of anaerobic conversion to form biogas has already been demonstrated for different species of algae (Gunaseelan, 1997; Chynoweth et al., 2001). The methane yields of 0.14 to 0.4 m³ per kg of ash-free dry weight are comparable to those of sewage sludge (Reith et al., 2005).

5.2.2 Global potential of sea-based renewable power generation

The potential of sea-based renewable energies needs to be considered in the context of global electricity consumption, which amounted to about 66.4 EJ (18,443 TWh) in 2010; depending on the scenario, it is expected to rise to 100.6 to 125.6 EJ (27,944-34,889 TWh) by 2035 (IEA, 2012: 180).

5.2.2.1 Offshore wind energy

It is estimated that approximately 1% of the incident solar radiation that reaches the Earth's surface is converted into kinetic energy in the atmospheric air masses (Lorenz, 1967; Peixoto and Oort, 1992). There are no studies on the theoretical potential of offshore wind energy, however, although Rogner et al. (2000) suggest that wind energy (onshore and offshore) might have a theoretical potential of 110,000 ± 50,000 EJ per year based on global air-mass movements (Rogner et al., 2012: 432). Since the oceans cover more than 70% of the Earth's surface, and near-surface wind speeds are higher over the sea than over land due to the lower level of friction, then most of this potential must be offshore wind energy. Studies on the technical potential of offshore wind turbines show very wide-ranging estimates, since they often use different technical assumptions and restrictions (Table 5.2-1; Lewis et al., 2011). The studies differ in terms of the meteorological data used

Table 5.2-1
The potential for offshore wind energy calculated in different studies and the assumptions for determining potential. *10D x 5D and 7D x 4D refers to the distance between individual wind turbines: 10 or 7 rotor diameters in the prevailing-wind direction and 5 or 4 rotor diameters in the secondary wind direction.
Source: WBGU, based on the authors mentioned

Authors	Boundary conditions	Potential [EJ/year]
Leutz et al., 2000	› 50% of coastal waters up to a depth of 50m	133.2
WBGU, 2004	› Max. water depth = 40m › Specific minimum distance to the coast taken into account (0–12 nm) › Areas with ice drift excluded › 10–15% of the technical potential is assumed to be a sustainable potential	Technical potential: 1,000 Sustainable potential: 140
Hoogwijk and Graus, 2008	› Max. distance from the coast = 40 km › Max. water depth = 40m › Max. electricity production costs = 36 US$ cents/MJ (10 US$ cents/kWh)	18.2 (more likely to be an economic potential)
Capps and Zender, 2010	› Hub heights = 80m and 100m › Two options for the distance between the turbines: 10D x 5D and 7D x 4D* › Three different turbine models are considered	For 10D x 5D* and 100m hub height and a max. water depth up to 45 m: 43.92–51.48 60 m: 72.36–84.6 200 m: 295.56–337.32 For 7D x 4D* and 100m hub height and a max. water depth up to 45 m: 78.4–91.9 60 m: 129.1–151.3 200 m: 527.9–602.5
Lu et al., 2009	› Area between 0 and 92.6 km (50 nm) from the coast can be fully used › Power density: 5.84 MW/km² (10D x 5D*) › 3.6 MW turbines (100m hub height) › Locations without capacity-factor restriction and with a capacity factor of at least 20% taken into account › Potential as a function of water depth	Without capacity-factor restriction Water depth: 0–20 m: 169.2 20–50 m: 165.6 50–200 m: 313.2 0–200 m: 648 Min. 20% capacity factor Water depth: 0–20 m: 151.2 20–50 m: 144 50–200 m: 270 0–200 m: 565.2

and the assumptions on turbine types and hub heights, power density, minimum and maximum distance from the coast and the water depths that can be developed. Furthermore, some authors use additional restrictions such as the maximum utilization of the available space, a minimum capacity factor or maximum permitted electricity production costs.

The development of fixed foundation structures that can be used in water depths up to 60m, floating platforms and offshore connections to power grids make it possible to develop considerably larger areas for offshore wind turbines. As a result, the frontiers of technical potential have shifted markedly in recent years. In the long term it will become possible to use floating platforms for offshore wind energy at water depths in excess of 200m.

Although quantifying the global potential of offshore wind energy involves considerable uncertainty, there is no doubt that even with the technology already available today it greatly exceeds the current global demand for electricity. Future expansion will therefore depend primarily on cost and sustainability issues.

5.2.2.2
Marine energies

Estimates on the theoretical global potential of marine energies (ocean-wave energy, tidal range, tidal stream, ocean currents, OTEC plants, salinity-gradient/osmotic power plants) come to as much as 7,400 EJ per year (UNEP, 2000); they are thus several times higher than global primary energy consumption (492 EJ per year of direct energy equivalents; WBGU, 2011).

The resultant technical potential, according to many estimates, are lower than the theoretical potential by a factor of about 10–20. Even so, it still considerably exceeds global demand for electricity (approximately 66.4 EJ per year in 2010; IEA, 2012: 180). Assessing technical potential is fraught with uncertainty in some technologies. The actually realizable percentage of this technical potential is further reduced by competing uses and protected areas for flora and fauna directly on the coast and in coastal areas.

Taking into account the hitherto high cost of the technically demanding installations, the current economic potential is estimated at only 7 EJ per year (Sims et al., 2007), although it is difficult to predict how the costs of the various technologies will develop in the future (Section 5.2.5).

Irrespective of whether the technical potential is over- or underestimated, it is unlikely that the resource itself will represent the limiting factor. Rather, efficiency and acceptance will be the crucial factors in deciding the scope of use. Estimates of the sustainable potential considered relevant by the WBGU are highly speculative, because the marine-energy technologies are at such an early stage of development and, to date, insufficient experience has been gathered on their environmental effects (Section 5.2.3). In particular, hardly any information is available on the cumulative effects of large arrays of such systems.

Ocean-wave energy

Estimates of the theoretical potential of ocean-wave energy vary widely – between about 30 and 300 EJ per year (Isaacs and Seymour, 1973; IEA, 2009a; Mørk et al., 2010).

The estimates of the technical potential of wave energy are much smaller and range between about 7.2 and 19.8 EJ per year (Cornett, 2008; Pelc and Fujita, 2002; WEC, 2010). On the basis of the technologies for extracting wave energy available in 2003, and assuming that they are further developed to the application stage, the economically exploitable potential is estimated at approximately 0.504 to 2.7 EJ per year (Wavenet, 2003; WEC, 2010). According to Thorpe (1999), this potential could rise to 7.2 EJ per year if all the potential for technical improvements were to be exhausted.

Tidal rise and fall and tidal stream

The total resource that results from the water-mass movements of the tides corresponds to a theoretical capacity of 2–2.5 TW (Hammons, 1993; Egbert and Ray, 2003). However, only a fraction of this can be exploited (Krewitt, 2009).

A tidal range of at least 4.5 to 5 m is needed to build and operate a tidal power plant that is economically feasible. The possible locations for building such power stations are therefore very limited. Worldwide there are about 20 regions (Figure 5.2-4) that look suitable for the construction of tidal power plants (Hammons, 1993). The global potential of tidal-barrage power plants is estimated by Lübbert (2005) at more than 30 GW, which corresponds to an annual power generation of about 0.216 EJ at a capacity factor of 23 %.

Pelc and Fujita (2002) and Hammons (1993) see a technical potential for tidal rise and fall and tidal streams of approximately 1.8 to 3.6 EJ per year (500–1,000 TWh), although they make the restriction that only a fraction of this can be exploited for economic reasons. Estimates made by Soerensen and Weinstein (2008) on the potential of tidal stream power stations are comparable in size at 2.88 EJ per year. For Europe, the technical potential amounts to around 0.378 EJ per year, just under half of which is located in the UK (Hammons, 1993).

Ocean currents

Large-scale ocean circulations lead to the formation of currents which, unlike tide-driven currents, flow continuously in the same direction (Lewis et al., 2011). Usually, the flow velocities are slower, which makes the economic development of this energy more difficult. One of the ocean currents that reach a minimum flow velocity of 2 m/s is the Agulhas Current east of Africa in the Indian Ocean. Information on the potential of ocean currents is limited to model calculations, according to which the technical potential of the Florida Current off the south-eastern US coast is estimated at 25 GW (Stewart, 1974; Raye, 2001). It is believed that 1 km wide installations off the coast of South Africa to develop the Agulhas Current might achieve a capacity of 100 MW (Nel, 2003; Sims et al., 2007).

OTEC plants

OTEC plants can be built both on floating platforms and on land if the ocean floor is deep enough near the coast enabling access to the required cold deep-sea water. Transporting cold deep water to near the surface causes a disturbance in the temperature structure in the region, which in turn has an effect on the potential. Models of the maximum steady-state resource (after equilibration has been reached) show that a continuous generation capacity of about 3–5 TW is possible (Nihous, 2007). This corresponds to a potential of 95 to 158 EJ per year without changing the ocean's thermal structure (Daniel, 2000). In view of the complex engineering challenges and the resultant high electricity production costs (Section 5.2.5), in the medium term this technology is expected to be used mainly to supply power to small island developing states (SIDS), which currently use generators to produce their electricity – at high fuel costs. Economic feasibility only seems possible if all co-use options, such as air conditioning and connected aquaculture systems, can be exhausted.

Salinity-gradient or osmotic power stations

Estimates have been made on the technical potential of osmotic power plants based on the global flow rate of rivers into the oceans, on the assumption that about 20% of it could be used. If the global volume of freshwater that flows into the sea every year is about 44,500 km³, there is a global potential of approximately 7.2 EJ per year (2,000 TWh/year; Krewitt, 2009). A similarly high potential has also been determined by the company Statkraft. In order to estimate the potential that is actually realizable, it should be taken into account that, for example, water with a high suspended load concentration of very fine particles (e.g. clay, silt) is hardly suitable for use in osmotic power plants. It should also be noted that the salinity of the sea water is considerably reduced over wide areas at the mouths of large rivers that flow into relatively shallow seas. This reduces the suitability and potential of many sites.

Algae cultivation for use as a source of energy

In land-based plants used as an energy source, the maximum percentage of incident solar radiation that can be exploited is of the order of about 1%. Microalgae, by contrast, can reach a photosynthetic efficiency of between 3% and a maximum of 6% (Borowitzka, 2008; Grobelaar, 2009). The cultivation of oil palms can achieve lipid yields of 6,000 litres per hectare per year, while hectare yields of 20,000 to 60,000 litres per hectare per year are possible in the cultivation of microalgae (Wijffels and Barbosa, 2010). The logical conclusion is that there is considerable potential in the cultivation of microalgae for use as an energy source, since theoretically very large areas are available for the land-based cultivation of marine microalgae, e.g. various coastal deserts. Since microalgae production is only believed to be economically viable in the medium-term in combination with the treatment of urban waste water, and given that gassing with CO_2 is required in order to achieve maximum growth rates, the availability of CO_2 and waste water can represent limiting factors (Lundquist et al., 2010). The authors do not expect the contribution of microalgae to the US fuel requirements to exceed 1%, taking locational requirements (air, water, land and sources of CO_2) into account.

Similarly, the cultivation of macroalgae in offshore areas of the ocean far from the coasts could have great potential. The area required would be enormous, however, since the conversion efficiency of macroalgae is lower. For example, 10.7 times the present global macroalgae production would have to be used to meet 1% of the USA's fuel needs, assuming the macroalgae industry's current level of productivity. This corresponds to a cultivation area of 10,895 km² (Roesijadi et al., 2010). Based on the results of several publications (Roesijadi et al., 2008; Bruton et al., 2009; Oligae, 2010), Roesijadi et al. (2010) have determined an average productivity of 2,960 tonnes per km² per year. At 0.14 to 0.4 m³ of methane per kg of ash-free dry weight, this corresponds to an energy yield of 10 to 28 TJ per km² per year, which is a factor of 2.5 to 20 lower than the area yields of microalgae. Area-specific productivity can be greatly increased. Currently, there are already experimental systems with a productivity of 8,000 to 16,000 tonnes (dry weight) per km² per year (Kraan, 2010).

Florentinus et al. (2008) have studied the global technical potential of aquatic biomass. Six different approaches to using micro- and macroalgae for energy sources were analysed and the specific yields, costs and potential determined. A total potential of 6,235 EJ per year was identified, about 6,000 EJ per year of which came from one variant in which free-floating algae are cultivated in offshore areas of the high seas where nutrient resources are especially low ('ecological deserts'). For this purpose, nutrients would have to be provided artificially, for example by artificial upwelling (Box 4.1-2).

5.2.3 Environmental impact of marine renewable-energy generation

The erection of wind turbines and plants for marine-energy generation can be expected to impact on the surrounding ecosystem. Many of these interactions can be summarized irrespective of the technology used, while other environmental effects are technology-specific. The interactions and possible effects of marine-energy generation are extremely complex. It can have effects at the level of the individual, the population and finally the ecosystem. Figure 5.2-7 shows the complexity of the necessary analyses and the different levels of observation.

Installations for generating energy on and in the oceans generally lead to greater navigation risks for shipping; oil spills caused by collisions in particular represent a relevant risk to the environment. The structures erected beneath the surface of the sea can have a

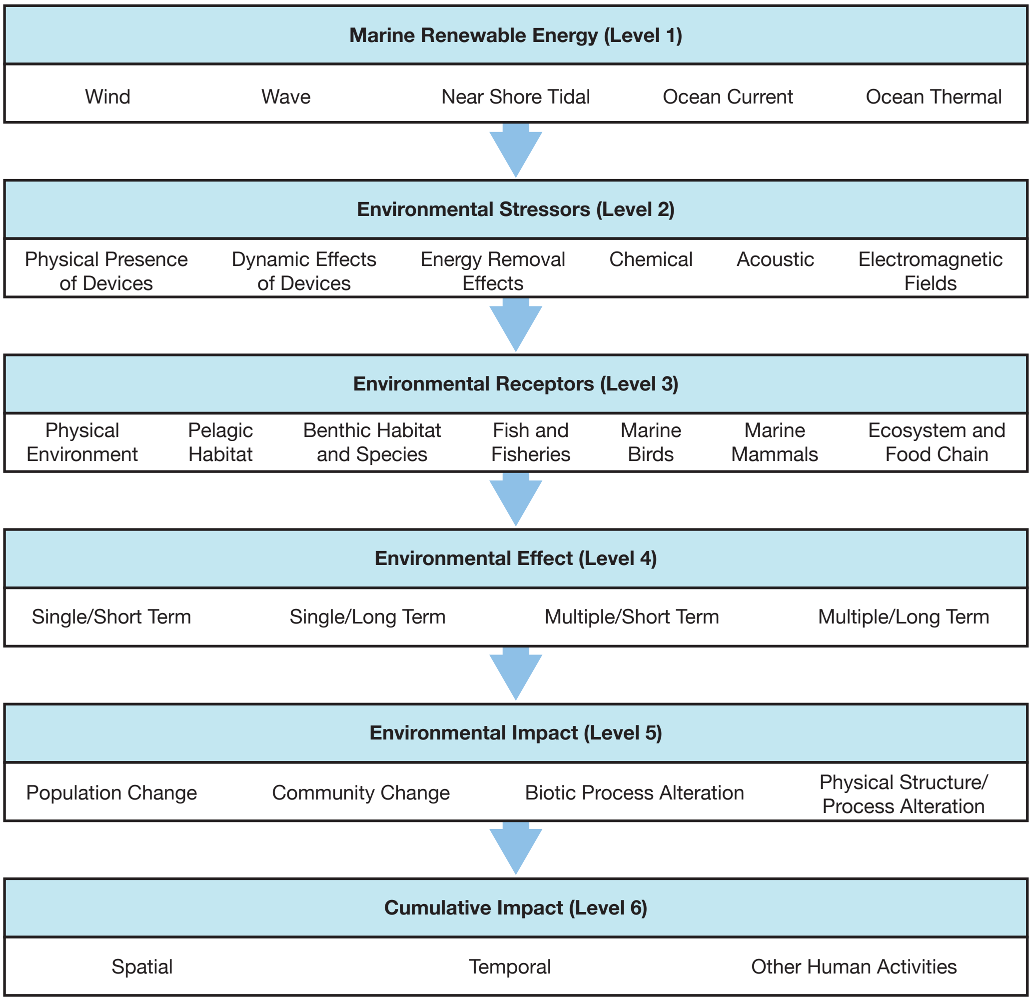


Figure 5.2-7
Different levels of environmental effects of marine renewable-energy generation. Depending on the form of energy and the technology of use, there are different effects on the surrounding ecosystem; these also vary over time (construction phase/short term, operations/long term). The environmental effect (Level 4) can be subdivided into the effect of a single installation during the construction and operating phases and an array of multiple plants during the construction and operating phases. These effects are measured e.g. by a change in the animal population or the species composition of the ecosystem.
Source: Boehlert and Gill, 2010

barrier effect on migrating marine mammals. Furthermore, noise emissions during operations and changes in the magnetic fields caused by electrical connections can lead to cumulative effects.

Current and wave power plants in particular can weaken currents and waves, and this can impact on sediment properties and organisms that depend on a higher input of kinetic energy in the form of currents or waves, e.g. species that live in the surf zone (Shields et al., 2011; Serri et al., 2012).

Furthermore, organisms that need a fixed substrate can colonize the surfaces of the installations. As a result, in regions where there is no natural hard substrate, the installations can contribute to the dissemination of sessile organisms and thus have repercussions on the composition of species. Furthermore, there is evidence to suggest that the erected structures cause an aggregation of various types of fish. However, it is not clear whether the structures actually lead to higher abundances in the entire region or only to a regional concentration (Inger et al., 2009). Since the areas used for energy generation are usually exclusion areas for fishing, they can function as refuges and reproduction areas for many fish species in a comparable way to marine protected areas (Section 3.6.2.1) and in this way perhaps contribute to the regeneration of fish stocks.

In particular, the construction of the plants – but also their maintenance and decommissioning – lead to increased shipping traffic. This involves additional material emissions both into the atmosphere and into the ocean. Constructing the plants and laying the connection cables causes sediment swirling, which temporarily increases the suspended load. Higher material loads can, for example, be caused by defective hydraulic lines or when toxins from protective coatings (anti-fouling) diffuse into the sea water.

The environmental effects caused by all technologies that are installed not on the coast, but directly in the sea, also include the input of energy in the form of noise and electromagnetic fields into the ecosystem. These two aspects are discussed in more detail in the following because of their cross-technology relevance.

Underwater noise

The construction and operation of offshore wind turbines and installations for exploiting marine energies cause additional anthropogenic noise emissions into the water column. In the European Marine Strategy Framework Directive (MSFD; Section 3.4) these noise emissions – being an 'introduction of energy' – are equated with marine pollution (EU, 2008; Chapter 1, Article 3, paragraph 8).

Particularly relevant are the extremely high volume levels that occur during pile driving for foundation and anchoring structures. Monopiles, jacket structures and tripods/tripiles (Section 5.2.1.1; Figure 5.2-1) are currently the most common types of foundation. It is highly probable that the sound pressure levels of up to 235 dB re 1 μPa (Tougaard et al., 2009) that occur during pile-driving work in the construction of offshore wind farms have adverse effects on marine mammals (Madsen et al., 2006), but also on fish (Thomsen et al., 2006). Marine mammals such as the grey seal, the common seal and the harbour porpoise are dependent on intact hearing. Harbour porpoises in particular use their hearing for orientation, but also to locate their prey. When small cetaceans hunt, they separate from their calves, so that acoustic communication is crucial in order for mothers and calves to find each other again. In addition, the animals' breeding season during the summer months coincides with the construction period of offshore wind farms, because suitable weather for erecting the installations prevails at that time.

All marine mammals that are found in the German EEZ are protected by the Habitats Directive under Annex II, and the harbour porpoise is subject in addition to general strict species protection under Articles 12 and 16 of the Habitats Directive (Sections 3.4, 5.4.2). There is not only a ban on killing or injuring the animals; any disturbance to the animals must be avoided, especially during the periods of breeding, rearing, hibernation and migration.

Harbour porpoises can be harmed by the noise generated by pile driving up to a distance of 1.8 km, and changes in the animals' behaviour have been observed up to a distance of 20 km from the noise source (Tougaard et al., 2009; Brandt et al., 2012). The far-reaching effects of the noise input must be seen against the background that a markedly accelerated development of offshore wind energy is needed if the objectives of the energy concepts of both the German government and the EU are to be met (Section 5.4.1). This means the simultaneous construction of offshore wind farms in the respective EEZ in the North and Baltic Seas, which will considerably restrict the animals' areas of retreat.

The current noise limits are based on the criterion of temporary threshold shift (TTS) in harbour porpoises. A reversible deterioration in the animals' hearing has been proven when they are exposed to noise in excess of 164 dB SEL (single-event sound-exposure level; Lucke et al., 2009). On this basis, a sound pressure limit was fixed for the construction of offshore wind farms of 160 dB re 1 μPa (SEL) or 190 dB re 1 μPa (peak-to-peak) respectively at a distance of 750 m from the point of emission. These limits were considerably exceeded, for example, during the construction of the offshore wind farms alpha ventus and Horns Rev 2 in the North Sea, where the levels reached 176 dB re 1 μPa (SEL). These limits can only be met by using noise-reduction measures.

A reduction in noise levels can be achieved by using shielding technologies around the driven pile. Several different sound-dampening measures are currently under development. Examples include various kinds of bubble curtain (large, multi-layer, guided), the bubble wand, various pile sleeves (BEKA shell, tubular casing, IHC noise mitigation screen, cofferdam applications) and hydraulic silencers (Koschinski and Lüdemann, 2011). However, these are not yet fully mature technologies that conform to the best demonstrated available technology, although the large bubble curtain (Figure 5.2-8) has been successfully used several times in practice, e.g. in the construction of the Trianel wind farm Borkum in the North Sea.

Other measures aimed at minimizing the risk of harming marine mammals include slowly ramping up the intensity of pile-driving and actively scaring the animals away for the duration of the construction phase before pile driving starts. The trend towards larger systems is also leading to bigger pile diameters. Since the sound pressure also increase as sizes grow, the demands on noise-reduction measures will increase in the future. In the long term, therefore, from the perspective of nature conservation the use of alternative foundation structures – e.g. gravity, bucket or floating foundations (Section 5.2.1.1; Figure 5.2-1) – represent a lower-impact alternative. Drilled foundations using technologies developed in tunnel construction are currently also under development and represent a possible

Figure 5.2-8
Use of a large bubble curtain to reduce noise emissions during pile-driving work to anchor an offshore wind turbine. The continuously rising air bubbles form a noise-dampening pile sleeve around the hydraulic hammer. However, even when this method is used, the restrictions on noise-emissions are not always met.
Source: Trianel GmbH/Lang

alternative to impact pile-driving.

Although the various technologies for preventing harm to marine mammals as a result of construction noise are not yet ready for operational use, technical feasibility is not far away. But there is still a considerable need for research (Section 8.3.4) before this will be the case, especially to accelerate the development of cheap but effective measures.

Operating noise and the noise emissions caused by the additional shipping traffic are less relevant to the surrounding ecosystems according to present knowledge. Initial studies conducted at the German alpha ventus test field (North Sea) have shown that the operating noise of the installations is below or only slightly above the ambient level, depending on the foundation structure used (Betke and Matuschek, 2011).

The relations between marine-energy generation and underwater noise shown here are described in relation to the example of offshore wind energy generation because the other technologies are at an early stage of development. However, they also apply to anchoring systems for other marine-energy installations. Little information is available to date on noise emissions during operations of other forms of marine-energy generation. The sound pressure levels emitted by tidal stream turbines are estimated at approximately 165 to 175 dB re 1 µPa, depending on the turbine size (OSPAR, 2009).

Electromagnetic fields

A comprehensive expansion of electric lines and power grids in the sea is required in order to transport electricity from offshore wind farms and marine-energy installations to the shore, feed it into the existing power grid and exploit compensatory effects. This includes grids covering large area, the direct connection of a wind farm or cluster of generating plants, and the cabling between the plants (Section 5.2.4; Figure 5.2-11).

In addition to mechanical stress and sediment plumes while cables are being laid, especially the possible effects of electromagnetic fields (EMF) from the cables on marine organisms are a potential threat to marine fauna.

When an electric current flows through a cable, a magnetic field (B-field) is created around the conductor; it increases in intensity in proportion to the size of the current. An electric field (E-field) also forms, and its strength depends on the voltage (Figure 5.2-9). The electric field is kept inside the cable by the shielding around industrial cables, but it is not economically feasible to shield the magnetic field.

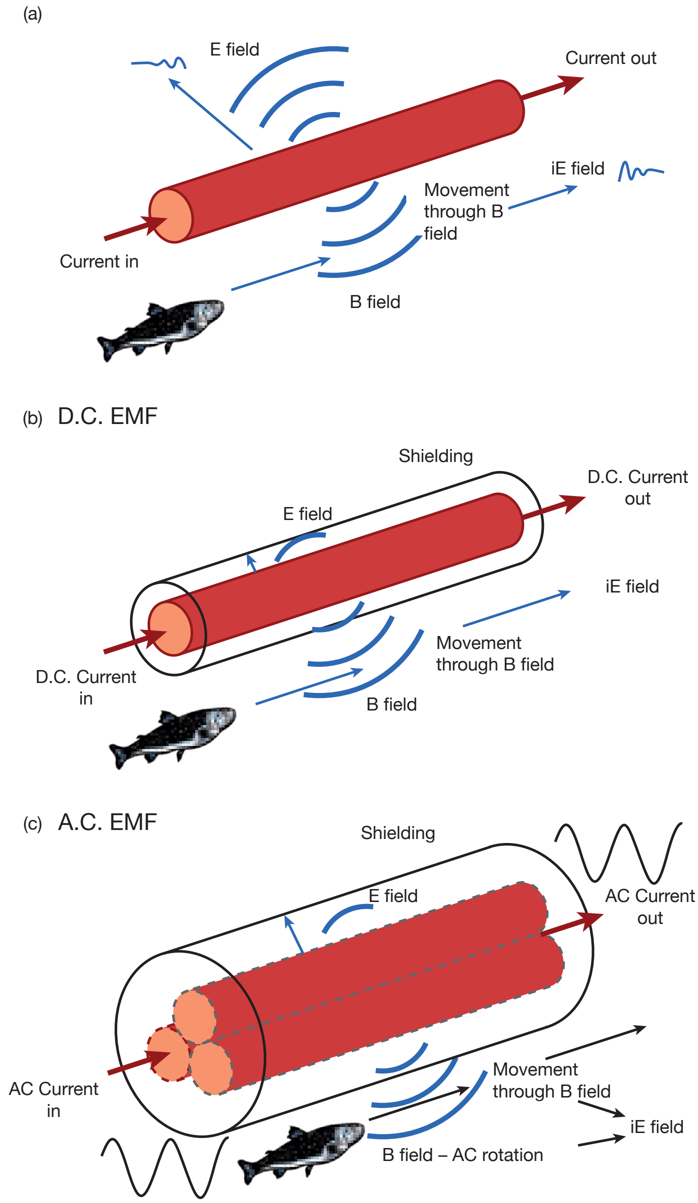


Figure 5.2-9
Diagram of electromagnetic fields around undersea cables. (a) In addition to the magnetic field (B field), an electric field (E field) also forms in the body of water around an unshielded cable. In addition, electrical conductors within the magnetic field lead to the formation of an induced electric field (iE field). (b) Shielded DC conductors prevent the leakage of the electric field into the body of water. Due to the static magnetic field, iE fields form when a conductor moves in the B field. (c) By contrast, the rotating magnetic field of the AC cable also causes the induction of iE fields in non-moving conductors. Source: Gill and Bartlett, 2010

When an electric conductor and a magnetic field are moved relative to each other, an electrical potential is induced in the conductor (generator principle) – this is called an induced electric field (iE field). Because the sea water or the body of a fish acts as an electrical conductor that is moving within the Earth's natural magnetic field, both magnetic and iE fields occur in nature. Electric fields are used by cartilaginous fish (sharks and rays) to detect prey organisms. Furthermore, the perception by fish of both magnetic and electric fields is believed to be associated with their orientation during migrations over long distances and with locating spawning grounds (Arnold and Metcalf, 1989; Fricke, 2000; Akesson et al., 2001). The Earth's magnetic field has a strength of approximately 50 µT in central Europe. This causes electric fields of about 50 µV/m to form, for example in oceanic currents; higher values can occur in straits (Kullnick and Marhold, 2004).

The strength of the magnetic fields and induced electrical fields generated by submarine cables depends very much on the cable technology used, and partly on how they are laid (positioning). If electricity flows in opposite directions in two conductors, the magnetic fields partially cancel each other out. As a result of this effect, the magnetic fields are largely cancelled out in a three-conductor AC (alternating current) power cable. In DC (direct-current) transmission, this is also the case in a bipole design when cables are laid directly parallel to each other; however, it is still a technical challenge to lay so-called 'flat-type' cables with both conductors inside a shared sheath. Forward and return conductors are therefore usually laid individually, one after the other; a distance less than 10 m between the two conductors can be realized using currently standard technology. A distance of less than 1 m can also be achieved if the best available technology is used and the weather is calm; however, this means higher costs because of the higher demands made on equipment and weather conditions. The smaller the distance between the conductors, the weaker the resultant B-field, and therefore also the iE field.

The first high-voltage direct-current (HVDC) cables were monopolar (e.g. the Baltic Cable between Sweden and Germany). In this case the body of water or the upper soil layers are used as a return conductor. However, chlorine and hydroxide are released at the (earth) electrodes. Because there is no conductor laid parallel with electricity flowing in the opposite direction to compensate, strong electric and magnetic fields form around the conductor. Monopolar submarine cables are no longer laid for ecological reasons (OSPAR, 2008). The currently planned connections between Germany and Norway (NorGer and NORD.LINK) are therefore being built as bipolar HVDC transmission lines.

By no means everything is yet known about the effects of anthropogenic electromagnetic fields on marine fauna – research on the subject is still at an early phase. This is partly due to the fact that the issue has only become important in recent years with the construction of offshore wind farms; on the other hand, the studies are very complex and expensive, and have rarely led to unequivocal results in the past (Hatch Acres, 2006; Gill and Bartlett, 2010).

In laboratory experiments, physiological and behavioural reactions have been demonstrated in different species of fish when they are exposed to artificial electromagnetic fields: for example, changes in the activity of muscles of the locomotor system, effects on hormone levels and on orientation when swimming (Gill and Bartlett, 2010). Reactions to the electromagnetic fields of submarine cables have been revealed in experiments conducted on demersal species of cartilaginous fish. However, the reactions differed both between the species studied and from one individual to another (Gill et al., 2010). The results of this study suggest that, although the animals perceive the fields, the biological relevance of the detected behavioural responses is uncertain. The same also applies to studies on the migration behaviour of eels in the vicinity of submarine cables (Westerberg and Begout-Anras, 2000; Westerberg and Lagenfelt, 2008).

In summary it can be said that a lot of further research needs to be conducted on the effects of electromagnetic fields on fish and other marine fauna (Section 8.3.4). In addition to electromagnetic fields emanating from undersea cables, the generators of tidal and wave power plants, which lie below the water surface, are another source of electromagnetic fields in the water column. These effects should also be the subject of future studies.

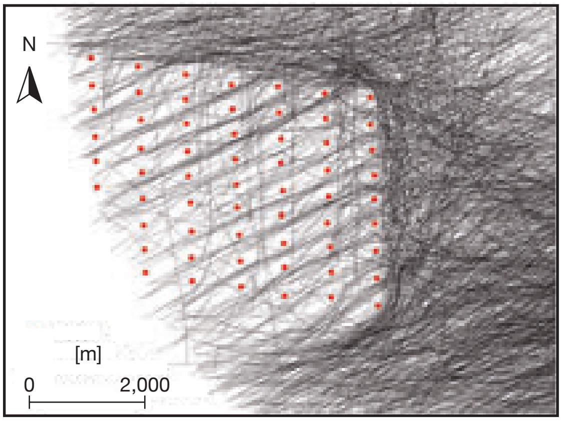


Figure 5.2-10
Westward-oriented movements of marine birds after a wind farm has started operations. The black lines represent the birds' flight paths, while the red dots mark the location of wind turbines.
Source: Desholm and Kahlert, 2005

Technology-specific environmental effects

In addition to these environmental effects which are common to virtually all the technologies, numerous specific effects can also be identified.

The rotors of offshore wind turbines tower up to more than 150 m above the surface of the sea and can act as a barrier for many marine and migratory birds. This usually leads to evasion and avoidance reactions (Figure 5.2-10), but collisions are possible, especially at night and when visibility is poor – also because the animals are attracted by the lights on the installations (Fox et al., 2006; Hüppop et al., 2006).

In sensitive species like loons, for example, the displacement effect of installations can lead to a major loss of habitat (Mendel and Garthe, 2010).

The level of noise emissions during piling work depends on the diameter of the piles and the properties of the sediment. In particular, pile-driving monopiles for wind turbines involves an especially large pile diameter. Since offshore wind turbines are already being constructed on a large scale today, while noise-prevention technologies are not yet sufficiently developed and measures not properly established, noise emissions during the erection of offshore wind turbines represent a relevant stress factor for marine fauna.

Wave power plants remove kinetic energy from the ocean and in this way lead to a calming of the sea. The amount of kinetic energy withdrawn from the sea is estimated at between 4 and 17% (Boehlert et al., 2008). This has repercussions on sediment properties and slows down exchange processes between the body of water and the sediment and the atmosphere. This can restrict the distribution of pelagic larvae (i.e. larvae that drift in the water column; Gaines et al., 2003).

In the WBGU's view, no more tidal-barrage power plants that separate entire estuary regions from the sea by a dam should be built in future, since such installations interfere greatly with unique estuarine ecosystems. The barrages alter salinity and hydrology in the estuary region. Slower flow velocities lead to changes in sedimentation rates (Kirby and Retière, 2009), and there is a high level of mortality among fish passing through the turbines (Schweizer et al., 2011). Tidal lagoons (Section 5.2.1.2) perhaps represent a less problematic alternative, although little information is available on their environmental effects at present.

In addition to the environmental effects of all the technologies mentioned above, it is in particular the risk of injury by underwater rotors that is relevant in the case of tidal-stream turbines (Cada et al., 2007). In addition to direct injuries caused by an organism's contact with the rotating blades, hydraulic stress factors can also cause damage, for example by changes in pressure, shearing forces or turbulence (Cada et al., 1997; Ploskey and Carlson, 2004). Especially when a large number of plants are built, this can affect the hydrology of the region and change sediment formation, which impacts on sea-bottom habitats (Shields et al., 2011).

Negative environmental influences through the use of OTEC plants stem almost exclusively from the need to pump cold deep water to the surface in order maximize the temperature difference from the warm water close to the surface to operate a combined heat and power engine. Because large volumes are required, the ocean's temperature structure may be regionally disturbed (Pelc and Fujita, 2002); nutrients and CO_2 are transported to near-surface layers. The latter may be released into the atmosphere as a result of the change in pressure, although the associated emissions are much lower than those of fossil-based power generation (Vega, 2002). The input of nutrients and CO_2 can be expected to affect ecosystem productivity and species composition (Boehlert and Gill, 2010). The environmental effects of the pumped deep water can be greatly reduced by returning it to greater depths (approximately 100m); however, this requires more pumping capacity, which will further reduce the already low level of system efficiency (Vega, 2002). The pumps for circulating the water can also damage small organisms, and any defective machinery can lead to the release of ammonia, for example, which is frequently used as a working medium.

The overall environmental effects of salinity-gradient power plants can be regarded as low. However, changing the location where the fresh water mixes with the salt water can be expected to alter local salinity relations.

The large-scale cultivation of macroalgae requires considerable amounts of nutrients, which must be provided artificially to make the necessary growth rates possible. This can be done by extracting nutrient-rich deep water or by direct fertilization (Box 4.1-2). Synergies are possible here in combination with OTEC plants. Integrated aquaculture approaches are examples of how the cultivation of algae can achieve positive environmental effects. However, excessive nutrient input or extraction can disturb the trophic structure of the ecosystem. Other risks lie in the introduction of genetically modified or non-indigenous species (Section 4.2).

To sum up, it can be said that the technologies of marine renewable-energy generation tend to have low to moderate negative effects on the environment, with the exception of tidal-barrage power plants. However, the noise levels emitted when anchoring the installations, particularly in the case of offshore wind turbines, often present a problem. The space intensity of marine renewable-energy generation for power-supply purposes means that considerable areas of the sea are required. This could potentially lead to conflicts with other uses and conservation interests (Section 5.4.2). Construction work should not go ahead in areas that are habitats for rare and sensitive species (e.g. loons in the North Sea) or along the migration routes of marine mammals and birds (in the case of wind turbines). Conflicts over use and conservation issues tend to decline as the distance from the coasts increases. Migration routes often follow coasts, and use interests are usually more pronounced in coastal regions. The technological trend towards greater distances from the coasts and greater water depths therefore offers options for avoiding impending conflict.

5.2.4 Infrastructure

Compared to land-based energy systems, very different boundary conditions apply to offshore structures. Particularly in the fields of corrosion protection, transport, accessibility and security aspects, the marine environment requires special adjustments, although most of them are known from the extraction of fossil energy carriers (Section 5.1.4). This applies for example to safety demands on the operating team, access procedures to the platforms and the provision of security by monitoring vessels.

5.2.4.1
Offshore logistics for renewable energy

Infrastructures for extracting fossil energy carriers can be extended for use in the renewable-energy field (Section 5.1.4); ships for transporting bulky components (e.g. rotors) are needed for the construction of offshore wind farms. This requires both new ships and the expansion of port facilities and locks. Depending on the types of foundation used, new ships will also need to be built to transport very heavy components (e.g. for gravity foundations; Section 5.2.1). Pile-driving and drilling work for the foundations of offshore wind turbines and ocean-current turbines also requires modified technologies and procedures, especially for large-scale installations for reasons of noise attenuation (Section 5.2.3). Although supply lines also exist for oil and gas platforms in the field of electric power transmission, their capacity is far below what is needed for the transmission capacity of large offshore wind farms. Offshore substations and converter stations and correspondingly efficient high-voltage cable connections to the shore are needed for this novel task. The mean distance to land is about 24km in the case of the European offshore wind-power projects that are in operation, under construction or in planning (4C Offshore, 2011). Although the use of three-phase cables in conjunction with transformer-based substations is the conventional system for power transmission today, high-voltage direct-current (HVDC) transmission becomes economically attractive when the distance to land is further than about 80km. Despite the higher investment costs, which are incurred primarily for the converter stations, losses are lower compared to AC transmission (Hanson, 2011).

Most existing offshore wind farms use alternating current to transmit the power they generate. The first wind farm to have a DC connection is the German BARD Offshore 1.

Compared to individually connecting each individual wind farm, there are significant economic and environmental advantages in sharing grid connections between several offshore wind farms or in building an offshore transmission grid (Section 5.4.1).

The technology for building a meshed offshore supergrid based on high-voltage direct-current (HVDC) transmission will soon be ready for use (Figure 5.2-11). Unlike previous HVDC lines, which could only be built between two connection points, it will then be possible to serve several connection points and simultaneously stabilize the connected AC grids.

New cable-laying ships and production facilities for manufacturing these cables must also be built because existing capacity is by no means sufficient for the planned European expansion of offshore energy generation.

Furthermore, it will be necessary to build special maintenance ships and to set up service centres on land, because, unlike oil and gas platforms, offshore wind farms and other systems using marine energies are unmanned during normal operations. They must therefore be easily accessible.

5.2.4.2
Offshore storage technologies

Storage facilities make it possible to match power generation that depends on meteorological conditions with demand. With the exception of marine-current and OTEC plants, marine-energy-generation technologies produce electricity intermittently; a combination with storage systems enable it to be integrated into the electric power-supply system.

Deep-sea pumped-storage power plants

A relatively new development aims to take advantage of the water pressure at great depths for power-storage purposes (Figure 5.2-12). A large-volume storage tank that is able to hold a large amount of water is sunk into the sea. The surrounding water, which is under high pressure, then flows into the tank through a turbine, thus generating electrical energy. When there is a surplus of power, this water can be pumped out of the tank again into the sea. First test plants are currently being built in Germany and the USA. Capacity-utilization rates of transmission grids, and thus economic efficiency, can be substantially improved in connection with future offshore super-grids.

Chemical long-term storage

If an energy supply is to be fully based on renewable energy, the long-term storage of electricity generated from renewable energy represents a particular challenge (Section 5.3; WBGU, 2011). Since the capacity of the storage technologies used today, e.g. to bridge a two-week period with little or no wind, is clearly insufficient, it is going to be necessary to develop and implement new technologies.

For Europe, in addition to the possibility of connecting with Scandinavian pumped-storage hydroelectric power, one of the few viable options is the chemical storage of electricity generated from renewable energy in the form of hydrogen or methane (SRU, 2011a; BMU, 2012). The generated electricity is initially used to split water into hydrogen and oxygen by electroly-

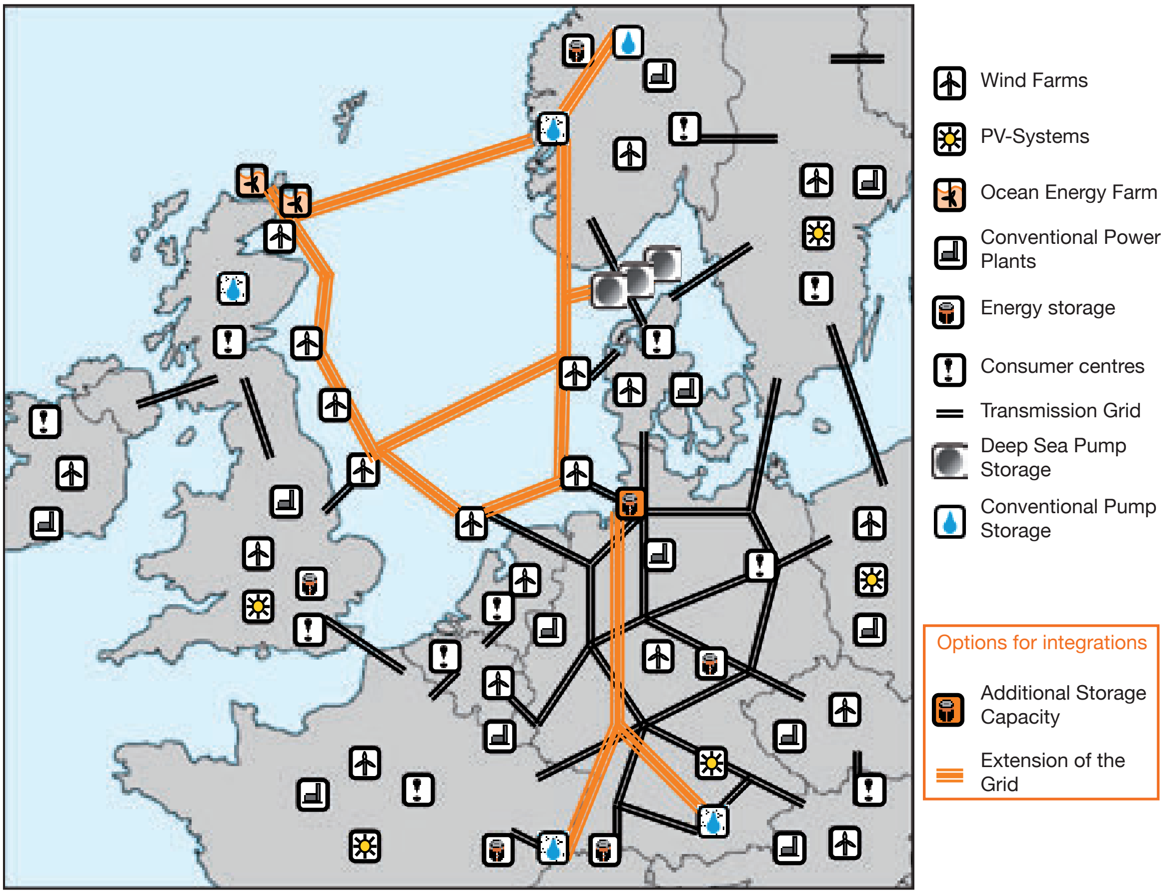


Figure 5.2-11
Schematic diagram showing the possible design of an offshore grid. Expanding and extending the existing grid makes it possible to incorporate generating and balancing options, some of which are quite distant.
Source: IWES/Knorr

sis. The hydrogen generated in this way can be stored directly as a fuel in above-ground or underground gas-holders (Figure 5.3-2). However, in order to achieve a high-enough energy density relative to the volume, the hydrogen must be compressed, which requires a considerable amount of energy. Alternatively, the hydrogen can be added to the existing natural gas system up to a maximum percentage volume of approximately 5%. This natural-gas system in Germany has a capacity of over 200 TWh_{th}, which would be sufficient to meet Germany's long-term storage needs amounting to 20-40 Tw_{el}. However, since there are hardly any technologies for the large-scale re-conversion of hydrogen, and the absorptive capacity of the natural-gas network would be exhausted relatively quickly, converting the hydrogen to methane is an interesting alternative.

Here, in what is known as the Sabatier process, the hydrogen generated by electrolysis reacts with carbon dioxide and is converted into methane (Figure 5.3-2). Although this involves additional conversion losses of about 15%, conversion into methane offers considerable advantages in terms of energy density and the use of the existing transport networks, storage and electricity-generating infrastructure (Section 5.3). The entire process from electricity to methane to electricity results in an overall efficiency of approximately 35%, although this can be improved to over 60% by using the waste heat.

Hydrogen electrolysis and methanation are established technologies; however, a considerable amount of research still needs to be done on intermittent operation in conjunction with fluctuating renewable generators – as well as on conversion efficiency and cost efficiency (Section 8.3.4).

In connection with marine-energy generation, the technology can be used locally to store renewable electricity surpluses, if enough of the necessary carbon dioxide is available in sufficient quantities (Section 5.3). CO_2 can, for example, be obtained in large quantities by the fermentation of (algal) biomass or by natural gas extraction (Section 5.2.1). There is also the possibility of spatially separating electrolysis and metha-

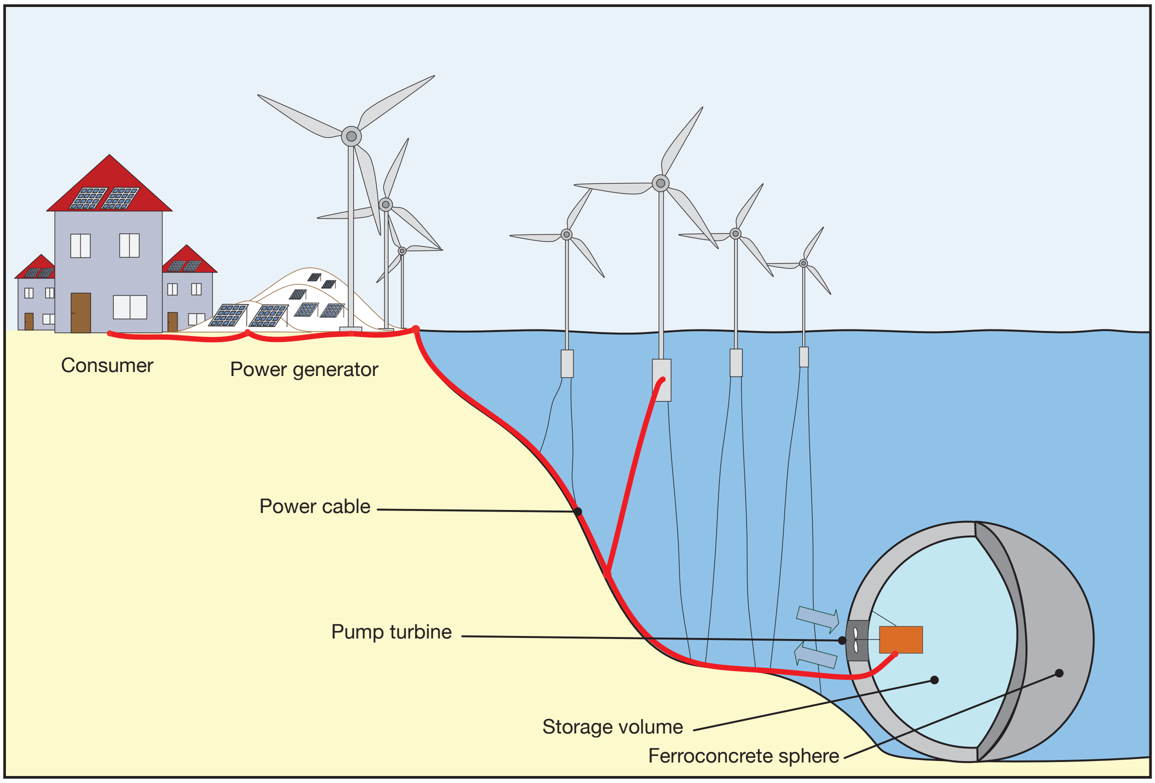


Figure 5.2-12
Schematic diagram of a deep-sea pumped-storage power plant for storing electricity generated by offshore wind farms or marine-energy technologies.
Source: IWES

nation according to the availability of electricity and CO_2; in this case the 'energy transport' between the two locations would take place in the form of hydrogen or methane (Section 5.3).

Deep-sea reverse osmosis: drinking-water preparation using hydrostatic pressure

In reverse osmosis, the natural osmosis process is reversed by pressure. This method is used in the desalination of sea water, although this requires an energy input of 10.8 to 36 MJ per m³ (Colombo et al., 1999). The osmotic pressure between fresh water and sea water is approximately 25 bar, so that pressures of 60 to 80 bar are normally used to produce drinking water. In conventional plants, generating this pressure involves high losses, because a larger volume of water must be brought up to this pressure than can be recovered as drinking water. Although some of the energy required to raise the pressure can be recovered by a pressure exchanger, much of the energy used is lost. Comparable pressures also prevail at great depths in the sea, so this can be used to force seawater through a selective membrane and thus obtain drinking water. A water column of about 500m is enough for this purpose. Instead of increasing the pressure of large amounts of sea water, it is sufficient to pump the much smaller amount of produced drinking water to the surface. Ignoring the efficiency losses of pumps, this corresponds to approximately 5.04 MJ per m³ (at a water depth of 500m). Furthermore, only a small amount of energy is required to support the exchange of the water enriched with salt on the membrane surface. In addition to pure drinking water production, the technology can theoretically also be used to generate electricity if stored fresh water is passed through a turbine to the membrane (at a depth of 500m), where it is released into the sea due to the pressure of the water column plus the osmotic pressure. Although the efficiency level is relatively low, the combination of drinking-water production (when there are electricity surpluses) with power generation (when there are electricity deficits) could contribute to the smoothing and thus to the integration of fluctuating renewable energies.

Carbon dioxide capture and storage

As a technical option to gain time for the transformation to emissions-free energy sources whilst utilizing at least some of the large fossil fuel reserves, technical solutions for separating CO_2 from the emissions of stationary plants are under discussion, as are options for the subsequent storage of compressed CO_2 in geological formations (CCS; Figure 5.1-5, Section 5.1.4.3; WBGU, 2011). Carbon dioxide capture and storage (CCS) is a necessary mitigation measure for countries that continue to use fossil energies, if anthropogenic global warming of more than 2°C is to be avoided. Beyond this, a combination of bioenergy with CCS is also under discussion as an option for withdrawing CO_2 from the atmosphere again in the long run (WBGU, 2011).

A technical possibility for realizing negative emissions would be to use bioenergy while capturing and storing the CO_2 produced (Section 5.3; WBGU, 2011). However, there is a risk that the stored CO_2 might gradually escape, which would influence the stability of the climate system. The WBGU therefore recommends only using formations for storage that can guarantee a retention time of at least 10,000 years (Section 7.5.4; WBGU, 2006).

5.2.5 Costs

Since there has been comparatively little experience to date with offshore wind turbines, and in particular with marine-energy technologies, there are only few estimates on the investment, operating and maintenance costs of power-generation plants on and in the sea. The electricity production costs (weighted average costs) are normally used for comparisons between different power-generation technologies. So far, however, figures are only available for offshore wind turbines. The electricity production costs are strongly influenced by the respective location, the legal regulations, the technical risks and the capital market.

5.2.5.1 Offshore wind energy

The technical challenges of installing, operating and maintaining offshore wind turbines for power generation are greater – and the costs correspondingly higher – than on land and depend on the distance from the coast and the water depth (IWES, 2012; ISE, 2012). The higher costs can be partially offset by the higher wind speeds and steadier winds that prevail the further the turbines are from the coast (Lewis et al., 2011; Bilgili, et al., 2011). Energy yields generated by offshore wind farms can be twice as high as comparable installations on land. Furthermore, it can be assumed that the electricity production costs for offshore wind energy will fall markedly in the future as a result of further research and development as well as learning effects and economies of scale (ISE, 2012).

Depending on economic, legal and technical parameters, the volume of investment needed for offshore wind farms with a capacity of 400 MW is €1 to €1.5 billion in Germany, where the grid operators are responsible for investments in the grid (KPMG, 2010). In other countries, grid-investment costs are borne by the project's executing organization. According to IWES (2012), the capital costs in Europe are between €120 million and €194 million, or between €1,700 and €3,315 per kW of nominal capacity. The IEA estimates that the capital costs of offshore wind turbines are about twice that of onshore plants on average (IEA, 2009b; IWES, 2012:50). The wide range spanned by capital costs can be explained by the different national regulations and specific geographical conditions of each individual offshore wind farm.

The capital costs are made up of the following cost components: turbine (37–50%), foundation or substructure (21–25%), grid connection (cable, transformer station, etc., 15–23%), and project development, financing costs and management (10–15%; IEA, 2009b:16; IEA RETD, 2011; IPCC, 2011).

Specifically, the capital costs depend on the weather and the wave conditions, as well as on the seabed topography, the water depth and the distance from the shore (Section 5.2.1; Figure 5.2-1). The capital costs of offshore wind turbines in Europe have risen markedly in the last few years due to increasing technological risks as plants are built further from the coast and at greater water depths, a lack of competition among technology providers, bottlenecks in the value chain, rising commodity prices and political risks (IEA RETD, 2011:51).

The operating costs of offshore wind turbines are made up of the following components: running and maintenance costs, rent, insurance premiums, provisions, administrative and management costs and grid-transmission charges, depending on the legal situation. To date there are no reliable estimates of average operating costs; this is because they are difficult to calculate for lack of experience. However, they can be expected to be higher than on land, because the technologies are less advanced and the demands on transportation and installation greater, especially under adverse weather conditions (IPCC, 2011; IWES, 2012). According to estimates by IWES, the operating costs of selected offshore wind farms in Europe lie between €34 and €148 per kW of installed nominal capacity (IWES, 2012:50).

The analysis of the electricity production costs of offshore wind turbines in Europe shows a wide range – and that they are currently twice as high as for wind turbines on land (ISE, 2012). The electricity production costs for offshore wind farms in very good locations are between €0.11 and €0.15 per kWh (ISE, 2012:17). In locations where there are fewer full-load hours, the electricity production costs are between €0.12 and

€0.18 per kWh (ISE, 2012:17). IWES has calculated theoretical electricity production costs under different overall conditions (capital costs, full-load hours and operating costs), and they are between €0.025 and €0.50 per kWh for European offshore wind farms (IWES, 2012:51). A study by the IEA's Renewable Energy Deployment Programme estimates the electricity production costs at between €0.12 and €0.25 per kWh (IEA REDT, 2011). It can be assumed that the electricity production costs for offshore wind power will fall significantly up to 2030 as a result of economies of scale and learning effects.

According to the ET Blue Map scenario, the capital costs of offshore wind turbines could fall by 27% by 2030 and by 38% by 2050. The operating costs are expected to fall initially by 25% and later by 35% over the same periods (IEA, 2009b). However, the expected cost reductions depend greatly on the projected rates of expansion of wind-turbine installations.

Investment requirements

The development of marine renewable energies will require a considerable injection of funds. Initial estimates of investment requirements exist for the development of offshore wind energy in Europe. An expansion with the aim of installing offshore wind turbines with a capacity of 150 GW by 2030 is likely to require an investment of approximately €220 to €390 billion (EWEA, 2011, and WBGU's own calculations based on data from IWES). Depending on the level of capacity utilization, the resulting generating capacity could cover between 14% and 23% of present-day electricity consumption in Europe (WBGU's own calculations based on data from IWES).

5.2.5.2
Marine energies

Studies on the costs of marine-energy technologies emphasize that calculations made up to now are provisional and involve considerable uncertainties – because of a lack of sufficient testing, operating experience, reference data and scientific scrutiny (GEA, 2012). To date, experience with individual prototypes can only be transferred to other locations to a limited extent because potential varies greatly from one place to another (Bömer et al., 2010). Estimates are available for capital costs at 2005 prices (Lewis et al., 2011; GEA, 2012), according to which the capital costs are between US$6,200 and US$16,100 per kW of nominal capacity for wave energy plants, between US$4,500 and US$14,300 per kW of nominal capacity for tidal power plants, and between US$4,200 and US$12,300 per kW of nominal capacity for OTEC plants. Marginal unit costs can be expected to decline significantly in the future when the technologies reach market maturity and economies of scale can be expected, as in the case of offshore wind turbines.

The investment costs for ocean-wave and tidal energy are currently estimated at about twice that of offshore wind turbines (IEA RETD, 2011). However, the global investment requirement cannot be reliably estimated because most countries have no specific targets for expanding these technologies. Up to now, power-generating prototypes in the wave and tidal-stream fields have been primarily financed by the public sector and venture capital (IEA RETD, 2011).

5.3
Vision of a future marine energy system

The vision of a marine energy system outlined below is an integral component of a transformation towards sustainability as described in the report 'A Social Contract for Sustainability' (WBGU, 2011). This vision of a future marine energy system describes the potential contribution of the seas within the process of transformation towards sustainability.

5.3.1
The status quo of marine energy generation

Energy systems have developed from solid fuels, such as wood and coal, to liquid ones like mineral oil to using growing proportions of gaseous energy carriers such as natural gas. In the course of this process, the extraction of mineral oil and natural gas has been increasingly moving out to sea, with installations operating at ever-greater depths (Section 5.1). Figure 5.3-1 shows schematically the status quo of fossil offshore energy production, including distribution to the centres of consumption.

The value-added processes of mineral oil and natural gas are shown to be very similar; however, they can only share the existing infrastructure to a partial extent. This is because, although both are hydrocarbons with similar chemical compounds, they are in different phases of matter (Section 5.1.4).

Although the present-day marine energy system (particularly the production of mineral oil and natural gas) and the transportation of energy constitute an important and reliable cornerstone of the current energy supply, the energy system can be regarded as non-sustainable, especially due to the CO_2 emissions resulting from the use of fossil energies (WBGU, 2011; Sections 1.2.4, 1.2.5; Table 5.1-1b). The following section therefore aims to describe how a marine energy system might be designed in the future that is better at meeting sustainability criteria. The technology options required for this are essentially already known; the visionary aspect lies in the implementation of such a concept by systemically linking up the individual components.

5.3.2
A future renewable marine energy system

Estimates show that the potential offered by renewable marine energies and offshore wind-energy use amounts to several times the current global demand for energy (Section 5.2.2). Furthermore, a considerable proportion of global energy needs can be met by using a variety of renewable sources on land. Many different aspects and factors will be crucial in deciding the extent to which different locations and technologies might contribute to meeting demand. In addition to the ecologically sustainable potential, which should represent the upper limit of expansion, the decisive factors will include costs, the level of development, the acceptance of technology by the population, ease of integration into the power-supply system, predictability, and many others. The composition of the renewable energy mix will vary greatly in different regions of the world depending on their regional potential.

The vision of a future marine energy system outlined in the following suggests what the sustainable contribution of sea-based renewable energies might look like in an integrated marine energy-supply system (Figure 5.3-2).

Based on its level of development to date, its relatively low costs, and its small to moderate impact on the environment, offshore wind energy looks likely to be a mainstay of sea-based power generation in many regions (Section 5.2). A massive expansion of offshore wind energy is already underway today; however, the currently most common bottom-mounted turbines are limited to water depths of up to 60m. This leads to increased competition for space in the coastal waters; there are also more likely to be negative interactions with fauna since the habitats and migration routes of marine mammals and numerous species of birds tend to be close to the coast (Section 5.2.3). The further development of floating wind turbines makes it possible to open up greater potential (Figure 5.2-1). As the distance from the coast increases, competition over the use of available space will decrease, as will negative environmental effects – one reason being because no pile-driving work is required to build the installations. The development of floating wind turbines is already well advanced, and the first prototypes with a capacity of up to two megawatts are undergoing trials (Section 5.2.1).

Other forms of marine energy, such as tidal-stream and ocean-wave energy, supplement the energy mix or might assume the primary function in regions where there is little wind. In order to make better use of the space available, one attractive option can be to use marine areas that are already developed and have a grid connection for several purposes. Depending on the resource(s) available, technologies can be used in combination, e.g. wind turbines together with wave power plants or macroalgae cultivation. These combined systems are referred to as multi-use platforms. Similarly, tidal-stream turbines can be combined with wind turbines. Here the availability of sufficiently high flow velocities is decisive for the choice of location; the wind turbines represent a secondary use here. It is furthermore current practice not to fish in areas of marine energy generation, so that the power-producing installations could simultaneously contribute to the regeneration of fish stocks (Section 4.1).

Ocean thermal energy conversion (OTEC) plants could play an important role in supplying renewable electricity to small island states, especially near the equator; in certain circumstances they could be combined with drinking-water preparation (Sections 5.2.1, 5.2.4). The nutrient-rich deep ocean water which is brought to the surface in this process can simultaneously supply nutrients for macroalgae cultures, which can be used as a source of energy; this can result in synergies and reduce the negative environmental impact (Section 5.2.3). Ensuring the availability of fresh water will become a growing challenge with the effects of climate change and a still-growing world population. Another option could be to also obtain drinking water by exploiting the water pressure at depths in excess of about 600m using the principle of reverse osmosis (Section 5.2.4), although deep-sea reverse osmosis has not yet been applied on an industrial scale.

Offshore grids need to be built to connect the renewable energy generated at sea to grids on land. The example of the planned offshore grid in the North Sea (Figure 5.2-11) shows how these grids can be used both to connect large regions such as the UK, Scandinavia and the European continent with each other, and to make high-performance transmission possible to connect offshore wind farms and marine energy plants that are far from the coast to the onshore grids. Similarly, grids can be built exclusively for the purpose of connecting marine areas of renewable power generation. As the distance from the coast increases, these lines can only be made economical if large areas with a high generating capacity are developed which bundle the grid connections of several wind farms, rather than building many small generating units, each with its own grid

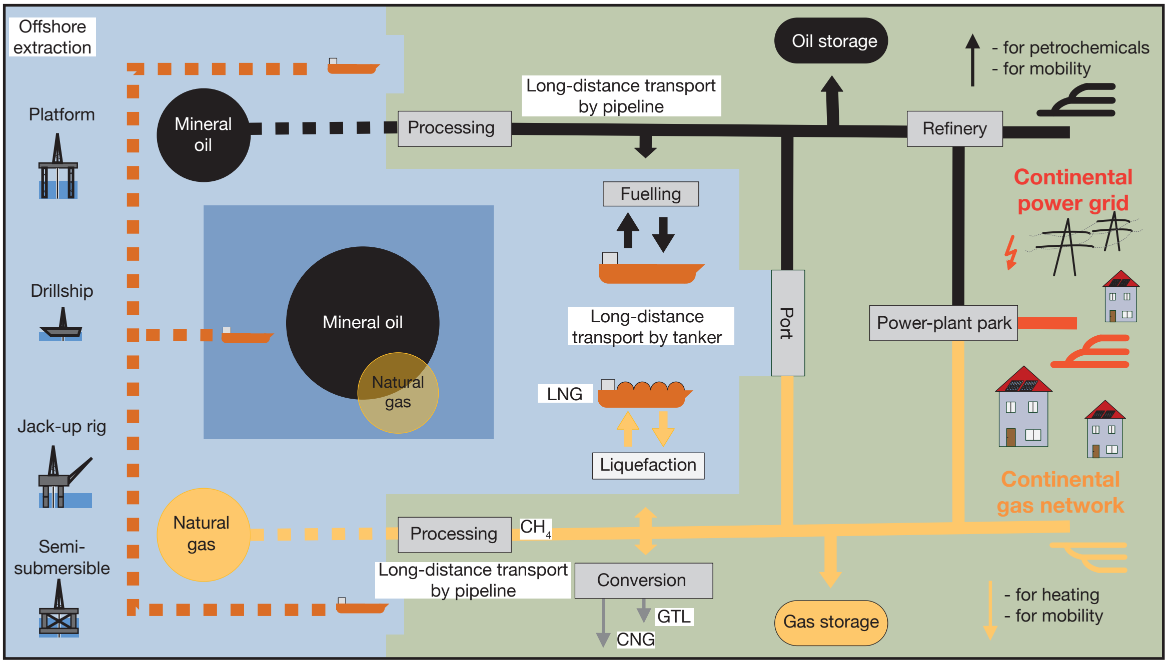


Figure 5.3-1
Schematic diagram of the status quo of fossil offshore energy generation and integration into the onshore energy system, showing the extraction technology, the transport technology and the various final uses on land.
Source: WBGU

connection (Section 5.2.4). This requires overarching coordination and anticipatory marine spatial planning (Section 5.4.2.1).

High-voltage direct-current (HVDC) transmission is a suitable technology for the low-loss transmission of power over long distances (Section 5.2.4). AC transmission is unsuitable for submarine cables over distances greater than 100km. When cables in bipolar HVDC connections are laid close together, the magnetic fields of the individual cables largely cancel each other out (Section 5.2.3). Furthermore, laying the cables in sediment helps further reduce the magnetic fields in the water column. According to current knowledge, there are indications to suggest that although artificial magnetic fields affect various marine animal species, no evidence of impairment has been collected to date; however, there is still considerable need for research in this field.

Linking ocean-based renewable energy generation with storage facilities is an interesting option in order to improve the capacity utilization of the electric lines and make it possible to flexibly meet the demand for the remaining load after renewable energy has been fed into the land-based grid (Section 5.2.4). In areas with sufficiently deep water (e.g. the Mediterranean or Atlantic), power can be stored by means of deep-sea pumped storage tanks (Section 5.2.4; Figure 5.2-12). This very young technology is characterized by very high potential and high efficiencies compared to pumped storage on land. The potential for classic, land-based pumped storage, by contrast, has been largely exhausted, at least in Europe, and it is often difficult to erect new structures due to civil protests and nature-conservation concerns.

Furthermore, chemical storage in the form of renewable hydrogen or methane (Section 5.2.4) offers a variety of applications. The generated electricity can be used for the electrolytic decomposition of water, and the hydrogen produced either used directly or further reacted with carbon dioxide to form methane (methanation). The CO_2 required should preferably come from biogenic sources, ideally from macroalgae cultivation for use nearby as a source of energy in sea-based electricity generation (co-utilization; Section 5.2.1). The on-site fermentation or gasification of biomass creates a mixture of methane and carbon dioxide, the CO_2 content of which (approximately 50%) can be further reacted with hydrogen generated from electrolysis to form methane. The resulting gas is more than 95% methane (natural gas) and can either be temporarily stored until it is used in power plants to generate electricity, or else fed into other use paths, e.g. mobility. Methane can be used – either directly, after liquefaction to liquid gas (LNG), or via the Fischer-Tropsch process – as a liquid fuel in the transport sector or in the production of chemical raw materials. A method for producing methane hydrates for the cost-

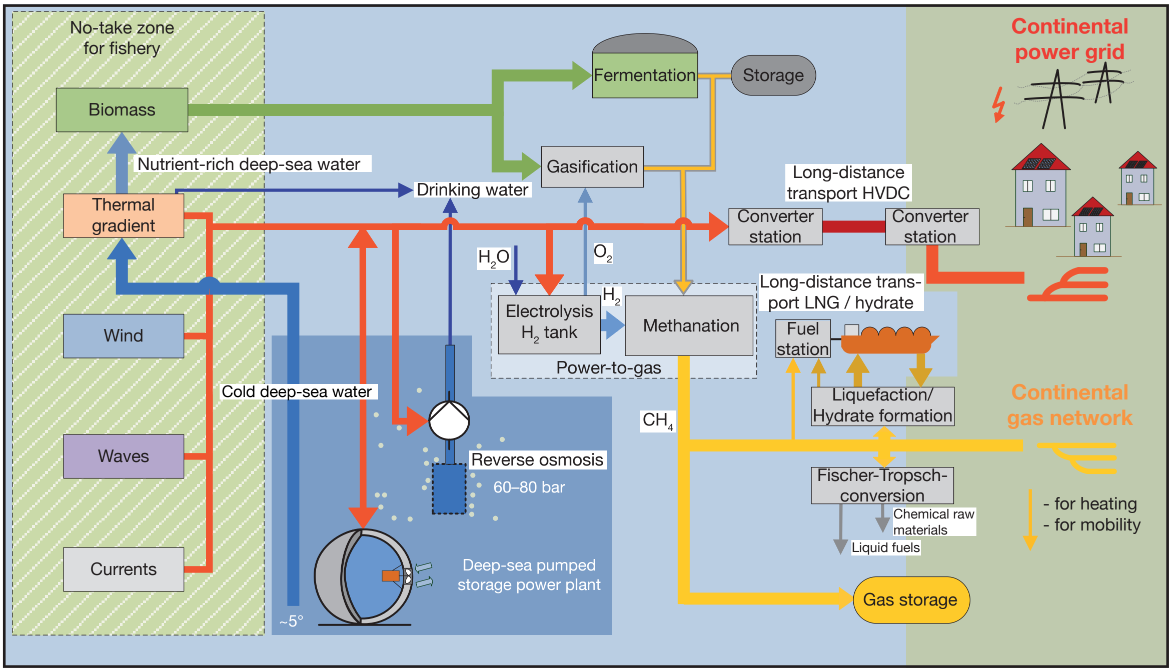


Figure 5.3-2
Vision of an integrated, sea-based supply of electrical energy with intermediate storage, the connected production of a chemical energy carrier (methane, LPG, artificial methane hydrate), and optional domestic drinking water preparation.
Source: WBGU

and energy-efficient transport of methane by ship is currently under development and could play an important role in the future. The WBGU expects mineral-oil-based fuels in the shipping industry to be increasingly replaced by methane-based fuels in the medium term (Section 5.1). This will make it possible for ships to use renewable fuels that have been completely produced on the seas (Figure 5.3-2).

Macroalgae can be cultivated on a large scale to produce biomass and CO_2 near where renewable electricity is generated. When it is used to generate energy on the spot by fermentation or gasification, there is no need to transport the biomass, approximately 80% of which is water (Section 5.2.1). Alternatively, it is also possible to store the CO_2 under the seabed in order to avoid long-term negative emissions if climate-protection targets are not reached (Section 5.2.4; WBGU, 2006, 2011). The algal cultures can ideally be supplied with nutrients, especially nitrogen, passively by positioning them in natural upwelling regions, i.e. regions where nutrient-rich deep-sea water naturally wells up to the surface of the sea. Furthermore, a combination with OTEC plants or a spatial link with fish mariculture could represent ecologically interesting variants (Sections 5.2.1, 4.2).

The storage of the gases would have an important function in the case of the presented idea of on-site methanation. Material flows that depended on the availability of electricity surpluses and biogenic CO_2 could be balanced with the help of gas stores, and the methane produced could be temporarily stored (Section 5.2.4).

5.3.3
Transformation of the marine energy system – from the status quo to the future energy system

The technologies of the mineral-oil and natural-gas industry offer a lot of experience that could be useful in the implementation of a marine energy-system vision (Section 5.1). Knowledge of laying pipelines and power lines in the sea, of storing CO_2 beneath the seabed and installing floating platforms anchored to the seabed can be transferred to the technologies needed for the sea-based generation of energy from renewable sources.

The energy-system vision outlined here of an integrated, sea-based power-supply system that will be able to make a major contribution to global energy supplies in the future is based on components that are already almost fully developed today (Section 5.2). Wind turbines anchored to the seabed and HVDC power lines laid in the sea are already commercial technologies, as is the coastal cultivation of macroalgae (Section 4.2). Floating wind turbines, tidal-stream turbines and wave power plants are already at the advanced prototype stage, and these technologies are likely to reach market maturity in the short to medium term (Section 5.2.1;

Figure 5.2-3). This also applies to the production of renewable methane from electricity, water and CO_2 (Section 5.2.4). An industrial-scale plant is expected to start operations in 2013. The main challenges lie in optimally interlinking the individual components and particularly in establishing economic feasibility.

Although technical development is well advanced, it will not be possible to implement the vision of a marine energy system of the future in the short term – not only for economic, political and social reasons, but in particular for structural reasons. In order to understand this challenge it is initially necessary to analyse the current energy system and the transformations that have either taken place already or are currently taking place (WBGU, 2011). Today, energy basically reaches consumers in four different forms: (1) as a solid fuel in the form of traditional biomass and coal, mainly for consumers without access to the central energy-supply systems, (2) in liquid form for transport and other oil-based applications, (3) as gas in pressure vessels or via pipe networks, and (4) in the form of electricity. A small portion of heating is provided by local district-heating networks. There is a historical trend towards ever-more-convenient, more efficient and cleaner energy carriers such as electricity and gas, which increasingly reach the consumers directly via supply networks (WBGU, 2011). The transition in the way the sea is used as a source of energy – from the extraction and transportation of hydrocarbons to the use of renewable energies – will require a system change. This represents a challenge because of the inertia of existing and established systems. In the following, the WBGU outlines a possible dynamic development.

Gas is very important as an energy carrier. In today's energy systems it functions as an important link in the electricity supply between the base load supplied by nuclear power and coal on the one hand, and fluctuating levels of fed-in power from renewable energies on the other (WBGU, 2011). In connection with gas networks, gas power plants represent storage facilities which deliver additional energy both at short notice during peak load periods and when there are gaps in supply due to the non-availability of wind and solar energy. In addition, CO_2 emissions per unit of energy produced in gas combustion are much smaller than in the combustion of other fossil energy carriers. This means that gas is suitable as a 'bridge technology', i.e. for making it possible to run an energy system using a high proportion of renewable energy (Sections 5.1.3, 5.2). Furthermore, the way in which gas is made, transported and used could enable a gradual system change towards sustainability to be realized.

Because of the volumes required, natural gas, which is increasingly being extracted offshore, will initially continue to provide the lion's share in order to meet demand (Section 5.1). However, the aim is to gradually substitute this with gas generated in a renewable way and with directly used renewable electricity (Sections 5.2.4, 5.3.2). In WBGU's view, it does not seem wise to make use of the contribution towards the supply of natural gas that could potentially be made by extracting methane hydrates; indeed, it is not necessary because enough conventional natural gas will be available up until 2040 (Section 5.1.6). Rather, mining methane hydrates would lead to investment in this field, creating path dependencies that would contradict its envisaged role – i.e. the use of gas as a temporary 'bridge technology' (Sections 5.1.6, 7.5, 8.3.4).

Offshore wind technology is an important component of the marine energy-system transformation. One possible way to transform fluctuating inputs of power from wind turbines into a more reliable supply is to use the electricity that is not fed into the grid for the electrolytic production of hydrogen. This can already be added to the natural gas in the grid up to a concentration of 5%; a percentage of up to 10% is also conceivable in the medium term (Section 5.2.4). To increase the percentage further it is necessary to add the step of converting the hydrogen together with carbon dioxide into methane, which can then be fed into the existing natural-gas infrastructure without any problem (Section 5.3.2). In the longer term, the CO_2 required for this purpose could be obtained by macroalgae cultivation. However, because this option will not be available on a large scale in the short term, one solution is to initially separate and use the CO_2 from offshore gas production. Further marine power-generation technologies described here, which are gradually reaching market maturity (Figure 5.2-3), can also be easily integrated into the combined electricity and gas infrastructure, contributing to better capacity utilization of the transport systems and hence to a reliable supply of energy from the sea (Figure 5.3-2).

The second important energy source that makes a significant contribution to the supply of energy today is offshore oil. In the WBGU's view, there will be far less need for this energy carrier after the transformation of the marine energy systems. Oil is used as an energy source mainly in the transport sector and, to a lesser extent, in heating. In both cases, technology options are foreseeable, or have already been developed, which can replace oil with renewable electricity and (renewable) gas. Particularly in maritime transport, gas represents an interesting fuel option which, in an integrated marine system, could be made available by renewable processes in the medium term. Oil should therefore be replaced by natural gas or renewable power much more quickly than natural gas – also because its negative environmental effects are more serious. In some areas, however, developments are currently moving in the opposite direction. It was shown in Section 5.1 that at present more and more technical and financial efforts are being made to tap the offshore oil reserves in the deep sea and the Arctic. In WBGU's view it would make much more sense to use the technologies and available know-how from offshore oil and gas production to build up a marine renewable energy system, including its infrastructure (Figure 5.3-2).

5.4 Governance

As the WBGU (2011) has shown, strong growth in on-grid energy – i.e. significantly increasing the amount of electricity and gas used as final energy – is of great importance for the transformation of energy systems. The WBGU's vision of a future marine energy system (Section 5.3) demonstrates that energy generation on and from the sea can play an important role in this context. However, this will require further technology developments (Sections 5.2, 5.4.3, 8.3.4). An integrated marine policy is needed to prepare the way for using the oceans for the sustainable generation of energy. Under such a policy, new ways of using the oceans, some of which develop as a result of technological innovations, would have to be made compatible with the needs of ocean conservation and traditional uses (Section 3.6). One important instrument of an integrated marine policy is marine spatial planning, which lays down the objectives and principles of the various uses of the marine space (shipping, fisheries, aquaculture, resource extraction, tourism, coastal and ocean conservation, infrastructures, renewable-energy technologies; Section 3.6.2). Marine spatial planning is an instrument that can be applied nationally, regionally and internationally. If marine energy generation is to have a role to play in the future global, sustainable supply of energy, this will also require – in addition to marine policy – a climate-friendly energy policy and an innovation policy that supports the necessary technological developments (Section 5.4.3). Only coordinated interaction between these three policy areas in a multi-level system will create the necessary planning and legislative framework for private companies and thus provide incentives for investment in climate-friendly marine-energy technologies (WBGU, 2011, 2012).

5.4.1 Energy policy

Decarbonization is a core element of the global energy transformation – with its agreed climate-policy goal of preventing global warming from exceeding 2°C. This transformation of the energy systems requires a national and, if possible, international climate-friendly energy policy (WBGU, 2011; GEA, 2012). The use of the oceans for energy generation should be embedded in such a climate-friendly energy policy as a further diversification of energy generation, in order to realize the vision of a future marine energy system described in Section 5.3: a switch to renewable-energy technologies both in and on the seas for generating electricity and gas. A second goal of international energy policy should be to overcome energy poverty: some 3 billion people currently still have no regular access to modern energy services in the fields of cooking, heating and lighting (WBGU, 2011). However, marine energy systems are very capital-intensive and therefore more suitable for a central power supply on land, e.g. for mega-cities on the coast, than for small-scale solutions or the electrification of rural regions. Energy efficiency and reducing final demand should on principle take priority in the transformation of energy systems (WBGU, 2011).

Energy policy worldwide is organized according to nation states, and the security of supply is the top priority in many countries. Nation states primarily use their own domestic resources for energy generation and try to avoid importing energy. Two further energy-policy goals are ensuring that the energy supply is both affordable and environmentally compatible. However, the geological distribution of fossil resources means that there have to be importing and exporting countries, particularly for oil and gas (Section 5.1; Dubash and Florini, 2011). As explained in Section 5.1, developing technologies for tapping and extracting offshore oil and gas reserves and resources is economically worthwhile when oil prices rise. It can be assumed that countries or regions whose territorial sea, EEZ and continental shelf contain oil or gas – e.g. Brazil, West Africa and China – will also want to extract these resources (Maribus, 2010). In its report 'A Social Contract for Sustainability' (2011), the WBGU recommends all countries to introduce a strict climate policy. Examples include pricing CO_2, phasing out subsidies on fossil energy carriers, or reallocating subsidies from fossil energy carriers to promote renewable-energy technologies. CCS is a necessary climate-protection option for countries that intend to continue using fossil fuels. In addition, the WBGU recommends using gas, a relatively low-CO_2 energy source, and substituting coal and oil (WBGU, 2011).

Under the UNFCCC, several industrialized countries have committed themselves to reduce CO_2 emissions and developed energy-policy strategies up to 2020 or 2050; they have been joined on a voluntary basis by further industrialized countries and emerging economies (WBGU, 2009, 2011, 2012). These energy strategies specify clear targets for expanding renewable energy. One example is the European Union, which, as part of a climate and energy package, in 2007 formulated – and in 2008 adopted – the 20-20-20 targets for the year 2020: the targets are to reduce CO_2 emissions by 20% compared to 1990, to expand renewable-energy technologies to 20% of the energy mix, and to raise their energy efficiency by 20% (WBGU, 2011). The Renewable Energy Directive (EU, 2009b) states how the 20% target for renewable energy is to be reached within the EU: the EU Member States have set national targets to raise the amount of power they generate from renewable sources to between 13% and 40% by 2020. Corresponding measures to reach the targets are set out in national action plans. Germany aims to produce 30% of its electricity from renewable sources by 2020, for example by creating 25 GW of offshore wind power generating capacity by 2030 (BMWi and BMU, 2010). The European Wind Energy Association expects national targets for offshore wind power to add up to about 43 GW (EWEA, 2012). In its Roadmap 2010-2050, the European Ocean Energy Association estimates that renewable marine energy technologies producing 3.6 GW could be installed by 2020. The 19 member countries of the Implementing Agreement on Ocean Energy Systems at the IEA (which include China, Mexico and South Africa) have formulated national targets for expanding offshore renewable-energy technologies (OES, 2011b). In their international vision for renewable marine energy technologies they expect to have installed 748 GW by 2050 (OES, 2011a).

To encourage investment in renewable marine-energy technologies and offshore wind-power plants, the overall conditions created by climate and energy policy and energy legislation must offer long-term investment security and guarantee appropriate returns (WBGU, 2012). An accompanying energy and innovation policy is required in addition to the legally binding formulation of expansion targets as a political signal to potential investors. Companies should be guaranteed entry to the market, network access and the transmission of the electricity they produce. Competition that is distorted in favour of fossil fuels should not be allowed. In addition, licensing and planning processes for offshore technical installations, as well as liability regimes, should be developed.

In the context of innovation policy, the design of degressive market-incentive programmes for a fixed period or promotion strategies are necessary for the roll-out phase and for the integration of renewable-energy technologies into existing power-supply systems or electricity markets. Up to now, feed-in tariffs have proved to be superior to a form of promotion to the use of quotas, tradable certificates or public tenders with an auction procedure for offshore wind power (WBGU, 2011; SRU, 2011a). Feed-in tariffs give investors long-term planning security, thus reducing investment barriers. At the same time, feed-in tariffs can be designed in a technology-specific way and thus encourage different energy technologies in parallel (WBGU, 2011). One possible advantage of public tenders for offshore wind farms vis-à-vis feed-in tariffs lies in the bundling of the grid connections of different parks in a designated area (SRU, 2011a). Nevertheless, the WBGU recommends temporary, technology-specific feed-in-tariff systems which effectively promote rapid capacity expansion (WBGU, 2011, 2012).

To minimize transaction costs, the WBGU recommends building up integrated electricity grids both in the regional seas and on land (Section 5.2.4; WBGU, 2011). This makes it possible to distribute the fluctuating amounts of electricity generated from renewable-energy technologies in a regionally optimal way; it also has a grid-stabilizing effect. The WGBU believes that an offshore power grid interconnecting the various marine power-generating plants (clustering) and also interconnecting different countries (meshed grid) has advantages over individual connections to land (Figure 5.2-11; Section 5.2.4). In a similar way to a continental, transnational power grid, a meshed grid improves the market integration of power from and on the seas. The electricity prices and fluctuations in the power supply can be reduced by such market integration. Moreover, the capacity utilization of individual offshore power stations can be increased. This would make it possible to use potential that is far from large centres of demand (Woyte et al., 2008; SRU, 2011a; Piria and Zavolas, 2012). At the same time, the development of a transnational offshore grid involves a number of challenges. Planning one requires the coordination of both the grid and the offshore power-generation plants between several countries and different national authorities. Furthermore, the terrestrial grids would have to be modified and adapted (SRU, 2011a).

Up to now, EU Member States have only planned at the national level for a transnational offshore grid in exceptional cases and in a rather cursory fashion. The current practice consists of point-to-point connections and can lead to higher costs and lock-in effects in the future. A key challenge is the creation of investment incentives for private companies. In addition to a national energy policy, a transnational energy policy is needed for countries with regional-sea coasts that want to link their power grids by means of an offshore grid.

At the same time, cross-border electricity grids require a harmonization of promotion policies and feed-in tariffs (WBGU, 2011, 2012; SRU, 2011a). Within the European Union, a coordinated system of payment for offshore-generated renewable energy would raise the efficiency of promotion. Power from renewable sources could then be generated at the most favourable locations, i.e. at low cost. The realization of a single energy market is an important precondition for this (WBGU, 2011).

5.4.2 Marine policy

The options for using marine energy depend on the technical and legal possibilities for building and operating energy extraction and generation systems. A differentiated analysis of the respective applicable legal framework is necessary, starting from the existing zoning of the seas into coastal waters, EEZs, the continental shelf and the high seas in accordance with the provisions of the UN Convention on the Law of the Sea (UNCLOS; Section 3.2).

The coastal state has sovereignty in coastal waters. The full jurisdiction of the coastal state extends both to the air space above the territorial sea and to the water column, the seabed and the subsoil of the territorial sea (Section 3.2). Access to energy and thus also the authority to build installations within the coastal waters are governed by the laws of the respective nation state (Wolfrum and Fuchs, 2011). The particularity that the coastal waters belong to the territory and territorial jurisdiction of the coastal state (Graf Vitz-thum, 2006) leads to a partial allocation of territorial seas to federal or municipal government structures with the corresponding legislative authorities. From the point of view of international law, it should be noted that all states must be granted the right of innocent passage (Section 3.2). This means that, when planning power-generation plants, countries must make sure that the passage of foreign vessels is not impeded. At the same time, all international and European regulations to protect and preserve the marine environment apply (BfN, 2012). Both the coastal state and other countries are allowed to install power cables or pipelines on the seabed or continental shelf (Section 3.2).

In the EEZ, jurisdiction for the economic exploitation of this zone is transferred to the coastal state, so that it can extract oil and gas and generate power from wind and marine energy (Section 3.2; Wolfrum and Fuchs, 2011). The coastal states have national jurisdiction over building and using artificial islands, installations and structures, including power-generation plants (Markus and Maurer, 2012). Under these transferred rights and territorial jurisdiction, national legislation thus also applies in the EEZ. It can be enacted by the coastal states to regulate access to energy and to construct mining facilities for fossil energy as well as renewable energy-generation plants in the sea (Wolfrum and Fuchs, 2011). Consequently, national legal regimes apply. This jurisdiction is internationally binding for the respective EEZ and applies vis-à-vis all parties interested in these forms of use. Nevertheless, freedom of navigation and overflight and freedom to lay submarine cables and pipelines still apply for all states parties in the EEZ (Section 3.2). This means that installations and structures may not be built if they obstruct recognized sea routes for international shipping. Furthermore, all treaties under international law for the protection of the marine environment also apply to the EEZ (BfN, 2012).

The legal regime of the continental shelf relates only to the seabed and subsoil that is defined as continental shelf. The importance of this regime for marine energy generation is comparable with that of the EEZ, not least due to considerable overlap with this area (Section 3.2; Rosenbaum, 2006).

On the high seas, both coastal and inland states are free to build artificial islands and other installations, and to lay submarine cables and pipelines as required (Section 3.2). Thus, in principle, all countries can build and use power plants on the high seas. Every state can itself regulate the way it exercises its own freedoms on the high seas by entitling or obliging its own state citizens – by enacting laws according to the flag-state principle (Brandt and Gassner, 2002). In this way, for example, national regulations for building power-generation plants can also be effective on the high seas, although they are restricted to the respective state's citizens.

On the high seas, all non-biological resources on and under the seabed are part of the heritage of mankind, and this is administered by the International Seabed Authority (Section 3.2). Accordingly, all uses of non-biological resources must be registered and licensed there. The extraction of methane hydrates, oil or gas is regulated by UNCLOS and governed by the established regulations of ocean conservation (Section 3.2). In addition, the International Seabed Authority's mining codes must be observed. This institution has also developed recommendations for assessing environmental compatibility in the exploitation of polymetallic sulphides. Overall, however, there is a need for regulation to protect the deep-sea environment from mining operations (Jenisch, 2010).

Despite technological developments, it seems likely that the use of the oceans for energy generation will remain restricted to territorial seas and EEZs, including the continental shelf, in the near future (Sections 5.1, 5.2). This means that primarily national regulation applies to the use of the oceans. Consequently, any coastal state can ambitiously develop its legal regime for the sustainable use of the oceans in its territorial sea and EEZ. This is why national policy on ocean conservation is important in addition to treaties under international law. Two suitable instruments are marine spatial planning and environmental liability (Section 3.6). Since a cost-efficient use of the oceans for energy generation requires a cross-border infrastructure in the form of power cables, pipelines, shipping lanes and ports, both international and cross-border cooperation should be sought for offshore energy systems (Sections 5.1.4, 5.2.4). Environmental standards and environmental liability can be specified in a cross-border manner in the course of this cooperation (Section 3.4). This makes it possible to take the dynamics of marine ecosystems and the precautionary principle into account. Furthermore, the free-rider position of individual coastal states could be eliminated in the course of cooperation (Section 3.1).

5.4.2.1
Marine spatial planning

The growing permanent use of the oceans – also by renewable-energy plants – requires comprehensive planning that takes all issues into account (Wolfrum and Fuchs, 2011), because marine renewable-energy systems are space-intensive and compete with traditional uses of the oceans, as well as with ocean conservation (EWEA, 2012). In order to minimize conflicts between the goals of climate policy (and thus a desire to expand renewable-energy technologies), ocean-conservation policy (involving an increased awareness of marine conservation) and still-growing opportunities for the commercial use of the seas (based on new technologies), a form of spatial planning for national and international waters can be developed in line with experiences made on land (Section 3.6.2.2; Wolfrum and Fuchs, 2011). The parts of the oceans that will be used as an energy resource in the foreseeable future will be the coastal waters and the EEZs, so that the coastal states will be responsible. The development of marine energy systems often has cross-border effects, e.g. on ecosystems, fish, birds or shipping (Sections 5.1.3, 5.2.3), so that cross-border cooperation in regional seas seems a good idea. Similarly, cumulative effects on ecosystems can arise when all coastal states develop their marine energy systems on the borders of their respective areas of jurisdiction. At the same time, it makes sense to link up marine renewable-energy technologies to compensate for volatile electricity generation and to store power. This requires not only cross-border cooperation, but also coordination of the ways in which the oceans are used for energy generation (EWEA, 2012; Gee et al., 2011). Marine spatial planning (Section 3.6.2.2) is therefore of great importance as an instrument for all regional seas, because it is a decision-making instrument. Marine spatial planning helps the coastal states and interest groups to better coordinate the use of the oceans for economic development and the protection of the marine environment (EU Commission, 2008). Cross-national planning processes for the Baltic Sea, the North Sea, the North-East Atlantic, the Mediterranean and the Black Sea should be strengthened within the EU (EU Commission, 2008). In the following regional seas, marine spatial planning is already being used nationally in some cases and has been laid down for cross-border offshore wind energy under the OSPAR regime (Sections 3.4, 3.6; Wolfrum and Fuchs, 2011): Baltic Sea, North Sea, North East Atlantic, Mediterranean, Black Sea, Caspian Sea, Caribbean, Gulf of Mexico, East Asian Seas, South Asian Seas, Northeast Pacific, Northwest Pacific, Persian Gulf, Red Sea, Gulf of Aden, South East Pacific, West Africa, Arctic, Antarctica (UNEP, 2012b).

Up to now, marine spatial planning has primarily been a process for documenting different land uses or uses of space in the sea with their respective ecological, economic and social effects. Data are collected, consultations with interest groups organized, plans prepared in a participatory way, and all the sea-related treaties that a coastal state has ratified are taken into account (Douvere and Ehler, 2009). The second step is to implement and execute the plan, and to assess – and if necessary reorientate – the plan. The uses are weighted according to political objectives and assigned to marine areas (EU Commission, 2008; BMVBS, 2011; EWEA, 2012). This affects activities on the seabed, in the water column and on the surface. In this way the space can be used for different purposes (Section 3.6.2.2). As a coordination instrument, sovereign planning allows a forward-looking, formative management of ocean use. It makes it easier to embed and coordinate individual projects in an overall strategy for the management of ocean use (Douvere and Ehler, 2009). An orderly planning process includes an environmental impact assessment and necessary compensatory measures, so that an ecosystem approach is ensured (Douvere and Ehler, 2009). Up to now, only five countries, one of which is Germany, have a binding system of marine spatial planning that is enforceable under national law (Section 3.6.2.2). At the same time, the planning of ocean use should increasingly be done in an interregional way in order to avoid cross-border conflicts over use and not to impair the system services of the marine ecosystems (Section 3.4; EWEA, 2012; Gee et al., 2011).

Marine spatial planning is necessary for the expansion of renewable-energy technologies in order to establish legal force for designated areas and to receive permits for private investors quickly (EWEA, 2012; WBGU, 2011). Synergy effects generated by shared uses – e.g. renewable energy generation and sustainable fishing, or renewable energy generation and the designation of protected areas – should be taken into consideration in this context (Section 5.2). Public participation in the planning process could be secured under the Aarhus Convention, which makes the administrative and planning process more transparent and contributes towards structuring it democratically (WBGU, 2011). However, public participation should take place at a time when all options are still open, so that all stakeholders have a real chance to influence administrative decisions. Only then can unsuitable projects be recognized and costly conflicts avoided (WBGU, 2011).

5.4.2.2
Construction of installations in the sea

Article 208 of UNCLOS is of particular relevance when constructing installations for energy extraction and production in the sea. It obliges coastal states to adopt and enforce legislation to prevent and reduce pollution caused by activities on the seabed or artificial islands, installations or other structures (Wolfrum and Fuchs, 2011). Marine or other forms of environmental pollution related to energy-production systems can be caused on the one hand when the installations are being anchored to the sea floor, and on the other by emissions during the system's operation (Sections 5.1.3, 5.2.3; Markus, 2010). Offshore wind turbines can also cause environmental hazards for sea birds and migratory birds (Section 5.2.3; Wolfrum and Fuchs, 2011). Regarding the quality of the protection regulations to be adopted, Article 208 of UNCLOS stipulates that they must not be less effective than international rules and standards. At present, there are no internationally binding standards that would apply to all coastal states because there is a lack of international regulations on emissions caused by marine energy systems.

Emissions are not the only risks during the construction phase or the operation of marine energy systems; pollution caused by the dumping of waste products is also possible. Unlike installations for extracting fossil energy, as a rule there is no further risk of contamination by dumping during the operation of renewable-energy plants (Rosenbaum, 2006). Under UNCLOS, states are obliged to pass laws to prevent marine pollution by unauthorized dumping, i.e. the intentional disposal of waste from ships, platforms or other marine installations. These national laws must not be less strict than global standards in terms of their protective effect. UNCLOS is referring here to the London Convention, supplemented by the London Protocol on the Prevention of Marine Pollution by Dumping (Section 3.3.2.6; Schlacke and Kenzler, 2009). These treaties lay down guidelines for methods of disposing numerous categories of waste. In addition, there must be checks in each case to determine whether prevention, reduction, recycling – or disposal on land – is a preferable alternative to waste disposal at sea. There is a widespread view that these minimum guidelines also apply to those states that have not signed the convention (Proelß, 2009). According to this view, the provisions of the London Convention would have to be taken into account by all UNCLOS signatories when constructing energy production systems.

Furthermore, in the European Union the applicable regulations on environmental protection must be taken into account when building renewable energy-generation plants in the sea (BfN, 2012). Under the Flora-Fauna-Habitat Directive and the Directive on the Conservation of Wild Birds, an impact assessment pursuant to Article 6, paragraph 3 of the Habitats Directive is required in designated areas, if installations are to be built. A construction project may be justified even if the result of the assessment is negative if there are imperative reasons of overriding public interest. The EIA Directive also provides for an environmental impact assessment (cf. Article 4, paragraph 2; Annex II 2(i) EIA Directive). Since the exact effects of renewable energy technologies on the marine environment are largely unknown to date, it can be assumed that such an examination is probably necessary even in the case of relatively small installations (Rosenbaum, 2006).

In Germany, the regulation on offshore installations (*Seeanlagenverordnung*) applies to the construction of offshore wind turbines in the EEZ. Since 2008, approval has required compatibility with the requirements of regional planning. A plan-approval procedure for offshore wind turbines has been in force since 2012. The Federal Maritime and Hydrographic Agency is responsible for the licensing process (BfN, 2012). All the stakeholders are involved in the multi-stage application procedure, and an investigation framework with thematic and technical minimum requirements is laid down to determine potential effects on the marine environment. Moreover, a conservation and safety concept must be developed, the best demonstrated available technology must be applied, and measures must be taken to reduce emissions during the construction phase (BfN, 2012).

The Federal Mining Act (*Bundesberggesetz*) applies in Germany to the laying of submarine power cables and pipelines; it also regulates marine conservation issues in the licensing procedure (BfN, 2012).

As is already being practised by some industrialized countries, including Germany, installations for generating energy should on principle be subject to a preventive ban with permit reservation. The required licensing procedure, in contrast to subsequent control measures, has the advantage that the risks that such an installation might involve can be assessed and judged before the plant is built and begins operations. The latest knowledge from research can be considered to ensure an adaptive process (Sections 3.1, 5.4.3, 8.3.4). An official licensing procedure, to be carried out by the coastal states, ensures that the public can get involved.

5.4.2.3
Regulation of oil and gas production

The offshore production of oil and gas will continue to play an important role in the use of the oceans in the medium term in view of the ongoing development of deep-sea extraction technologies, as well as new discoveries (Brazil and the Arctic) and their importance for national supply security (Section 5.1). Under UNCLOS national legal regimes apply to the offshore production of oil and gas in coastal waters, the EEZs and the continental shelf. The nation states formulate and adopt protection and safety standards. This means that different environmental, health and safety standards exist internationally in the offshore industry. Emergency planning and liability provisions are also different. In the event of damage, the state itself is responsible for remedying the damage and is not liable for damages vis-à-vis other countries (Section 3.6.5). To date, there are hardly any international regulations on conservation and safety concepts or on environmental liability for the use of fossil energy from the sea (Section 3.6.5).

The transportation of oil and gas is governed internationally by the International Maritime Organization (IMO) under MARPOL (Sections 3.3.1.3, 3.3.2.5). In the field of international law, 104 countries had signed the International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC Convention, 1990) by 2013 (Luk and Ryrie, 2010). These countries undertake to develop emergency plans and to cooperate across borders in the event of an accident. However, this does not mean that uniform standards have been settled for liability or for remedying damage.

The 1992 regional Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) contains rules on the offshore extraction of oil and gas (Section 3.4.2). It was concluded between 15 states and the European Commission to protect the North-East Atlantic from anthropogenic pollution. Irrespective of the substance groups involved, this protection also applies to pollution from the land and by the offshore industry. Fisheries, shipping and air-born pollution are not covered by the scope of the treaty. Since the subsequent addition of Annex V, the Convention has also been geared to conserving the ecosystems and protecting biological diversity (Section 3.4.2; Jenisch, 2008). It also relates to the marine subsoil. It obliges companies to use the best available technology in application of the precautionary and polluter-pays principle. Under this convention, a national licence must be obtained beforehand in order to be allowed to produce oil and gas or to build a production platform.

The Helsinki HELCOM Convention for the Baltic Sea only requires that installations should not be disposed of on the high seas (Section 3.4.2).

The European Union has laid down requirements of environmental protection for the offshore production of oil and gas (Woolf, 2011). The EIA Directive applies to the use of marine natural resources within EU territory. Inside designated protected areas under the Birds Directive and the Habitats Directive, raw materials may be used as long as the protective purpose of the areas is not impaired. However, according to the European Commission's guidance document 'Non-energy mineral extraction and Natura 2000', projects require an environmental impact assessment. Furthermore, the EU has also designated certain seabed ecosystems such as reefs and corals as protected areas under a regulation to protect vulnerable marine ecosystems on the high seas from bottom fishing. This protected status could be impaired by offshore production projects (Jenisch, 2010).

After the oil spill from the Deepwater Horizon oil rig in the Gulf of Mexico in 2010, the European Commission launched an initiative to develop uniform regulations on safety, environment and health for the offshore oil and gas industry within the European Union. The proposal for a 'Regulation of the European Parliament and of the Council on safety of offshore oil and gas prospection, exploration and production activities' stipulates, among other things, that companies will in future be fully liable for all damage caused and must already prove their ability to pay during the application process. Moreover, the companies are to be obliged to carry out a detailed risk analysis for every rig and submit emergency plans to the supervisory authorities (EU Commission, 2011b). In the future, accident reports are to be collected in a publicly accessible database. Consideration is also being given to the idea of sanctioning misconduct on the part of companies by withdrawing their drilling licence. By adopting these unified regulations the European Commission wants to ensure that in future the highest safety standards apply uniformly throughout the European Union, that emergency plans exist, and that a uniform liability and compensation regime applies.

5.4.2.4
Regulations on the storage of CO_2 in the sea or the seabed

The current arrangements under the London Protocol allow the storage of CO_2 under the seabed in principle, whereas the injection of CO_2 into the water column is not permitted (Sections 3.3.2.3, 3.3.2.6). They also contain guidelines – but no binding liability rules – for assessing and monitoring potential CO_2 storage activities in the seabed. The regulations were adjusted under OSPAR, so that CO_2 storage in the seabed has been allowed since 2007.

The WBGU already examined the option of storing CO_2 both in the sea and under the seabed in its special report *The Future Oceans – Warming Up, Rising High, Turning Sour* (WBGU, 2006) and explained why the injection of CO_2 into sea water is not a sustainable option, i.e. due to uncontrollable risks and the insufficient retention period. The situation is different when it comes to storing CO_2 in geological reservoirs beneath the seabed, such as partially emptied gas and oil fields, which have already served as stores in nature (Figure 5.1-5). There are leakage risks, although these can be minimized by selecting suitable storage sites. However, permanent monitoring and emergency plans are essential. There is still a considerable need for regulation under international law in this field. The WBGU's assessment of the sub-seabed storage of CO_2 is that it is less risky than storage in land-based locations (WBGU, 2006).

5.4.3
Promotion of innovation

Many innovations are needed and sustainable marine technologies must be developed in order to implement the vision of a future marine energy system. For this reasons, several methods of innovation promotion are summarized below.

The WBGU defines technological innovation as the process of generating and implementing new knowledge in new production processes or marketable products. Innovation promotion is defined as political measures that raise companies' ability and willingness to innovate. This traditionally includes both instruments of science, technology and innovation policy and educational, economic and industrial policy. Measures of environmentally sound technology development must be added to avoid unwanted environmental effects (WBGU, 2011).

Since innovation processes can differ considerably depending on the field of technology, the industrial sector, the area of knowledge and the company size, it makes sense to make a broad, three-way distinction between the production of scientific and technical knowledge, the transformation of knowledge into products and processes, and the adaptation of both to market demand. For the most part the implementation of knowledge in new products and processes takes place in companies. However, the relevant knowledge is produced not only through research and development, but also during production, systems integration and the application of products and processes (Smits and Kuhlmann, 2004; Pavitt, 2005). The innovation process needs to be distinguished from the different stages of development through which a technology passes between the initial idea and its application. The development process comprises interactive stages, although there is no unified definition for these. Broadly speaking, it is possible to distinguish between the stages of research and development, conception and study, prototype, market maturity and market penetration.

5.4.3.1
Promotion of systemic innovation

Systemic innovation research emphasizes that innovations do not arise in isolation in companies, or only as a result of interaction between research institutions and companies, but also as a result of exchanges of information with customers, suppliers, competitors, investors and private or public organizations. It also stresses that the behaviour of the players involved in the innovation process is determined, and the innovation process influenced, by institutions, e.g. social norms, routines, rules and laws (Edquist, 2000, 2005). Looking at innovation policy from a systemic perspective, therefore, innovations should not be considered exclusively from the angle of 'necessary knowledge' and 'relevant markets'. Systemic innovation policy also includes the creation, modification or abolition of relevant organizations and their target-oriented interaction, as well as institutions in the form of rules, standards and laws.

Systemic innovation research simultaneously emphasizes the risk of lock-in situations due to the evolutionary nature of knowledge production and the associated path dependencies. A negative lock-in means that the organizations of an innovation system are specialized in certain technologies, but cannot – or do not want to – develop other technologies. Policy-makers therefore have the task, when existing innovation systems are being modified or new ones developed, of intervening in favour of radical innovations in an early phase of technology development, in order to support both the necessary production of knowledge and the relevant interaction for the diffusion of the knowledge and its implementation in marketable products, as well as the market entry of innovative firms (Edquist, 2000). From the perspective of systemic innovation research, it also follows that politics not longer only compensates for market failures, but also for system failures and should actively play the role of a system designer or integrator. System imperfections include, among others, insufficiently articulated demand, weak networks among young firms (preventing the exchange of knowledge), excessively strong networks among established companies (preventing the production of knowledge and therefore new products), the specific design of existing legislation, the regulation and support of established companies, inadequate capital markets, and lacking organization and representation of interests among young companies (Smits and Kuhlmann, 2004).

A number of studies show that considerable technical progress is still possible in offshore wind technology (EWEA, 2009; Wiser et al., 2011; LCICG, 2012). It is unclear, however, whether all the potential for innovation is being tapped by private research and development alone. Support by public funds is therefore justified in the field of sustainable energy from the sea (Section 5.2.1). The Low Carbon Innovation Coordination Group points out that the development of innovative turbines, anchoring systems and transmission technologies, for example, definitely require support from the public sector. High investment costs, uncertainty about future demand, engineering risks and long development periods impede a purely privately financed development. At the same time, a lack of competition between the manufacturers reduces the pressure to innovate, since the production of wind towers and above all the production of transmission technology and installation vessels is dominated by a small number of manufacturers (LCICG, 2012). Which research and development activities should be funded by the public sector alone, or in cooperation with the private sector, must be examined on a case-by-case basis.

5.4.3.2 Technology development

There are numerous measures that can be taken to avoid, limit or reverse the negative consequences of the use of marine ecosystems. Many measures aim to provide incentives for innovation, for example by raising the cost of production processes that harm the environment. The effectiveness of such measures can be increased if – parallel to the incentive – the generation of relevant knowledge is promoted as a basis for innovation.

In order to avoid negative external effects from the application of new technologies from the outset, the environmental effects and risks should already be assessed during the development process of a technology and countermeasures taken as necessary. The earlier in the development process – i.e. before the testing and demonstration phase – possible undesirable effects are detected, the smaller the real (negative) environmental effects are likely to be and the easier it might be to counter them (Haum et al., 2004).

In addition, during the demonstration and diffusion phase, environmental effects must be continuously monitored and the technology development adjusted as necessary. It is important – both in linking technology development with technology impact assessment and when monitoring the environmental effects during the deployment phase – that the marine environment is understood in the spirit of the ecosystem approach as a complex, interacting system in a constant state of flux that provides ecosystem services for humanity and is simultaneously altered as a result of human use. Far-reaching and indirect effects of new technologies could be discovered and avoided in this way.

5.4.3.3 Innovation potential

The WBGU understands innovation potential as a technology's development possibilities. The objectives of development can be, for example, cost reductions, new applications or a reduction in environmental effects. Whether and how technologies develop is determined by the level of development, the amount of effort made, the effectiveness of the innovation activity, the specific overall conditions and demand.

Offshore wind

The first wind turbines for offshore use were similar to the turbines used in onshore wind-power plants, where most turbines have a horizontal axis and three rotor blades; these are currently also used in the offshore sector. Only in the past ten years have turbines been developed that are specially adapted for offshore use (Section 5.2.1). The adaptations include special corrosion protection, sealed nacelles and redundant components to ensure a high level of availability. Publicly funded research and development have played a key role in the development progress made up to now in offshore wind energy.

In the short term three-bladed turbines will remain the dominant design in the offshore sector, too. In the medium to long term, however, the development of special offshore designs can be expected (EWEA, 2009). Turbines with only two rotor blades and turbines with vertical axes are currently in development. Floating turbines are also being developed (Section 5.2.1).

Table 5.4-1
Offshore wind energy: Innovation potential in the areas of resource assessment, installations and the value chain. Exemplary development opportunities in the view of the WBGU.
Source: WBGU

Resource assessment	Installations	Value chain
› Standardized methods for modelling wind resources › Public database on wind resources › Improved forecasting models	› Stronger, lighter materials › Superconductors for generators › Better understanding of very large, flexible rotors › Database with offshore operating experience › Further development of anchoring systems at water depths of less than 60 m › New generation of genuine offshore turbines › Anchoring systems for water depths of up to 200 m	› Development of training courses for all the skills required in offshore wind turbines › Development of automated, large production plants › Development of recyclable components › Development of specialized installation ships › Reducing installation times › Provision of adequate port facilities

The industry believes that numerous incremental innovations are possible in the coming years through design optimization, material efficiency and the use of new materials, all of which will lead to cost reductions. Also, it is assumed that radical innovations in other technology fields, such as new materials or sensors, will be used in wind energy and could make turbines with a capacity of up to 10 MW possible. However, innovations in offshore wind-power plants depend to some extent on innovations in the entire value chain. For example, suitable installation ships and cranes are necessary for the use of 10 MW turbines (Section 5.2.4; EWEA, 2009).

Offshore wind-power plants offer a specific potential for innovation. The size of the wind turbines is less limited than on land, and the relatively high cost of anchoring them in the sea provides incentives for developing larger turbines. In this case, innovations that reduce the weight of rotors, towers and nacelles become more important. Technological developments are also to be expected, driven by the different requirements of environmental protection than on land, coupled with higher technical requirements of the installations (EWEA, 2009).

Wind-power plants are complex systems, and optimising them in terms of costs, performance and environmental effects requires that they are not seen in isolation, but are integrated into the respective wind regime, the installation location, the installation process, operations and the energy system, and that all the turbines interact within a wind farm (Section 5.2.1; Table 5.4-1).

Even if new developments can lead to higher capital costs at the beginning, this will most likely be offset by improvements in energy generation. Lower capital costs and higher energy yields are expected in other areas, such as rotors (Lewis et al., 2011:59).

Marine energies

Since the term marine energies (Section 5.2.1.2) summarizes a large number of technologies at different stages of development, a differentiated discussion on the potential for innovation is not possible. The following remarks relate to ocean-wave and ocean-current technologies (Figure 5.2-3). The development of wave and current energy systems would benefit from a better understanding of how the plants behave in the sea. This requires improved analyses of their potential, improved models of marine hydrodynamics, an improved understanding of cumulative effects when plants are arranged in a special order (array effects), and improved combined wave-flow models through basic research (Müller and Wallace, 2008).

Given the early stage of development, there is development potential in all technology components and in the extraction of marine energy, in anchoring systems and installation processes in the sea, as well as in the development of instruments and processes for the design, operation and maintenance of the technologies (EU-OEA, 2010).

With all technologies there is a need for innovation to protect the electrical and hydraulic systems against water ingress and corrosion and to reduce fouling by flora and fauna. There is also a need for development to improve the systems' capacity to withstand mechanical stresses and in the field of maintenance. Development work is also required to integrate systems better into the onshore power grid (Lewis et al., 2011).

5.4.3.4
Measures

A national innovation strategy that guides a country's innovation system is crucial to promoting innovation for a sustainable use of the seas. Relevant subsystems of the innovation system include not only research and education, but also the capital markets, the legal framework, the size and age of companies, and the entire economic structure (WBGU, 2011).

Technologies that are at an early stage of development – e.g. marine energy technologies, storage systems, marine grid technologies and the technologies for integrated uses described in this report (Sections 5.2, 5.3.2) – need to be further developed, and public support for research is essential for this, in order to be in a better position to assess the advantages and disadvantages of the individual technology approaches; this government support can take the form of the competitive promotion of experimental projects or public demonstration projects (Section 8.3.4).

Governments can provide incentives for companies to be more innovative by offering subsidies or tax concessions. Publicly financed cooperation between industry and science, as well as international research and technology cooperation, can help spread relevant knowledge. Promoting the market entry of new technologies is also especially important, since there is often insufficient private capital available in this field (WBGU, 2011, 2012).

Recent research on innovation processes underlines that research and development measures should not be separated from commercial roll-out measures or be used one after another, but should be coupled. The early use of measures to support market entry accelerates learning processes, even when technologies are not yet competitive. At the same time, public research funding should not be automatically phased out as soon as a technology has reached market maturity. Sustained public research makes it possible to codify experience-based changes, improve the production process, develop supporting innovations, cut costs and improve performance (Neuhoff, 2005; Johnston, 2010; Mitchel et al., 2011).

A number of measures to promote innovation go beyond the production of knowledge and its diffusion between organizations and target the level of the innovation system. They include standards, because these can affect the innovation behaviour of entire industries. They also include measures that improve information and knowledge flows at the system level, structure discussions and mark areas for technological searches, such as information campaigns, technology-foresight programmes, publicly accessible databases or platforms for exchanging experience and knowledge. To promote new, sustainable technologies at early stages of development, policy-makers can support the creation of market niches, thus allowing development and learning processes, so that the selection pressure exerted by the market is weakened for a certain period.

Development of sustainable technologies

Undesirable environmental effects can already be avoided at early stages of a technology's development, for example by linking basic and applied research with risk research and sustainable technology assessment (Section 8.3.4).

To be more specific, possibilities include direct interaction between the natural and social sciences or the integration of all stakeholders involved in research and development activities. Similarly, the establishment of sustainable principles in the research process can help prevent unwanted environmental effects because such concepts alter the areas where the search for technological solutions takes place (Section 8.3.4). It can also be assumed that scientists will be more likely to reflect on potential consequences for the environment and society in the early stages of technology development if appropriate education and training makes them more aware of the relevance of their work. It could also be beneficial if environmental and other regulatory authorities saw themselves more as part of the innovation system and not just as (possibly) reacting players. This could have the effect that authorities find out about a prototype's possible negative environmental effects before a state-imposed environmental impact assessment is made (Section 5.4.2.2; Rejeski, 2012).

Overall conditions

In order to accelerate the pace of innovation for marine, sustainable energy technologies, not only is direct and indirect public support needed in the production of knowledge and its implementation; the overall conditions must also be such that they make companies more willing to invest (WBGU, 2012). Increased private investment has a double effect on the pace of innovation. On the one hand, a higher overall level of investment can also increase the funds available for internal corporate innovation activities. On the other, increased investment in sustainable marine energy-generation capacity and infrastructure can accelerate innovation processes in the production and application of technologies via learning effects and economies of scale.

The relevant overall conditions also include the coordination of innovation, energy and environmental policies, as the latter two policies can have an influence on innovation processes (WBGU, 2012; Rave et al., 2013). One of the necessary overall conditions is a long-term, stable energy policy with strategies and targets (Section 5.4.1) which ensures the integration of renewable energy into the power-supply system and is reliably implemented in laws and concrete measures. Particularly in the case of marine renewable energy, this requires infrastructure measures such as adapting and expanding the (offshore) power grid, an integrated energy market, possibilities for energy storage, more flexible demand and the development of reserve and expansion capacity (Sections 5.2.4, 5.4.1; Rave et al., 2013). From the point of view of making marine renewable energies more competitive, it is also important to take into account – or price in – societal costs that are caused by the use of fossil and nuclear energy sources, and to phase out subsidies for the use of conventional energy sources (Section 5.4.1; WBGU, 2011, 2012).

Only when policy-makers convincingly and lastingly support the development of an energy system tailored to a high proportion of renewable energy (Section 5.3) will companies become more willing to innovate. Building up and continuing promotion systems for marine renewable energies, and creating an electricity market to integrate marine renewable energies into a liberalized energy market are part of relevant overall market conditions (Section 5.4.1). Efficient, participatory planning and licensing processes and easier access to capital are also be part. Further important overall conditions are legal security, the long-term validity of measures and the protection of confidence in investments (WBGU, 2011, 2012).

Environmental-policy instruments, such as the promotion of renewable energy, create incentives for innovation for the business sector if properly designed. Companies are more likely to follow these if climate policy is combined with coordinated innovation promotion (Section 5.4.1; WBGU, 2011). Ultimately, innovation promotion is most successful when it is part of a broad transformation policy that supports the transition to a sustainable stewardship of the seas through a coordinated combination of policy instruments across all policy fields (WBGU, 2011).

5.5 Conclusions

- *Generating renewable energy from the sea can be an important component of the global* 'Energiewende'*:* Renewable energy on and in the seas has great potential and should be used as a component of the global energy-system transformation towards sustainability. The focus in this context should be on electricity and gas production from renewable sources on integrated multi-use platforms. Use of the oceans for energy generation should be integrated into the energy-system transformation on land. Mining marine methane hydrates will not be necessary for the foreseeable future, and the extraction of offshore oil deposits should be phased out as quickly as possible because of the climate effects of using fossil fuels.
- *The* 'Energiewende' *in the seas can only be achieved with integrated marine and energy policies:* Supportive, coordinated marine and energy policies are needed in order to use the oceans sustainably for energy generation (Section 7.5.1). On the one hand, old and new uses of the sea must be coordinated by means of marine spatial planning; this also includes comprehensive environmental monitoring of existing power-generating plants. On the other, it is necessary to build cross-border and integrated marine power grids, so that the fluctuating amounts of electricity from renewable-energy technologies can be optimally distributed across a region and an integrated electricity market realized. Since most of the technologies for generating renewable energy from and on the sea are not yet ready for the market, both public measures to develop technologies and incentive programmes for their commercial roll-out are meaningful.
- *Marine energy systems are suitable for supplying densely populated coastal areas:* Using the oceans for energy generation is very capital intensive and therefore particularly suitable for supplying power to densely populated coastal areas or mega-cities on the coast, not so much for rural areas. Since the different uses of marine space (shipping, fisheries, aquaculture, resource extraction, tourism, coastal and ocean conservation, infrastructures, renewable-energy technologies) are concentrated in such areas, the space-intensive development of renewable energy on and in the oceans should be closely accompanied by marine spatial planning.
- *The use of the seas for energy generation is primarily a task for the nation states, but it also requires cross-border cooperation:* Since technological limitations are likely to restrict energy generation in the seas to the territorial sea and the exclusive economic zone, including the continental shelf, in the near future, nation-state regulations on ocean use are primarily relevant here. Since a cost-efficient use of the seas to generate power requires a cross-border infrastructure in the form of power cables, pipelines, shipping lanes and ports, international and cross-border forms of cooperation are also necessary for energy systems in the sea.
- *The pace of change can be increased with the help of an energy and innovation strategy:* The energy-system transformation is subject to great time pressure,

so it is essential to accelerate the pace of innovation. A legally binding, reliable and long-term-oriented energy and innovation strategy in the respective countries – with clearly defined expansion targets for renewable-energy technologies in the sea – would therefore be an important signal to potential investors. Among other things, such an energy and innovation strategy should encompass research and education, the capital markets and the overall legal framework. In addition, licensing and planning processes should be developed for offshore technical installations, as well as suitable liability regimes.

- *Sustainable technology and technology-impact assessment should be integrated into early phases of technology development:* The environmental effects of new marine technologies for generating renewable energy should already be assessed during the development phase; it is not a good idea to wait until commercial systems are in use. This can help avoid undesirable effects from the outset.

Synthesis: The Blue Revolution 6

6.1 The oceans as the common heritage of mankind

The WBGU regards global public and common goods – such as the atmosphere and the seabed beneath the high seas – as the 'common heritage of mankind'. As a principle of international law this means that global public and common goods belong to all of humanity and must remain accessible. In international environmental policy, the principle is interpreted for the future in such a way that the world's natural resources are to be preserved, so that they can also be used by future generations. This results in a system of shared sovereignty rights between states which is based on a global regulatory framework geared towards sustainability goals. The conservation and management of the common heritage of mankind requires stewards, a regime for conservation and use that serves exclusively peaceful purposes, and rules on sharing to ensure that the benefits and costs of the regime are fairly distributed (Chapter 7).

Because large sections of the oceans are openly accessible for many uses, the consequences of the *Tragedy of the Commons* (Hardin, 1968) can still be observed in many areas. And even in cases where regulations apply, they are not strict enough to force ocean users and those who cause damage to ensure the long-term conservation of the oceans and its ecosystem services.

Many people and organizations have taken up the cause of conserving the oceans as the 'heritage of mankind'. Two prominent examples are Elisabeth Mann Borgese and Arvid Pardo and their farsighted and radical commitment to a new Convention on the Law of the Sea in the 1970s (Mann Borgese, 1975; Pils and Kühn, 2012). Of all global public goods, the sea is probably the one that is most deeply ingrained in the public consciousness and deemed most worthy of protection, because of its strong symbolic significance. Even so, this has not stopped the pollution of the oceans, the destruction of the oceanic environment, overfishing or the ruthless exploitation of marine resources.

6.2 Expansion into the oceans

Whereas in former centuries humanity regarded – and indeed shunned – the sea as a source of insecurity, chaos and danger, modern navigation and technology have created the impression that, apart from certain risk factors, it can be brought under control. Yet under the impression of events like the gigantic oil spill after the explosion of the *Deepwater Horizon* oil rig in 2010, the tsunami-triggered multiple meltdown of the Fukushima nuclear power plant in 2011, the disastrous flooding of the Asian coasts in 2004, and hurricanes like Katrina (2005) and Sandy (2012), which brought major cities like New Orleans and New York to a standstill, the oceans again look like a source and venue of disasters, not to mention the insidious threat of rising sea levels caused by climate change (WBGU, 2006).

Unchecked expansion into the oceans, as experienced in the case of overfishing and currently being continued in aquaculture, should therefore not be the watchword; rather, as the exemplary areas of application in this report show, a wise, 'horticultural' approach to the ocean as a common good should characterize the political ideas on ocean governance and use, also for future generations. This includes respecting the systemic interdependences involved in the use of the sea, especially in the context of land use.

The seas have been changing more slowly compared to the atmosphere, much of the biosphere and the land, but this situation seems unlikely to continue. Human interventions in critical functions of the planet are increasingly being reflected in significant changes in the oceans (Chapter 1). On land, human use of the natural environment has already been pushed to evident and, in some cases, painful limits, so that many are now targeting the seas as the final available major source of raw materials. This is illustrated by the extraction of raw materials, as exploration and drilling operations are moved ever further out into the deep sea. Energy and communications infrastructures are moving further and further away from the coasts, out into the open sea. After all, the oceans offer a lot of potential for renewable energy generation, with wind, waves and tides.

Because the per-capita amount of available arable land is shrinking more and more as a result of overuse and rising population levels, while at the same time the demand for fish is growing worldwide due to changes in eating patterns, the pressure of exploitation on fish populations is also on the increase. However, ocean fishing already reached its limits long ago. Many fish stocks have already been deemed to have collapsed.

Nevertheless, food production and renewable energy generation are becoming recognized as future uses of the oceans. This development can be regarded as paradoxical. Man has become a global force in the Anthropocene, exerting an impact on the natural environment. In this context human activities often reach or even overstep the planetary limits. However, the breaching of guard rails of the Earth system is more directly observable on land than in the sea. This promotes expansion into the oceans, which are regarded as an 'empty space', or the 'last frontier' which must now be overcome. Yet if humanity commits itself to the goal of sustainable development, this must incorporate all parts of the Earth system. The Great Transformation towards a low-carbon, sustainable society is an objective that can be observed in the efforts of many change agents in both the public and private sectors, as well as in civil society. It covers fields ranging from sustainable urban development to sustainable economic activity. It must now also apply to the outsourcing of human activities into the oceans.

6.3 A new initiative for the conservation and sustainable use of the seas

For these reasons, a new initiative for the conservation and sustainable use of the oceans is *necessary*; at the same time it is *possible* and also *advantageous*.

This initiative is *necessary* because the oceans have been degraded (e.g. by the production of oil and gas or by plastic waste) and overused (e.g. by fishing) in many places, and because the natural marine environment is being severely damaged or even destroyed in many locations (e.g. coral reefs as a result of climate change). For these reasons the phrase *Drama of the Oceans* (Mann Borgese, 1975) is still applicable. The top priority now is to end the predominant methods of managing the seas, which are often geared to short-term profits, and switch to business models which guarantee long-term returns that are both lucrative and secure, while preserving the marine ecosystem services for future generations (Section 7.3.7).

An extended marine regime is *possible* because the applicable Convention on the Law of the Sea (UNCLOS) already provides a good basis for an intelligent and effective development (Section 3.2); it is not, therefore, necessary to create a new law entirely from scratch. Furthermore, there are important public and private pioneers of sustainable marine policy.

A transnational regime is *advantageous*, not least because the sea can make valuable contributions to the transformation towards a low-carbon, sustainable society (WBGU, 2011), which is only made possible by a farsighted use of the sea as a global common good, making the most of new opportunities.

A *Blue Revolution* is needed, and that means extending the idea of a social contract for the Great Transformation to include the seas. This first requires an awareness of the importance of the sea to humans and the environment. Oceans cover nearly three-quarters of the Earth's surface. The 'blue continent' is of key importance for the Earth system and for modern civilization. It is a source of food and resources, a medium for global infrastructure and transport, and an essential element of the climate system. Oceans connect the world; they are the lifeblood and the liquid foundation of the global society; and they are part of the Great Transformation towards a sustainable society (WBGU, 2011).

6.4 Elements of a new marine policy

If this transformation is to reflect the limits and negative externalities of the entire planet, it must include the 'blue continent', the largest of all the Earth's continents. Recalling the *Drama of the Oceans* (Mann Borgese, 1975), this implies a paradigm shift that must be reflected in political thinking and action. That means, for example, that more intensive and improved generation of energy on and in the sea must be accompanied in particular by the decarbonization of energy systems on land. A wise and farsighted marine policy should focus the design of the technological revolution – which is making it possible to use resources further and further out to sea – on future needs in a way that takes into account all social and ecological consequences and side-effects, as well as their systemic interdependencies. It may be necessary to simply 'leave the sea alone' for a while, especially in regions where states have now begun a frantic race for resources – such as in the Pacific and the Arctic.

Sustainable interaction with the oceans should be based on the application of three principles: the oceans should be understood as the 'common heritage of mankind' (Section 7.1.2); their use and the extent of their exploitation should be seen systemically as part of an overall picture; and the precautionary principle should be applied in all decisions relevant to the oceans (Section 7.1.4). A wise marine policy also has economic, political and cultural dimensions. (1) It should identify new, sustainable uses and flesh out the marine development model in the sense of the Great Transformation. (2) Next it should support regimes which transfer regulations (such as bans, controls and sanctions) that are universalizable within the meaning of UNCLOS to the nation-state and local level, and at the same time introduce civil-society participation and control into global regimes. (3) Finally, it can use the iconic power of the sea to promote a culture of marine awareness. The technological and territorial expansion into the sea, which is also being made possible by the emergence of new players, should be contained and civilized by a social contract that is specifically geared to the oceans and their interaction with the land.

The framework concept of UNCLOS is being hampered by the hesitant ratification of some conventions and the inadequate implementation of the regulations by the states parties. Effective implementation requires a high degree of global and national cooperation. Cooperation is already taking place in some areas (e.g. under regional fisheries agreements (RFMOs) or port state memorandums); overall, however, no – or insufficient – regulations exist for many regions and fields. There is a tense relationship between the freedoms of the high seas (including shipping, cable and pipe laying, fishing, science) and coastal-state jurisdiction in the EEZs on the one hand, and the enforcement of UNCLOS provisions on protecting the environment on the other. The flag-state principle leads to problems in the enforcement of environmental requirements, especially on the high seas. Developing countries in particular lack the capacity to ensure that ships flying their flag comply with the rules; they are also sometimes unable to exercise effective coastal and port-state controls.

The zoning of the oceans, the limited scope of regional agreements, and UNCLOS's lack of detail have caused a fragmentation of ocean governance. In addition, many players and institutions do not liaise well with each other. Ocean-related matters continue to fall under the respective responsibilities of departments with long histories: naval ministries were responsible for the military 'use' of the sea surface; ministries of fisheries and agriculture are responsible for coastal food resources, and environmental or maritime authorities for waste disposal at sea. Moreover, inter-governmental agreements on the law of the sea regulate supra-regional maritime traffic, the use of marine resources, fishing zones, etc.

Although UNCLOS contains systemic elements, as a whole these are not strong enough (Chapter 3). For example, there is inadequate consideration of land/sea interactions and interactions within the Earth system, which came into focus only after UNCLOS was signed. Some other marine-conservation conventions follow an ecosystem approach, but only in some cases do they commit states to take precautions, pay the costs (polluter-pays principle) and target sustainable development. Risks associated with novel developments, which could not be foreseen when UNCLOS came into being, remain largely unregulated. As a result, a legal vacuum can arise for new forms of use whose potential and risks cannot yet be fully assessed. In addition, real-estate ownership on land creates a critical mass of affected owners who assert their rights when they suffer damage. There are no such affects relating to the oceans because there is no individual ownership.

To sum up, the WBGU advocates ensuring the conservation and sustainable use of the seas by developing more effective ocean governance (Chapter 7), while improving and further developing existing international regulations. UNCLOS offers a solid foundation for this as a 'constitution of the oceans' (Chapter 3). At the same time, the emerging global awareness of the need to protect the oceans is promoting a consensus on a new marine policy (Chapter 2). If this consensus could be enshrined in a virtual social contract for the seas, this could be the symbolic framework that could hold such a new marine policy together.

Civil society should be made aware of the need to protect the oceans and mobilized for their conservation, also for future generations. Furthermore, a steward should be given the task of asserting these conservation interests – and the powers required to do so (Chapter 7). Sustainable interaction with the oceans can also only succeed if the idea is promoted by change agents and supported by proactive states. Countless such pioneers in (semi-)public and private organizations and movements are already involved in marine conservation worldwide. The emerging global (civil) society is a key, indispensable force for the protection of the oceans as the Common Heritage of Mankind (Chapter 2).

Common goods like the oceans are protected outside of the state and the market by means of conventions and collaborations between the user communities. Ultimately this means all of us, and it highlights the role of civil society in the need to protect the oceans: the responsibility of consumers in the consumption of seafood; practising ocean-friendly tourism; and even non-violent protest campaigns, where they seem necessary, against ruthless polluters and exploiters of the seas. Sustainable interaction with the oceans can only succeed if change agents, supported by proactive states, get more involved than they have up to now.

Building on the above elements, in the following chapter the WBGU drafts a visionary future for ocean governance (Section 7.2), but also offers directly applicable options for gradually improving current ocean governance (Sections 7.3–7.5).

Recommendations for Action 7

In its report 'A Social Contract for Sustainability', the WBGU described the necessary structural transition towards a sustainable society (WBGU, 2011). Taking the example of limiting anthropogenic climate change as a *conditio sine qua non* of sustainable development, it clarified the need for a transformation towards sustainability and showed how the vital, comprehensive step of achieving a climate-friendly global economy can be accelerated. Against this backdrop, the present WBGU report turns its attention to the subject of the oceans: in the context of this Great Transformation towards a sustainable, low-carbon society, what might sustainable interaction with the oceans look like?

The challenge is how to return the world's oceans to a good environmental status. The oceans need to be protected and the sustainable use of marine resources and ecosystem services assured in the long term, for the benefit of the present and future generations. In this way the oceans can make a significant contribution to the said transformation, as explained in this report using the example of two key areas: food and energy. Food from the sea based on fisheries and aquaculture rooted in the principle of sustainability can contribute protein that is valuable for food security and, in so doing, help ease the growing pressure on terrestrial land use (Chapter 4). In addition, the current rapid development of technologies for generating energy from the sea can become a major factor in the decarbonization of energy systems and in climate protection (Chapter 5).

However, if these contributions are to be made, the present trend must first be reversed: sustainability must become the norm, because humankind's interaction with the oceans is far from sustainable. We have already profoundly changed the world's oceans (Chapter 1). They are overexploited, and their ecosystems are inadequately protected. Fish stocks are poorly managed in both ecological and economic terms. Offshore oil and gas production in ever deeper waters is becoming increasingly risky. Yet it is not enough just to ensure the sustainable use of the oceans themselves. Humankind's indirect impact on the oceans is no less of a cause for concern: climate change is adversely affecting ecosystems in the sea and on the coasts; CO_2 emissions are acidifying the oceans; the run-off of nutrients from land is creating oxygen-starved 'dead zones', while long-lived plastic waste and pollutants such as pesticides and heavy metals are accumulating in the sea. The largely still undiscovered 'blue continent' is proving to be fragile, and parts of it have already been irreversibly damaged.

The state of the oceans is an example of the immense influence of human societies and their flows of energy and materials. This influence is expressed by the term 'Anthropocene' (Crutzen and Stoermer, 2000), which is used to describe our present era in which humankind is a dominant factor in the Earth system (Chapter 1). This realization must lead humanity to take on responsibility for the Earth system and, therefore, also for the oceans. This must be done by elevating sustainability to the status of a guiding principle and by ensuring that no 'planetary guard rails' are breached (Box 1-1) and the fundamental resources of life are preserved (Chapter 2).

Given these challenges, it is essential to address the issue of the conservation and sustainable use of the oceans – i.e. the issue of ocean governance (Chapter 3). Because of the above-mentioned interactions in the Anthropocene era, ocean governance should, in the interests of sustainability, be embedded in a system of governance for the entire Earth system, and hence also in the transformation towards sustainability (WBGU, 2011). In particular, the focus must be on reducing anthropogenic CO_2 emissions enough to contain climate change and ocean acidification (WBGU, 2006, 2009). In addition, sustainable land use should keep the run-off of agricultural nutrients (mainly nitrogen and phosphorous) and sediments into the sea within reasonable limits. Not least, it is a matter of how industrial production is designed, because products, waste and long-lived pollutants very often find their way into the sea via rivers and the atmosphere. The ways in which pollutants can spread – and the recycling and disposal of products at the end of their useful lives – should therefore already be taken into consideration during the production process. Accordingly, the conservation and sustainable use of the oceans should be sustainable and precaution-oriented, and take account of systemic interactions.

The shortcomings of present-day ocean governance are one reason why the condition of the oceans has deteriorated hugely in recent decades. In some cases, this is attributable to the rights to use marine resources, which are still unrestricted (the 'commons problem'). The existing law of the sea does not do enough to urge ocean users and polluters to conserve the oceans and their ecosystem services in the long term, to remedy damage and be more committed to sustainable use of the seas. As a result, damage is widespread.

At the same time, the oceans are being put to all kinds of new uses. Examples include new shipping routes as the Arctic ice melts, prospecting for and extracting energy and mineral resources, deep-sea fishing, the generation of renewable energy on and in the sea, and offshore aquaculture. Especially when taken together, these uses pose new threats to marine ecosystems. In many cases, they also are competing with each other. The WBGU makes these challenges to future ocean governance the focus of its recommendations in this report.

In its special report 'The Future Oceans – Warming Up, Rising High, Turning Sour', the WBGU took a closer look at the interface between greenhouse-gas emissions and the oceans (e.g. warming, rising sea levels, ocean acidification; WBGU, 2006). In the current flagship report, the WBGU focuses on ocean governance, and particularly on food and energy, which were also at the centre of its 2011 flagship report entitled 'A Social Contract for Sustainability'. The report formulates recommendations on the sustainable use of fish stocks, sustainable aquaculture and the development of renewable marine energy systems. The WBGU shows that sustainable stewardship of the oceans is urgently necessary, and that ocean governance needs to be extensively reformed to this end. The oceans can also be a part of the transformation towards a low-carbon, sustainable society, and this can yield substantial advantages worldwide for sustainable energy supplies and food security.

7.1 Guiding principles for future ocean governance

Given the need for a transformation towards sustainability and the outlined challenges that this entails for ocean governance in the future, the WBGU recommends three guiding principles that should underpin humankind's interaction with the oceans. *First*, the oceans should be seen as the 'common heritage of mankind' (Section 7.1.1). *Second*, a systemic approach should replace the sector-specific approaches that are commonplace today, integrating conservation, use, pollution and all the interactions between these factors in a single 'big picture' (Section 7.1.2). *Third*, the precautionary principle should be followed to ensure that scientific uncertainty is not used as a pretext to delay measures to prevent damage (Section 7.1.3).

The WBGU regards principles as fundamental orientation aids in the sense of an optimization imperative. It follows that the principles discussed here should be realized to the greatest extent possible in future ocean governance. On the basis of these guiding principles, the WBGU therefore urges the creation of a regime for the conservation and use of the oceans which would ensure the long-term protection of ecosystem services, biological diversity and yields from the sustainable use of the oceans. As a result, the oceans would be able to make their contribution to the necessary transformation towards sustainability. The United Nations Convention on the Law of the Sea (UNCLOS) – the 'constitution of the oceans' – and existing sectoral marine treaties lend themselves as a suitable institutional platform. Key examples of the latter include the UN Fish Stocks Agreement (FSA; Section 7.3.4.3) for the fisheries sector, the Implementing Agreement to Part XI ('The Area') of UNCLOS, the London Convention and the London Protocol for pollution at sea, and the MARPOL Convention for shipping. These positive existing approaches should be further developed and combined with non-binding behavioural standards such as the FAO Code of Conduct for Responsible Fisheries, in order to avoid current harmful uses and to integrate new possible uses (such as offshore aquaculture and energy from the sea) in a sustainable way.

The sections that follow expand on these three principles, which the international community should look to for orientation as it advances a future system of ocean governance. The principles originate from the international environmental and sustainability debate and have increasingly become established in international law. With regard to the detailed design of a regime for ocean conservation and use, ten criteria are proposed (Section 7.1.4) as a basis on which a sustainable, precaution-oriented and systemic approach to ocean governance can be evaluated and fleshed out.

7.1.1 The oceans as the 'common heritage of mankind'

Perceiving the oceans as a public and common good, the WBGU has adopted the concept of a 'common heritage of mankind' (Section 3.1.5). This approach was suggested for the oceans as early as the 1960s by Arvid Pardo and Elisabeth Mann Borgese in the negotiations on the United Nations Convention on the Law of the Sea (UNCLOS). Although it was not enforced as a principle of international law for the oceans as a whole, it was enshrined in Article 136 of UNCLOS for the seabed outside of national jurisdiction ('the Area') and its mineral resources.

In the WBGU's view, it follows from the common heritage of mankind principle that global public and common goods must be accessible to all people and not be fully at the disposal of any state, individual or company. From a political perspective this results in a system of shared sovereignty rights between states which is based on a global regulatory framework geared towards sustainability goals. In international environmental policy, the common heritage of mankind principle is interpreted in such a way that the world's natural resources are to be preserved so that they can also be used by future generations.

The conservation and management of humankind's common heritage requires stewards, a regime for conservation and use that serves exclusively peaceful purposes, and rules on sharing to ensure that the benefits and costs of the regime are fairly distributed. The conservation and use regime should be designed to help prevent unregulated access to the oceans' ecosystems and the overexploitation that often results. At the same time, it should not stop member states from exercising their national rights of use or allow them to avoid their conservation obligations. Freedoms can thus be granted to nation states – also along the lines of Grotius' *Mare Liberum* ('The Freedom of the Sea'). However, these freedoms are limited by the freedoms of other states which also have a right to use the oceans. In addition, the conservation and use regime must also make due provision for the need to conserve this protected public good for future generations. In acknowledging the common heritage of mankind principle, the international community thus agrees to shoulder responsibility for the conservation and sustainable use of the oceans as a global environmental resource. In doing so, it places the tasks of conservation and management on a collaborative basis and ensures that both the benefits and the costs of use are equitably distributed.

7.1.2
The systemic approach

The sectoral approach, which is widely prevalent in ocean governance at present, is characterized by a view that is limited to the respective form of use and does not do justice to the systemic requirements of sustainability; it also regularly undervalues environmental aspects. Both within ecosystems and between ecosystems and social systems, complex and dynamic interactions exist which should be taken into account with the aid of a systemic approach.

This approach aims to help ensure that healthy, productive and resilient marine ecosystems and the biodiversity they contain can be conserved in the long term and used sustainably. It is important to see the 'big picture' of anthropogenic burdens and their interdependencies, as well as their cumulative impact. Human interaction with the oceans should focus on achieving a good environmental status. The WBGU proposes the introduction of a systemic approach in order to integrate both the different levels of the system and the interactions between the natural and social systems that should be taken into account when dealing with the oceans. The approach comprises the following levels: *First*, marine ecosystems are themselves complex systems which should be protected and used according to an 'ecosystem approach'. Developed in the context of the Convention on Biological Diversity (CBD, 2000, 2004c), the ecosystem approach is now widely recognized by governments and should serve as the basis for the management of marine ecosystems. *Second*, the systemic approach should go far beyond the uses of the marine ecosystems and also take land/sea interactions into account. Since many of the risks to the oceans are caused by economic activities on land, the oceans' interactions with terrestrial systems – and how these affect the oceans – must also be examined. Examples include the run-off of pollutants from industrial production, the careless handling of waste, and the consequences of intensive agricultural methods which feed nutrients and sediments into rivers and the atmosphere. *Third*, in the era of the Anthropocene linkages in the Earth system should also be taken into account – e.g. CO_2 emissions from fossil fuels, which damage marine ecosystems both indirectly (via climate change and rising temperatures) and directly by seawater acidification. *Fourth*, on all these levels it must be taken into account that there are complex and dynamic interactions between society and nature. The WBGU therefore regards integrating these interactions between marine ecosystems and societies as indispensable for a comprehensive systemic approach and elevates this perspective to the principle of future ocean governance.

7.1.3 The precautionary principle

According to the precautionary principle, steps based on state-of-the-art science and technology should be taken to prevent possible environmental damage, even when there is no full scientific certainty on the likelihood or extent of damage. Scientific uncertainty does not justify delaying or failing to take action to avoid potential damage, provided there are reasonable grounds for assuming that a risk genuinely exists.

The precautionary principle was established as a key tenet of national environmental policy in the 1970s, for example in Germany's Federal Pollution Control Act in 1974. The same principle has been implemented with variations in wording in international environmental policy, for example in the Montreal Protocol (1987), the Third Conference on the Protection of the North Sea (1990), the UN Framework Convention on Climate Change (1992), the Cartagena Protocol (2000) and the Stockholm Convention (2001). To quote the Rio Declaration on Environment and Development: "(…) to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UNCED, 1992a).

The application of the precautionary principle is particularly important in complex systems – to which marine ecosystems and their land/sea interactions doubtless belong – since it is difficult to predict how these systems will react to influences or disturbances. It is therefore important to allow enough scope for decisions to be flexible and reversible. The precautionary principle is already acknowledged in many regulations and decisions on ocean governance, but rarely comes to concrete and stringent application.

7.1.4 Ten criteria for a future system of ocean governance

In Chapter 3, the WBGU developed touchstones for analysing the existing system of ocean governance at the various levels, from local to global (Section 3.1). Building on this, it has formulated ten criteria for guiding measures aimed at redesigning the ocean governance of the future. These ten criteria take into account both the specifics of the oceans and general demands on governance. They are suitable not only as a basis for drafting a visionary future form of ocean governance (Section 7.2), but also for gradually improving ocean governance in its present form (Section 7.3-7.5).

- *Adaptive management* aims to continuously improve the knowledge base for governance and to promptly use it in the conservation and sustainable use of the oceans. Adaptive management broadens our knowledge of the structure and dynamics of ecosystems via a learning process and thus iteratively improves the protection and management of the seas.
- *Incentives for innovation* encouraging a sustainable, low-risk use of the oceans reward players who develop long-term, sustainable business models on the use and conservation of the seas instead of seeking short-term profit maximization.
- A *clear assignment of rights of use* is necessary to prevent the overexploitation of the sea, a public and common good. This makes it possible to exclude certain users and thus to coordinate use – either via markets or by negotiation. Furthermore, the societal costs of use can be charged to the users according to the 'polluter pays' principle, so that the external costs are internalized.
- Neither the conservation nor the sustainable use of the oceans as a global public and common good will be possible without an unprecedented level of global cooperation culture and *global cooperation mechanisms*. Global cooperation forms the basis for the development of international treaties on marine conservation and use, as well as for the joint implementation of these treaties.
- *Subsidiary decision-making structures* – assigning decision-making powers primarily to decentralized decision-makers at the regional or local level, and secondarily to central international agencies – are crucial for the acceptance of global and national regulations. Moreover, such an interpretation of subsidiarity makes regulations easier to enforce efficiently.
- *Transparent information* ensures that all players have access to the relevant data.
- *Participatory decision-making structures* make it possible to reveal interests; they lead to decisions that all stakeholders can understand.
- *Fair distribution mechanisms* aim to ensure an equitable distribution both of the benefits of marine resource use and of the costs – e.g. of conservation, monitoring, surveillance and sanctions. This applies to cost and benefit sharing between countries and different levels of a country's government.
- *Conflict-resolution mechanisms* are necessary in order to coordinate the many and complex use interests of different stakeholders (e.g. governments and individuals).
- *Sanction mechanisms* at the different governance

levels are key instruments for enforcing compliance with regulations on use.

7.1.5 Implementation and enforcement

Analysis of ocean governance in its present form shows that existing agreements contain plenty of good approaches, but that, for various reasons, these are in many cases neither implemented nor enforced by national governments (Section 3.7). The currently valid law of the sea is too weak when it comes to mechanisms for implementing and enforcing international agreements. It is not enough to agree and lay down principles, criteria and material (framework) regulations (such as the Oceans MDG and Oceans SDG; Section 7.3.3.1); good ocean governance must also ensure that rules are adhered to and enforced.

The WBGU therefore recommends that mechanisms to verify compliance with rules and to reinforce implementation and enforcement should be built into future ocean governance. Accordingly, options for such mechanisms feature both in the vision of a comprehensive reform of the law of the sea outlined by the WBGU (Section 7.2) and in the subsequent recommendations for action (Section 7.3).

Verifying compliance with international agreements is necessary. In itself, however, it is not enough to ensure that agreements that are legally binding under international law are indeed implemented and enforced. The WBGU therefore argues that sanction mechanisms must be made an integral part of future ocean governance, and that the International Tribunal for the Law of the Sea (ITLOS) needs to be strengthened. Doing so would create an incentive for governments to translate international agreements into national law and ensure that they are implemented. Where countries lack the political or administrative capacity this would require, the WBGU believes it is the responsibility of the international community to support these countries by transferring services and resources.

7.1.6 A social contract for the seas

The WBGU notes that the world's oceans are in an unsatisfactory state and that there are negative trends. It follows that simply maintaining the current form of ocean management cannot be the yardstick for humanity's future interaction with the oceans (Chapter 1). The underlying governance regime must therefore be further developed and improved (Section 3.7). These insights reflect a broad consensus in the scientific community and have repeatedly been acknowledged by the international community – most recently at the Rio+20 Conference in 2012 (UNCSD, 2012).

Above and beyond the need to take account of guiding principles and the ten criteria for sustainable ocean governance, the WBGU also believes there is a need to agree a social contract for the seas. Back in 2011, the WBGU already contributed a 'social contract for the transformation' to the discussion, linking a culture of attentiveness (born of a sense of ecological responsibility) with a culture of participation (as a democratic responsibility) and a culture of obligation towards future generations (future responsibility) (WBGU, 2011). The transformation towards a sustainable society is a societal searching and learning process. The aim of the social contract is to conserve the natural life-support systems needed by the present and future generations. To achieve this goal, a regulatory framework is needed which references sustainability and is developed through a broadly based societal dialogue on the key issues of coexistence. In the context of this virtual agreement, individuals and groups in civil society, the corporate and scientific communities, national governments and the international community pledge to assume shared responsibility for protecting natural life-support systems through agreements on the long-term use of essential global commons. Given the unequal distribution of both access to and the consumption of resources, as well as the different levels of development in world society, the social contract must accommodate the need for fairness, justice and social equality.

The WBGU believes a societal consensus on sustainable ocean stewardship must be reached if ocean governance is to be reformed. This consensus must then be condensed into a clearly specified social contract. Such a social contract for the seas would effectively be part of the social contract for a Great Transformation towards a low-carbon, sustainable society (WBGU, 2011). The social contract for the seas should lay the foundation for developing a new regulatory framework to underpin sustainable interaction with the oceans. The WBGU therefore believes that the protection of the oceans and their sustainable and equitable management must be central goals of this social contract. The WBGU further asserts that not only coastal states, but the whole international community and civil society share this responsibility.

7.2 The WBGU's vision of a comprehensive reform of the international law of the sea

The WBGU is convinced that profound changes in ocean governance, especially in the international law of the sea, are necessary and appropriate in order to arrive at a sustainable stewardship of the oceans. However, resolute implementation of the guiding principles and criteria of governance outlined in Section 7.1 would require major changes to relevant agreements – above all to UNCLOS – and would therefore require a common political will on the part of the states parties. In the WBGU's view, such an initiative currently has little chance of implementation, because there seems to be too wide a gap between what is politically feasible and the changes in ocean governance that are necessary from the sustainability perspective.

Against this background, the WBGU has decided to explore two paths, each with a different ambition and speed. *First,* the WBGU outlines the vision of a fundamental and comprehensive reform of the existing law of the sea – irrespective of the current chances of implementing it – offering orientation on how best to address the challenges of marine conservation and the sustainable use of the oceans. *Second,* the WBGU develops recommendations for action which link up with ongoing political processes, are easier to implement, and are therefore suitable as steps leading towards the vision of a comprehensive reform of UNCLOS. These detailed recommendations are listed below in Section 7.3.

Above all, this vision stakes out the goal of a form of ocean governance tailored to sustainability – a goal which the international community can then pursue step by step in the long term. The WBGU has drafted a brief sketch of this vision to serve as a compass for change and an early-warning system to identify and avoid negative developments. Experience shows that political feasibility is difficult to predict. Numerous political events and crises in recent contemporary history – such as German reunification, Germany's phasing out of nuclear power after Fukushima, the Arab Spring and the euro crisis – show that, given urgent challenges, reforms can become feasible which are so radical that they were previously considered totally unrealistic. However, such reforms should be well thought through and discussed beforehand. The WBGU wants the vision presented here to contribute to achieving this goal. The processes of democratization witnessed since the Industrial Revolution, and the way in which human rights have gradually become established in international politics, would not have been possible if progressive thinkers on democracy and human rights had not painted pictures of society which were initially perceived as bold, visionary or even seditious (depending on one's point of view).

The vision outlined below builds on UNCLOS in its current form, in particular on the common heritage of mankind principle it enshrines (Article 136 of UNCLOS). It shows the fundamental changes in ocean governance that would be needed to ensure the conservation and sustainable use of the oceans. At the same time it upholds key tenets of the existing law of the sea, such as the zoning of the oceans. Figures 7.2-1 and 7.2-2 illustrate this vision in a simplified form by juxtaposing the status quo of ocean governance with the WBGU's vision.

7.2.1 The common heritage of mankind, the systemic approach and the precautionary principle: three guiding principles for ocean management

In light of its function regarding the use of mineral resources in the Area (i.e. the seabed seaward of national jurisdiction), the 'common heritage of mankind' principle explained in Section 7.1.1 is established in the WBGU's vision as a legally binding guiding principle for the oceans. This principle serves the purpose of conserving the sea – together with its resources, ecosystem services and biological diversity – as a global public good for future generations. This emphasis on a long-term perspective and ecological integrity has a lot in common with the concept of sustainability predominant since the UN Conference on Environment and Development in Rio de Janeiro (UNCED, 1992a), which mentions conservation and sustainable use in the same breath. Accordingly, the preference often given to uses based on a short-term profit motive should be rolled back in favour of sustainable uses based on long-term cost/benefit calculations. According to the common heritage of mankind principle, therefore, the oceans are the object of conservation and common, sustainable management to the benefit of the whole of humankind. The resultant benefits, too, should be shared equitably (Section 3.1).

The regime for marine conservation and use based on the common heritage of mankind principle should apply in differentiated forms to the maritime zones seaward of the territorial sea (the Exclusive Economic Zones or EEZs, the continental shelf, the high seas and 'the Area'; see Section 3.2.1) and include all their resources.

Section 7.2.2 outlines the institutional design of a corresponding conservation and use regime in which a World Oceans Organization (WOO) is set up as a global steward of the common heritage of mankind (Section 7.2.2.1). Trusteeship for the management of the oceans as part of the common heritage of mankind, and the rules on sharing benefits and costs, are designed differently depending on the maritime zone (Section 7.2.3). The rights and obligations of the states parties to the reformed UNCLOS thus vary across the different maritime zones. The material and procedural design of the common heritage of mankind principle is discussed in Section 7.2.4.

To ensure a sustainable stewardship of the oceans, it is not enough for the common heritage of mankind principle to be established in the reformed UNCLOS and adopted in both regional treaties and the national law of the states parties to the Convention. Rather, these steps must be backed up by the systemic approach and the precautionary principle (Sections 7.1.2, 7.1.3). Together, these three principles of environmental protection and international environmental law should permeate every aspect of the reformed law of the sea. In particular, they must form the basis for an integrated conservation and use regime which transcends the boundaries of maritime zones.

7.2.2 Institutional changes

The introduction of mineral-resource management for the Area as the common heritage of mankind in the existing UNCLOS showed that governance based on the common heritage of mankind principle requires both new institutions and new instruments. In the following section, the WBGU outlines an institutional design accompanied by the geographical expansion of the common heritage of mankind principle.

7.2.2.1 A global steward of the seas: the World Oceans Organization

A new international organization should be set up in line with the extended scope and powers of a future conservation and use regime under a reformed UNCLOS. In its capacity as international steward of the sea as the common heritage of mankind, this organization would assume monitoring tasks in respect of international agreements and also have the right to file suits with the International Tribunal for the Law of the Sea (ITLOS). In addition, the organization would monitor the condition of the marine ecosystems and their trends.

This World Oceans Organization (WOO) should not be given the function of an international 'super-authority for marine matters'. Rather, it should only intervene if the management and monitoring tasks assigned primarily to the states parties to the Convention or the Regional Marine Management Organizations (RMMOs; Section 7.2.2.2) are not being carried out in accordance with international agreements. The institutions set up under the existing UNCLOS – the International Seabed Authority and the Commission on the Limits of the Continental Shelf – should be integrated in the WOO's new organizational structure. In their capacity as independent entities within the WOO, they would retain their existing fields of jurisdiction for the Area and the continental shelf respectively. It would also be worth examining whether it would make sense to integrate other existing marine organizations that are not party to UNCLOS, such as the International Maritime Organization (IMO) and the Intergovernmental Oceanographic Commission (IOC). Further studies and analyses would be necessary to clarify this matter (Section 8.3.2.2).

Global steward of the marine environment

The WOO would function as a global steward of the marine environment and the resources of the high seas, the EEZs and the continental shelf. The accountability obligations of the states parties would enable the WOO to identify shortcomings in the stewardship of the sea. It would have access to legal remedies and be authorized to bring RMMOs and states parties before the International Tribunal for the Law of the Sea (ITLOS) (Section 7.2.2.3) in order to prosecute treaty violations. To address conflicts over ocean conservation and use, the WOO's function as steward of the high seas should further include a right of initiative in designating marine protected areas and in marine spatial planning (Section 7.2.4).

Setting standards

States parties to UNCLOS are required to follow international ocean-conservation standards according to Article 192 ff. This should be reinforced by gearing these standards to scientific knowledge on sustainability. Subject to proposals by the WOO and with the participation of the states parties, UNCLOS should be formulated in more concrete terms where gaps exist, particularly with regard to aquaculture and energy – following the pattern set, for example, by comitology at the EU level. Such changes to UNCLOS would build a framework within which the states parties could be given extensive design freedoms, allowing them, for example, to prescribe a level of conservation which goes beyond international conservation standards.

The WOO would be responsible for analysing existing national and international rules on the prevention, reduction and monitoring of marine pollution, in order to find common ground and thus identify existing standards. On this basis, the WOO could close any gaps

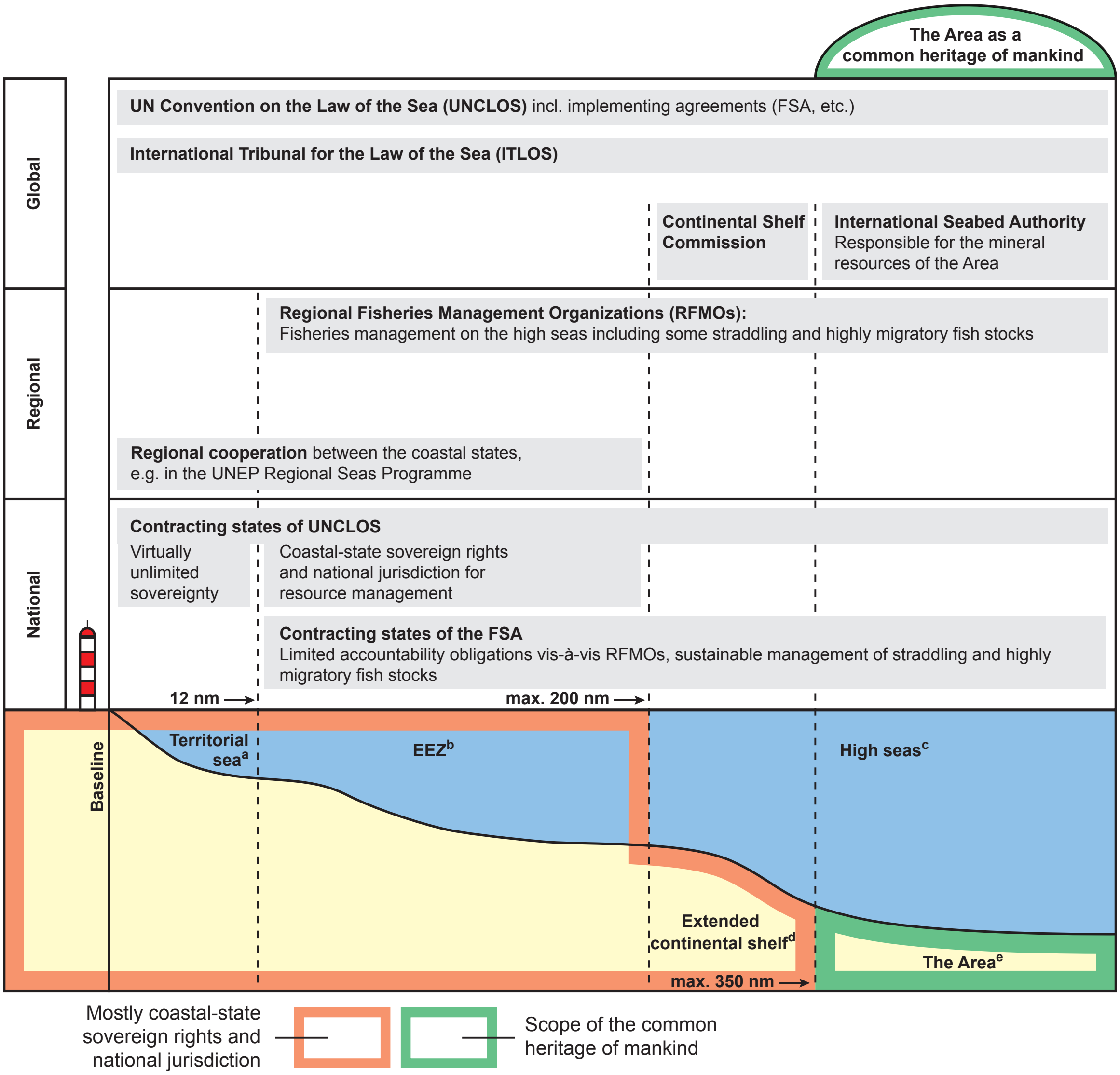


Figure 7.2-1: Status quo of ocean governance, simplified diagram.
The common heritage of mankind is today limited to the mineral resources of the seabed seaward of national jurisdiction ('the Area'). These resources are administered by the International Seabed Authority. The UN Convention on the Law of the Sea (UNCLOS), together with its implementing agreements (primarily the UN Fish Stocks Agreement, FSA), defines the framework of ocean governance. The Regional Fisheries Management Organizations (RFMOs) organize the management of fish stocks on the high seas and of the straddling and highly migratory fish stocks in the exclusive economic zones (EEZs). The coastal states have far-reaching sovereign rights to use all resources in their EEZ and the mineral resources of the continental shelf. Regional cooperation between coastal states is organized through programmes and agreements (especially UNEP Regional Seas Programmes).

a The territorial sea extends up to 12 nautical miles (nm) from the baseline. It comprises, inter alia, the seabed and its subsoil. The coastal state has territorial sovereignty in the territorial sea.

b The EEZ covers the marine area seaward of the territorial sea, extending for a maximum of 200 nm measured from the baseline. The EEZ comprises the water column as well as the seabed and its subsoil.

c The high seas begin seaward of the EEZ and are limited to the water column. They are not subject to any national sovereignty; freedom of navigation, fishery, research, etc. applies here.

d The continental shelf comprises the seabed and its subsoil seaward of the territorial sea. The continental shelf regularly overlaps with the EEZ and has no separate importance. The continental shelf can, however, extend further than the seaward boundary of the EEZ ('extended continental shelf'). The outer limit of the continental shelf may not be more than 350 nm from the baseline (or 100 nm from the 2,500 m isobath).

e The Area comprises the seabed and its subsoil seaward of national jurisdiction.

Source: WBGU

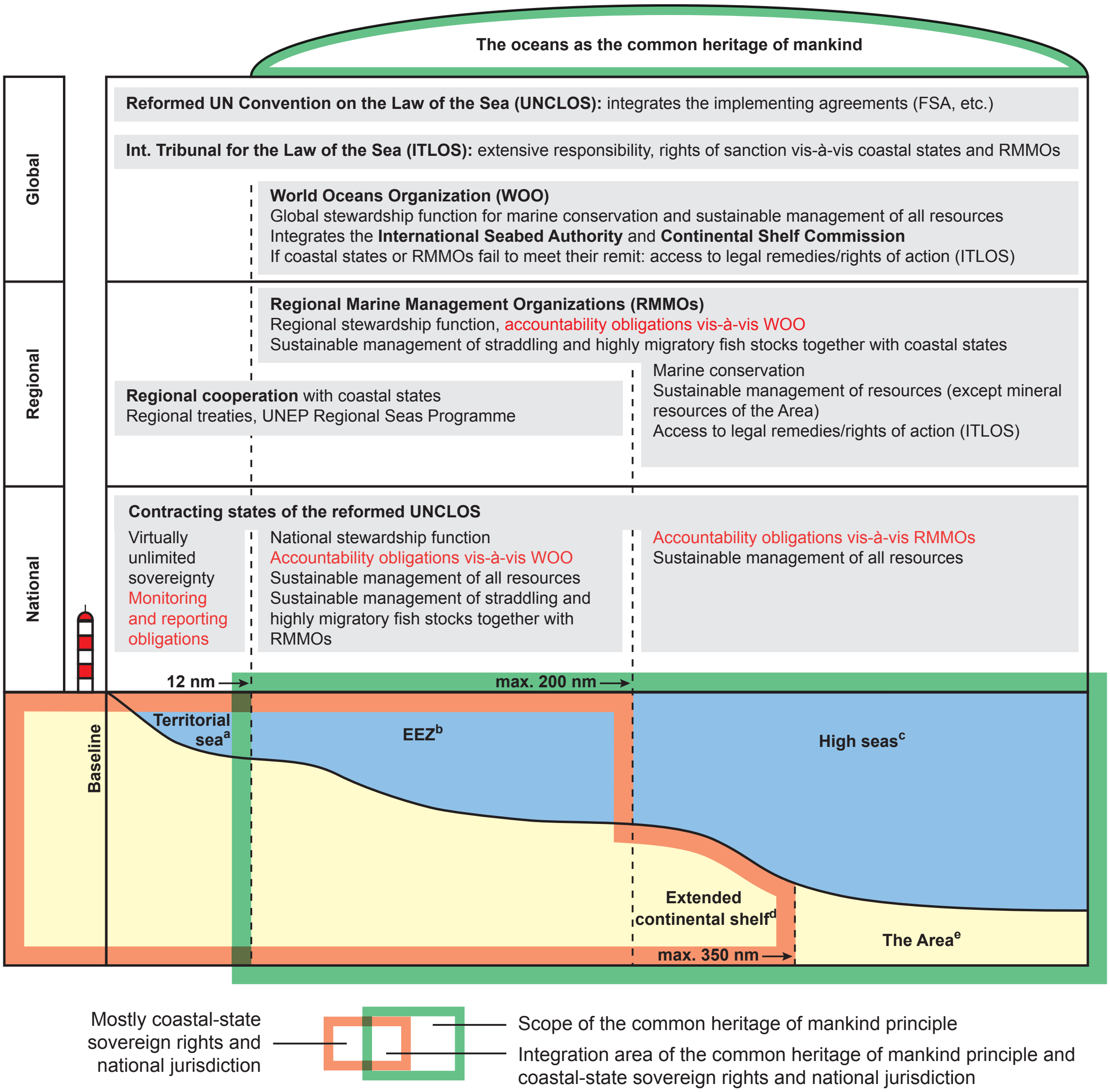


Figure 7.2-2: Vision for a future system of ocean governance, simplified diagram.
All marine areas, with the exception of the coastal waters, are given 'common heritage of mankind' status. This includes all resources seaward of the territorial sea, including mineral and biological resources. The coastal states retain their rights of use over the resources in the exclusive economic zone (EEZ) and the mineral resources of the continental shelf. As stewards of the marine environment within the EEZ, the coastal states have an obligation to use these resources sustainably. The rights of use therefore also involve accountability obligations vis-à-vis the new World Oceans Organization (WOO). The International Seabed Authority and Continental Shelf Commission are integrated into the WOO. The Regional Fisheries Management Organizations (RFMOs) are integrated into the Regional Marine Management Organizations (RMMOs) which organize the sustainable management of all resources on the high seas. They also organize the management of straddling and highly migratory fish stocks in cooperation with the coastal states. The WOO takes on the role of the oceans' global steward and monitors compliance with rules on their conservation and sustainable use. It has access to legal remedies, especially rights of action, at the International Tribunal for the Law of the Sea (ITLOS). Regional cooperation between the coastal states under programmes and agreements continues.
Red text: Accountability obligations vis-à-vis higher levels of governance.
a-e: See Figure 1 for explanations
Source: WBGU

by proposing its own mandatory standards on the conservation of the marine environment to the community of the states parties, who would then give legitimacy to these standards. The WOO would thus define the global minimum standards for national and regional legislation to protect the oceans.

7.2.2.2
Regional stewards of the seas: Regional Marine Management Organizations

Regional Marine Management Organizations (RMMOs) should be set up under regional intergovernmental agreements to organize the sustainable management of regional resources on the basis of the guiding principles (the common heritage of mankind, the systemic approach and the precautionary principle) set forth in Section 7.1. Geographically, their jurisdiction would essentially be limited to the high seas, where they would oversee the conservation and sustainable use of the oceans. RMMOs should monitor, conserve and sustainably manage the biological resources (fish stocks, aquaculture and genetic resources) and the use of marine energy (wind power, wave power, platforms, cables etc.) on the high seas, as well as equitably distributing the benefits from these uses. They would also be responsible for implementing a system of regional marine spatial planning on the high seas (including marine protected areas). Each RMMO would have to cover one region of the high seas and – along the lines of the RFMOs in the fishing context – should essentially be formed by the countries that border on or use the given marine region. The RMMOs in their entirety should cover the management of the whole of the high seas, if possible with no overlaps. In its capacity as regional steward of the marine environment, an RMMO would monitor the environmental compatibility of marine users' activities. The RMMOs would be accountable to the new WOO (Section 7.2.2.1), and the compulsory reports they submit would enable the WOO to maintain a clear overview of global marine use and quickly spot any anomalies.

Highly migratory fish stocks (such as tuna and swordfish; Section 4.1.4.4) would constitute an exception to the administration of biological stocks by RMMOs and still need independent organizations in the future. This exception is necessitated by the distribution area of these fish stocks, which extends far beyond the jurisdiction of individual RMMOs or EEZs. Accordingly, these highly migratory fish stocks should continue to be managed by specialized RFMOs, but these should be accountable to the WOO. In consultation with the coastal states concerned, and in compliance with the rules laid down in the UN Fish Stocks Agreement, the RMMOs should engage in the collaborative management of straddling stocks that are not highly migratory but that cross the borders between EEZs and the high seas.

The RMMOs would be responsible for ensuring the sustainable use of marine resources and equitably distributing the benefits, by either selling or auctioning the rights of use to the states parties (Section 7.2.3.1). Some of the proceeds could be used to finance necessary marine conservation measures, monitoring systems and measures, and capacity building in developing countries (Section 7.3.6).

7.2.2.3
Extend the jurisdiction of the International Tribunal for the Law of the Sea

In the event of violations of UNCLOS, states parties can already file suits with the Hamburg-based International Tribunal for the Law of the Sea (ITLOS). However, cases are only actually brought before ITLOS if both parties wish to have this tribunal involved in settling a dispute. This restriction should be abolished in the future. Other procedures for settling disputes can be chosen as alternatives to ITLOS. Examples include the International Court of Justice and a variety of special courts of arbitration (Section 3.2.3). The WBGU recommends that ITLOS be given greater powers to create a judicial reference in the field of the law of the sea and marine environmental law. In future, disputes over the interpretation of the law of the sea and marine environmental law, and actions to prosecute cases of marine pollution, should be assigned primarily to ITLOS. The interpretation of UNCLOS would also remain the responsibility of ITLOS as the 'guardian of the treaties'. A procedure for referrals to ITLOS should be established for corresponding issues of interpretation brought before other national or international courts.

The new WOO should be given the right to initiate proceedings on UNCLOS violations (Section 7.2.2.1). Furthermore, selected and recognized non-governmental organizations should be endowed with class action rights once a recognition procedure has been completed.

7.2.3
Rights and duties of states parties on the high seas and in EEZs

The rights and duties of states parties pursuant to the common heritage of mankind principle should vary according to the maritime zone (Section 7.2.1). In particular, the legal regime for the high seas must be modified to ensure that marine resources are distributed equitably. Moreover, the marine conservation aspect must be given greater weight than in the past in the

EEZs. Despite the need for changes, the coastal states' existing rights of use under a reformed UNCLOS should remain essentially as they are.

7.2.3.1
Conservation and sustainable use of the high seas

To date, the use of the high seas has been shaped by the freedoms enjoyed by the states parties (freedom of navigation, freedom of fishing). The existing UNCLOS establishes an independent use and distribution regime for mineral resources in the Area that takes account of the common heritage of mankind principle. However, the water column above it lacks any global cross-sectoral concept for sustainable use and conservation. While the environmental prescriptions enshrined in UNCLOS are binding, they are no more than framework regulations that need to be fleshed out (Section 3.2). The guiding principle of the common heritage of mankind proposed by the WBGU (Section 7.1.1) fits in with current international efforts to reorganize the use of the high seas (e.g. UN, 2012a). Since the application of the common heritage of mankind principle would, according to the WBGU's vision, be extended vertically into the water column, the conservation obligations and rights to the use of the high seas would be incumbent upon humankind as a whole. Up to now, only some states parties have been beneficiaries of the high seas due to their economic and technological superiority.

The reform outlined in this document envisages a fundamental redesigning of the way in which the natural resources of the high seas are managed. Contrary to the current arrangement, marine biological resources (such as fish stocks and genetic resources) should in future also be sustainably managed in line with the common heritage of mankind principle, and the benefits generated by this management be fairly distributed – as is the case under the regulations on seabed mineral resources.

To implement a new conservation and use regime for the high seas, the WBGU believes that the following changes need to be made to relevant institutions and instruments:

- The UN Fish Stocks Agreement (FSA) would become part of the reformed UNCLOS (Section 7.3.4.3). All biological resources on the high seas should be the object of regulation in future. Guidelines for the sustainable use of these resources would be made legally binding under the reformed UNCLOS, drawing on the FSA and the FAO Code of Conduct for Responsible Fisheries, which would be incorporated. The content of the planned implementing agreement on the biological diversity of the high seas should also be incorporated into the reformed UNCLOS (Section 7.3.4.2).
- In line with the subsidiarity principle, the management of marine resources on the high seas should be decentralized and transferred to the RMMOs (Section 7.2.2.2).
- The WBGU proposes that the gains from the use of marine resources on the high seas should benefit not just the users themselves but all of humankind (Section 7.2.2.2), focusing in particular on the interests of developing countries (Article 140 of UNCLOS). Elements of profit distribution and benefit sharing already feature in the existing UNCLOS: on the one hand, the community of states parties will participate in profits from the mineral resources of the extended continental shelf; on the other, the international community will participate in profits from the use of seabed mineral resources. Similar distribution mechanisms would therefore have to be created for all resources on the high seas. Beyond this, the effective participation of developing countries in the use of the resources of the high seas should be promoted (Article 148 of UNCLOS).

7.2.3.2
Conservation and sustainable use of the Exclusive Economic Zones

As well as being extended vertically into the water column on the high seas, as described above, the application of the common heritage of mankind principle should also be extended horizontally into the EEZs. It should be stipulated as a guiding principle for the exercise of coastal states' national jurisdiction in the EEZs and on the continental shelf. In the EEZs, application of the common heritage of mankind principle should essentially remain limited to the intergenerational aspect, which requires the states parties to use the oceans sustainably in the interests of future generations. The states parties have a material obligation to protect the oceans, according to which they must use the rights allocated to them in such a way that damage to the marine environment is avoided, and use the marine resources in a way that takes the needs of future generations into account (Section 7.1). Trusteeship for the management of the common heritage of mankind in the EEZs would thus be transferred to the respective coastal states. Violations of the common heritage of mankind principle would have to be sanctionable in order to achieve a sustainable use of the sea (Section 7.2.4).

The WBGU takes the view that, regarding the application of the common heritage of mankind principle within the EEZs, the coastal states should retain their extensive national jurisdiction regarding the use of the EEZs that is assigned to them under the terms of the existing UNCLOS. At the same time, the international community should place them under obligation to conserve and sustainably manage the common heritage of mankind in keeping with their function as trustees, and to be accountable for these activities. According to the WBGU's vision, the coastal states can thus use their EEZs exclusively but may not damage or destroy them.

The states parties should not merely pay lip service to the goals of sustainable management (e.g. maintaining fish stocks within their EEZs), but also implement them in practice and monitor compliance. As has already been proposed for the high seas, guidelines for the management of biological resources along the lines of the UN Fish Stocks Agreement and the FAO Code of Conduct for Responsible Fisheries should be incorporated as legally binding provisions into the reformed UNCLOS. Violations of these guidelines should be linked to sanction mechanisms in cases where countries fail to meet their obligations (Section 7.2.4). The states parties should be accountable to the international community, represented by the WOO (Section 7.2.2.1), for the sustainable stewardship of the resources in their respective EEZs. Accountability should involve specific reporting duties and prescribed targets and timelines. The reports should be in the public domain, so that the general public and relevant associations are informed and can monitor the situation if appropriate.

7.2.4
Instruments

On top of the establishment of guiding principles and the ten criteria outlined in Section 7.2.1, and in addition to the institutional and organizational design of use and conservation regimes described in Sections 7.2.2 and 7.2.3, it is also imperative to design an appropriate set of instruments in order to reach the specified goals. To this end, the WBGU believes the following steps to be of vital importance:

- *Introduce rights of action and sanctions:* The WOO should be endowed with supervisory powers, and the states parties should be accountable to it (Section 7.2.2.1). It should therefore be possible for the WOO and states parties to the reformed UNCLOS to sue those states parties that fail to meet their reporting or conservation obligations at ITLOS. ITLOS should be entitled to impose sanctions depending on the severity and frequency of misconduct (Section 7.2.2.3). These sanctions might include export or import restrictions on illegally sourced resources. Furthermore, a country that is in breach of the Convention could be excluded from participating in licence auctions for the resources of the high seas (Sections 7.2.2.2, 7.2.3.1). As a last resort ITLOS should have the power to restrict a state's sovereign rights in the EEZ if it has abused its powers.
- *Set up a stricter liability regime:* A much more effective international cross-sector liability regime should be created covering all activities that involve a potential risk to the seas (absolute liability; Section 7.3.10). In accordance with the 'polluter pays' principle, the organizations responsible – irrespective of whether they are private or public organizations – should bear primary liability for the environment, while the states parties that permit such activities to take place should bear secondary liability. Residual state liability should take effect where it is not possible to unequivocally identify who is responsible. Such state liability makes it more likely that states parties will, in their own interests, implement and enforce strict rules on environmental protection.
- *Strengthen civil-society engagement:* Civil society (especially NGOs committed to marine conservation) should be given access to ocean-specific information, be informed about planning and approval processes relating to the law of the sea and international environmental law (such as energy use, deep-sea mining and aquaculture), and be given corresponding rights of participation and class action rights.
- *Expand marine protected areas and establish spatial planning:* An ecologically representative and effectively managed system of marine protected areas should be established; in the WBGU's view at least 20–30% of the area of marine ecosystems should be designated for this system (WBGU, 2006; Section 7.3.9.1). The relevant content of the targeted implementing agreement on biological diversity on the high seas should be incorporated into the reformed UNCLOS (Section 7.3.4.2). Furthermore, using graded zones allowing different intensities of use, this system of marine protected areas should be a core component of marine spatial planning (Section 7.3.9.2). Spatial planning should be established at the national, regional and global levels as an instrument of the law of the sea. It should also be applied to (rival) uses on the sea, in the sea and below the water column. Spatial planning also includes the exploration and mapping of the oceans and the involvement of civil society in the planning process, including rights to information and participation and class action rights. For the high seas, the WOO should be vested with authority to oversee and coordinate marine protected areas and spatial planning (Section 7.2.2.1). To take account of regional peculiarities, the planning and operation of marine protected areas and marine spatial planning on the high seas should be handled by the RMMOs (Section 7.2.2.2).
- *Provide for environmental impact assessment:* Interventions by planned activities in the oceans should

only be allowed if the dangers they present for existing ecosystems have been evaluated in advance and weighed against the benefits of the interventions. This process should be obligatory. Such environmental impact assessments (EIAs) should be established in the reformed UNCLOS. An EIA forecasts how a planned marine activity is likely to affect human health, biological diversity, soils, water, air and climate, and the world's cultural assets. Accordingly, a strategic environmental assessment should be required for plans and programmes relating to the oceans, such as spatial planning or the creation of marine protected areas.

- *Establish a 'marine impact assessment' for land-based activities:* Land-based industrial production (chemicals, long-lived products, by-products and production waste) should be subjected to a 'marine impact assessment'. As early as the authorization stage for industrial production plants, it is important to ensure that only those substances and products that have no harmful effects can reach the oceans. It would be desirable to have the goals and framework of such a 'marine impact assessment' formulated internationally as part of a reformed UNCLOS, with implementation taking place at the national level.

7.3 Recommendations for action: the road to a comprehensive reform of the law of the sea

In contrast to the WBGU's vision of extensive reforms to the law of the sea described above (Section 7.2), the recommendations for action that follow are easier to implement politically as they do not require any changes to UNCLOS itself. The latter leaves room for the formulation of implementing agreements to expand on its provisions and specify them in greater detail. These enhancements should be further complemented by supportive governance on other levels. The recommendations in this section are designed in such a way that they could open the door for further reforms. They are thus the first steps recommended by the WBGU for realizing a sustainable form of ocean governance as outlined in its vision (Section 7.2). The recommendations are ordered as follows: the knowledge and action base comes first (Section 7.3.1), followed by broader strategic recommendations on improving the overall conditions impacting on the use of marine resources (Section 7.3.2). Then recommendations on public (Sections 7.3.3–7.3.7) and private (Section 7.3.8) ocean governance are presented, including the instruments that such governance requires (Sections 7.3.9–7.3.10). The WBGU also refers the reader to the recommendations set forth in its special report *The Future Oceans – Warming Up, Rising High, Turning Sour* (WBGU, 2006), in which it takes a closer look in particular at the interface between greenhouse-gas emissions and the consequences for the oceans (e.g. warming, sea-level rise, ocean acidification).

7.3.1 Strengthen the knowledge and action base of ocean governance

7.3.1.1 Improve marine environmental monitoring

Sustainable ocean governance depends on comprehensive monitoring of the oceans, because monitoring delivers scientific knowledge about the status of, and trends in, the marine environment, thereby laying an important foundation for political and economic decisions. In accordance with Article 200 of UNCLOS, the states parties have an obligation, for example, to engage in research programmes on the pollution of the marine environment and to encourage the exchange of information thus acquired. Given the increasing challenges of the Anthropocene, current monitoring practices are inadequate in many sectors (Section 3.6.1). Alongside some countries' lack of monitoring capacity, this is primarily due to inadequate networking between what are predominantly national monitoring activities. The gathering and exchange of new scientific knowledge and data should therefore be promoted, partly to improve the scientific basis for measures to conserve and sustainably use marine resources.

The WBGU recommends the rapid expansion of a global monitoring system for the oceans. To this end, indicators must be harmonized and a globally networked geodata-management system built up to ensure that the data acquired are transparent, accessible and interoperable. It is important to work together with current national and international processes in this context. At the UN level, these processes primarily include the Global Ocean Observing System (GOOS), the monitoring activities of the FAO in the areas of fisheries and aquaculture, UNESCO's Intergovernmental Oceanographic Commission, the WMO and the UNEP World Conservation Monitoring Centre. These activities should be better coordinated, networked and combined.

In addition to these measures, a suitable international framework, within which the international community can cooperate to ensure appropriate monitoring, should be created for the high seas in particular, for which no monitoring powers yet exist. Furthermore, it should be noted that monitoring of the marine environment also serves an important function in establishing compliance with policy goals agreed by the international community (Section 7.1.5). For this reason, the extension of monitoring activities should go hand in hand with the further development and supervision of policy objectives for the oceans, e.g. in the Oceans Compact (Box 3.3-1; Section 7.3.3.1). Concepts already exist for funding the expansion and maintenance of such a global monitoring system. The WBGU's recommendations on this issue can be found in Section 7.3.6.

7.3.1.2
Process scientific knowledge for policy-makers and support the Regular Process

Political decisions on the future of the oceans, and strategies for the sustainable use of marine resources must be based on a well-founded pool of scientific data. As early as 2005, the United Nations General Assembly (UNGA) passed a resolution establishing a Regular Process for Global Reporting and Assessment of the State of the Marine Environment (the Regular Process), which takes both scientific and socio-economic aspects into account. During the launch phase of this process between 2005 and 2009, an 'Assessment of Assessments' was drawn up which statistically evaluates a total of 1,023 ocean-related reports with a global, regional or national focus. The process of producing the 'First Global Integrated Marine Assessment' is currently underway. The report is scheduled for completion by December 2014, which would enable the UNGA to address it in autumn 2015. If this process leads to a high-quality report that receives the backing of broad swathes of the scientific community, it could provide a powerful stimulus for international policy-makers. The IPCC reports provide a unique and reliable overview of the current status of knowledge and possible alternatives in relation to the climate and could serve as a model in this context (Section 8.4.3). As things stand, however, it remains unclear whether the First Global Integrated Marine Assessment can meet this expectation.

In 2012 UN Secretary-General Ban Ki-moon (UN, 2012a) stressed the importance of the Regular Process as the scientific foundation underpinning the Oceans Compact he had initiated (Sections 3.3.1.1, 7.3.3.1). He also called on the countries of the world to give this Compact the necessary support. At present, however, the Regular Process is relatively unknown among German marine scientists. The WBGU suggests that the German Federal Government should give the project much stronger financial and conceptual support and integrate the Regular Process into the existing scientific infrastructure.

7.3.1.3
Set up a multi-stakeholder forum

To improve the general ability to act at the international level, the WBGU recommends setting up a multi-stakeholder forum. The aim would be to initiate a consensus-oriented process which, based on the scientific state of the art (including the Regular Process; Section 7.3.1.2), would agree guidelines for the future stewardship of the oceans. Similar processes on other subjects in the past have helped clarify interests of different actors and thus given policy-makers greater leeway to take action. Examples include the World Commission on Dams (WCD) and the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD).

Whether or not the WBGU's recommendations become generally accepted in practice will depend primarily on whether the relevant policy-makers and interest groups can be convinced of the need to use the oceans sustainably. It will not be possible to implement these or comparable reform proposals if they face powerful political resistance. A multi-stakeholder forum could play a part in reconciling the conflicting interests of the various marine actors, overcoming political blocking tactics and clearing the way for a comprehensive reform of the law of the sea. Political representatives of all groups of countries (industrialized, emerging and developing countries) and of the existing international marine organizations should participate in this forum. The scientific community, too, should be represented in an advisory capacity in the form of recognized oceanographers and transformation researchers. Representatives of the business community and civil society should participate as equal members of the forum in order to take account of economic, social and ecological interests. The formation of an Oceans Advisory Group has been announced as a possibility for the Oceans Compact initiated by UN Secretary-General Ban Ki-moon (Box 3.3.1; Section 7.3.3.1). This group could be the seed from which the forum proposed by the WBGU might grow.

7.3.2
Create the necessary conditions for sustainable management

In addition to the need to create a solid knowledge and action base, it is also necessary to fundamentally rethink the way we interact with the oceans. The top priority now is to end the currently predominant methods of managing the seas, which are often geared to short-term profits, and to switch to business models which enable long-term yields while preserving the marine ecosystem services for future generations (Section 7.3.7). Suitable institutional and political conditions should be created to enable the individual actors to change the way they think, and to facilitate change in the predominant business models, management methods and consumption patterns. To this end, the WBGU outlines its basic recommendations for the development of suitable conditions here before discussing and defining them in greater detail in later sections of Chapter 7.

- *Integrated ocean strategies at all levels of governance:* By bundling fundamental principles, ocean strategies can cultivate a shared understanding of how to interact with the oceans (Section 7.3.3). In doing so, they lay the foundation for designing suitable conditions for ocean management with a long-term focus. The international community and each individual country should formulate clear guidelines for the use of marine resources. At the international level, too, regulatory frameworks and coordinated, intergovernmental strategies must be equally clear – in the context of the Oceans Compact and regional treaties, for example (Section 7.3.3).
- *Evaluation and pricing of ecosystem services:* To lay the basis for a realignment of marine management, the value of the ecosystem services provided by oceans and coastal areas, which seem to have been regarded as costing nothing up to now, must be calculated and explicitly communicated. In this context, the value of marine ecosystem services should be estimated in all countries and taken into consideration in decisions on public investment and development projects. The guidelines for the UN Statistics Division's System of Environmental and Economic Accounts, and projects such as the World Bank's WAVES partnership, serve as examples and important approaches to factoring natural assets into public investment and development policy. Such approaches are reinforced by the international TEEB process (The Economics of Ecosystems and Biodiversity; Section 1.1.7) and should in future be supported by the German Federal Government (Section 8.3.1). Based on information on the value of marine ecosystem services, prices should be set for these services in all countries and taken into consideration in ocean users' economic calculations. Appropriate pricing can create both negative and positive incentives. The WBGU's recommendations on this can be found in Section 7.3.7.1.
- *Phase-out subsidies:* To prevent governments from continuing to encourage unsustainable ocean-management practices, subsidies – in fisheries and aquaculture, for example – should at the same time be rapidly phased out in all countries (7.4.1.3).
- *Infrastructures for sustainable management:* Furthermore, all countries should set aside capacity to oversee sustainable fishery management and develop sustainable aquacultures. Developing and newly industrializing countries should be supported in this process financially and with capacity building. The related recommendations on fishery and aquaculture are listed in Section 7.4. For sustainable energy generation on and in the oceans, it is also necessary to integrate new power-generation plants into existing power grids. This requires both direct connections to power grids and steps to ensure that the overall grid has sufficient capacity. The WBGU's recommendations on the use of energy from the oceans are listed in Section 7.5.
- *Public funding of research and development:* Fisheries and aquaculture on the one hand and the energy sector on the other both harbour tremendous potential for innovative solutions and technologies with a long-term orientation. Since private players generally invest too little in research and development due to the externalities of technological development, policy-makers should create new incentives for innovation in fisheries, aquaculture and energy use (Sections 8.3.3, 8.3.4).

7.3.3
Develop strategies for future ocean governance

7.3.3.1
Develop the Oceans Compact into an Integrated World Oceans Strategy

The Oceans Compact initiated in 2012 by UN Secretary-General Ban Ki-moon aims to establish a strategic United Nations vision on sustainable interaction with the oceans, and to translate this vision into a Global Plan of Action. An important aspect of this strategic vision involves reducing institutional fragmentation at the UN level. The WBGU sees an urgent need for a significant improvement in the coherence of the United Nations' ocean-related activities above and beyond the existing approaches adopted under the aegis of UN-OCEANS. In its capacity as a stakeholder forum, the planned 'Oceans Advisory Group' aims to advise the UN organizations and help coordinate a collaborative approach (Box 3.3-1). The WBGU advocates speeding up the implementation of this plan.

In addition to the above measures, the WBGU recommends that the Oceans Compact initiative be used to map out a shared conceptual basis and, in the medium term, to further develop it into an integrated UN World Oceans Strategy. To this end, guiding principles should be agreed such as those that underpin the WBGU's vision (the common heritage of mankind principle, the systemic approach and the precautionary principle; Section 7.2.1). In line with the Millennium Development Goals (MDGs), or in the context of the yet-to-be-developed Sustainable Development Goals (SDGs), this global UN strategy should be equipped with a list of objectives for the seas ('Ocean MDGs' and 'Ocean SDGs') and backed up by indicators. In combination with appropriate monitoring (Section 7.3.1.1), specific and clearly measurable indicators can measure and evaluate target achievement over a defined period. The WBGU's planetary guard rails should also be taken into consideration when developing such Ocean MDGs and/or Ocean SDGs (Box 1-1).

A UN strategy of this kind, negotiated and ratified by the UN General Assembly, should serve as a compass for international marine conservation policy in the context of the Great Transformation towards a low-carbon, sustainable society. The new requirements identified and scientific knowledge gained in recent years would be factored into this strategy, which would create a common target horizon, improve mutual understanding between the UN institutions involved, and thus promote a coherent UN marine policy with a commitment to sustainability. Above all, the strategy could serve as a point of reference for regional and national players and perhaps best be compared with the Rio Declaration and Agenda 21 (UNCED, 1992a, b), which bundled fundamental principles of sustainable development which were then tackled and implemented at the regional, national and local levels.

7.3.3.2
Ratify regional, national and local marine strategies

The impact of the Oceans Compact, too, depends not least on the reception it is given at the lower levels of governance. The guiding principles should also be anchored in regional, national and local marine strategies to facilitate agreement on a common target horizon and help improve the implementation of integrated marine policies.

For the EU, it makes sense to incorporate these guiding principles into the Marine Strategy Framework Directive (MSFD), the implementation of which requires the development of national marine strategies. The WBGU therefore advises the German Federal Government to give its backing to a corresponding further development of the MSFD at the European level. The 'National Strategy for the Sustainable Use and Conservation of the Oceans' (BMU, 2008), which was ratified by the German Federal Government in the course of implementation of the MSFD, and the 'Ocean Development Plan' (BMVBS, 2011) mark the first steps towards an integrated German marine policy. As German marine policy continues to develop, the precautionary principle already established in the strategy should be reinforced and the systemic approach established as a further development of the ecosystem approach. In the medium term, the Federal Government should develop and refine its marine strategy by incorporating the common heritage of mankind principle as a guiding principle.

7.3.3.3
Take on a pioneering role – forge subglobal alliances

Thanks to their excellent marine research and their technological, economic and political resources, Germany and the EU are favourably placed to play a pioneering role in marine policy world-wide. This is also and especially true with regard to development of the Oceans Compact (Section 7.3.3.1). The WBGU therefore recommends that an ocean governance policy committed to both the common heritage of mankind principle and sustainability should be strengthened by forming subglobal alliances with like-minded states. Acting as pioneering coalitions, such alliances could make important contributions along the road to the Oceans Compact. Political alliances are recommended – i.e. alliances within which the states involved work together to pursue common interests and objectives. Initiatives to form such alliances should be supra-regional in order to give the agreements they reach – on the conservation and sustainable use of the oceans – as universal validity as possible (Section 7.3.5).

One consequence of the unsatisfactory outcome of the Rio+20 Conference in summer 2012 is that efforts are already being made in this direction. Germany's Environment Minister Peter Altmaier has announced his intention to examine the possibilities for setting up such an initiative to conserve the world's oceans (Altmaier, 2012).

7.3.4
Support and flesh out the international law of the sea

Due to its nature as a framework treaty, UNCLOS is inherently designed to be further specified through cooperation between the states parties. However, both the Convention itself and treaties designed to flesh out this legal framework reveal many and varied deficits (Section 3.2). The legal framework for fisheries, for example, is comparatively well developed, although the quality of the provisions is questioned in relation to sustainable management and there is often a lack of effective enforcement (Section 4.1.4). For this reason, the EU should continue to vigorously promote global and sustainable fisheries governance in international forums and treaties – first and foremost in UNCLOS, the UN General Assembly, the FAO and the World Bank (Section 7.4.1). Recommendations on governance in the field of aquaculture can be found in Section 7.4.2, recommendations on managing the use of renewable energy in the oceans in Section 7.5.

International – global and regional – treaties that further specify UNCLOS (Sections 7.3.4.2, 7.3.4.3) should be supplemented or amended in such a way that the conservation and sustainable use of the oceans is ensured. To this end, the WBGU proposes that international cooperation transcending the boundaries of the individual sectors (fisheries, shipping, use of energy, mineral resources, etc.) be improved. For instance, cooperative forms of contract fulfilment, such as those in the fisheries sector, and the monitoring of port states could serve as models for the implementation of environmental regulations. As a general rule, they could be used to reduce deficits in implementation and enforcement across all forms of use.

7.3.4.1 Promote the signing, ratification and implementation of UNCLOS

The WBGU regards UNCLOS as the basis for a social contract for the oceans and recommends developing the Convention further in order both to overcome existing deficits in ocean governance and to strengthen and continue developing the sustainable use of the oceans. In international environmental law, UNCLOS is of outstanding significance due to its widespread recognition in legal practice. Yet it has still not been signed by a number of coastal states (including the USA, Colombia, Turkey and Libya). International recognition of this international treaty should be further reinforced by the states parties stepping up their diplomatic efforts to urge the remaining non-signatory coastal states to sign up, and to urge the signatory states that have not yet ratified the treaty to go ahead and do so. Similarly, more intensive diplomatic pressure should be exercised to ensure that existing laws and agreed political objectives are implemented and applied more rigorously.

7.3.4.2 Reach a new implementing agreement on biological diversity on the high seas

Over the last ten years or so, scientific knowledge has led to a growing realization that there are gaps in regulation when it comes to the conservation and sustainable use of biological diversity on the high seas. The resolutions passed by the World Summit on Sustainable Development in Johannesburg (WSSD, 2002; also referred to as the Rio+10 Conference) and various decisions made by the Convention on Biological Diversity played a part in the UN General Assembly's setting up the working group on Biological Diversity Beyond Areas of National Jurisdiction (BBNJ) in 2004. The discussion centres primarily on closing three specific regulatory gaps by a new implementing agreement to UNCLOS: (1) the sustainable use of marine genetic resources (including access and benefit sharing), (2) nature-conservation measures, in particular based on marine protected areas, and (3) environmental impact assessments, which are gaining in importance due to an increase in activities and forms of use on the high seas driven by technological progress.

The WBGU regards this development as very helpful and recommends that this process be energetically pursued and supported. Given the scientific state of the art, the urgent need for action and the defined political objectives, the hope in the run-up to the Rio+20 Conference was that the decision to begin concrete negotiations might be taken there. This hope was disappointed. While agreement was reached to develop an implementing agreement to UNCLOS, the start of concrete negotiations was once again postponed. The Global Ocean Commission, an independent initiative launched by international leaders, has been set up to help speed this process up again (GOC, 2013).

The German Federal Government should continue giving high priority to overcoming political blockades along the road to the planned implementing agreement. The agreement should be legally binding and, in addition to issues (1) and (3) referred to above, should aim to designate a network of marine protected areas on the high seas. As a minimum requirement, this network of protected areas should meet the qualitative and quantitative standards agreed in the Strategic Plan drawn up by the CBD (Aichi Target 11; CBD, 2010a) and seek to realize the WBGU's quantitative objectives (2006; Sections 7.2.4, 7.3.9.1). To attract special attention and raise the political profile, the conclusion of negotiations could be accompanied by a high-level 'UN Oceans Conference' where policy-makers could resolve the last remaining problems and sign the agreement. The WBGU advises the German Federal Government to investigate whether a financing mechanism might also be included in the agreement which could be used to implement a number of the recommendations made in Section 7.3.6.1. An implementing agreement of this kind would also be an important step towards a fundamental reform of the law of the seas, as outlined by the WBGU in Section 7.2.

7.3.4.3
Advance the UN Fish Stocks Agreement and Regional Fisheries Management Organizations (RFMOs)

The use of fish stocks on the high seas is in urgent need of reform because of the need to reduce the ongoing threat to stocks and to prevent damage to marine ecosystems. Fisheries governance on the high seas should be reinforced accordingly and moved up the political agenda.

The 1995 UN Convention relating to the conservation and management of straddling stocks and highly migratory fish stocks (UN Fish Stocks Agreement, FSA), an implementing agreement to UNCLOS, is a core element of global fisheries governance and of particular relevance to the high seas. The general principles of the FSA – targeting precaution-oriented and knowledge-based fishing practices that take their impact on ecosystems into consideration – are formulated in far greater detail than those of UNCLOS and also relate to stocks in the EEZs, which constitutes substantial progress. The German Federal Government and the European Union should therefore use diplomatic channels to support the signing and ratification of the FSA by as many countries as possible to enable it to achieve the status of customary international law in the longer term. Above all, those countries that engage in fishery on the high seas and are members of Regional Fisheries Management Organizations (RFMOs) should accede to and ratify the agreement. In the longer term, the common heritage of mankind principle should be established in the FSA, and its jurisdiction expanded to cover all species fished in the high seas. The role of the 'Review Conference', which so far has been limited to the retroactive evaluation of fish-stock management, should be broadened to ensure that requirements and standards develop in line with the scientific state of the art.

The RFMOs play an indispensable role in organizing cooperation between countries on the sustainable management of shared fish stocks on the high seas and, in many cases, also in the EEZs. From a global perspective, however, the RFMOs have largely failed in the sustainable management of the fish stocks under their jurisdiction (Section 1.4.4). There is a broad scientific and political consensus on the need for urgent action to persuade states to manage their fish stocks sustainably within the framework of their cooperation in RFMOs. Examples of best practices have been witnessed of late, together with a general trend towards an improvement of RFMOs, since these problems have been tackled more vigorously in UN committees. Among other things, this has led to performance reviews and the wider use of best-practice solutions (Section 4.1.4.4). The WBGU's detailed recommendations are as follows:

- Alongside UNCLOS, it is principally the FSA and the FAO Code of Conduct for Responsible Fisheries (which is not legally binding) that form the legal basis for fishery on the high seas. All RFMOs should therefore adopt the provisions of these agreements under their own legal basis, request existing members to ratify these agreements and make ratification compulsory for new members, as is already happening to some extent. The WBGU recommends that the RFMOs be significantly strengthened. To begin with, the RFMOs should together formulate a solid basis for action – e.g. in the form of a strategic vision, objectives, rules and processes – in order to help overcome barriers to a change towards sustainability. The overall recommendations for the sustainable management of fish stocks set out in Section 7.4.1.1 can serve as a yardstick for this purpose. Regular and transparent performance reviews involving the participation of external experts are also advisable, as are clear procedures for resolving disputes. The WBGU recommends that mechanisms be established – perhaps using a process involving institutional support from the FAO – that could help the RFMOs to learn more from each other and share best-practice solutions more effectively.
- RFMOs should set up transparent data management for ecosystems, fish stocks, catches and by-catches, ships and fisheries' outlay – and this data management should be coordinated globally. The recommendation to designate at least 20-30% of the area under their jurisdiction as marine protected areas (Section 7.3.9) with sufficiently large zero-use zones should also be implemented by the RFMOs. Strict and effective monitoring using modern technology and inspectors should become standard practice for all RFMOs. RFMOs should instruct their member states to impose appropriate penalties on fishermen who violate the RFMOs' rules. There should be a globally accessible register and compulsory licensing for all fishing and supply vessels sailing under any flag that wants to operate on the high seas in RFMO areas. RFMOs should be able to ban unlicensed fishing boats and/or fishermen with unlicensed fishing equipment access to fish stocks. The RFMOs should make full use of their rights under UNCLOS and the FSA to make it difficult or impossible for ships from non-cooperating states to use RFMO stocks. Measures specifically targeting IUU fishery (Section 7.4.1.5) are in the common interests of the RFMO member states. Transparent data management and stricter reporting and accountability duties (management plans, stock and catch statistics, etc.) would make it easier for UN institutions and non-governmental organizations, for example, to verify the effectiveness of management.

- To close the last remaining gaps, the existing RFMOs should incorporate hitherto unregulated fish stocks into management (e.g. pure high-sea stocks, deep-sea stocks), and RFMOs should be set up in those regions of the oceans that are still unregulated. In the process, provision should also be made for the prospective option of expanding RFMOs into Regional Marine Management Organizations in line with the WBGU's vision (Section 7.2.2.2). As a general rule, comprehensive cooperation with adjacent RFMOs should be targeted.

7.3.5
Strengthen regional ocean governance

To make better use of the potential of regional ocean governance, the WBGU recommends aligning it with the guiding principles outlined in Section 7.1 – the common heritage of mankind principle, the systemic approach and the precautionary principle – and with the ten criteria for sustainable ocean governance. Regional cooperation follows the subsidiarity principle: competencies or actions are passed down to the lowest-possible level of governance suitable for solving the problem. Regional ocean governance should be significantly strengthened and expanded with the aim of establishing and enforcing mandatory as well as voluntary regulations. For the most part, the following recommendations build on the current system of regional ocean governance and thus represent a continuation and extension of existing structures. The Arctic is discussed in detail in Box 7.3-1.

7.3.5.1
Strengthen and expand the UNEP Regional Seas Programme

The agreements reached as part of the UNEP Regional Seas Programme and the results that have been achieved are important milestones on the road to effective regional ocean governance (Section 3.4.1).

In the context of the UNEP, the German Federal Government and the EU should encourage the development of regional programmes supported by agreements for all marine regions, covering as much of the global ocean as possible. Agreements should also be sought for regional programmes – such as the East Asian Seas Programme, signed up to by the majority of ASEAN countries – that are already up and running but not yet supported by international agreements. For the sake of coherence of governance, the relevant regulations under global agreements (e.g. FSA, CBD, CITES) should also be integrated to support their regional implementation. Furthermore, the WBGU recommends significantly upgrading the UNEP Regional Seas Programme in financial and organizational terms and bringing it into close cooperation with the Oceans Compact initiated by UN Secretary-General Ban Ki-moon (Section 7.3.3.1). This would raise the political profile of the programme and strengthen both the overall programme and the various regional programmes.

7.3.5.2
Strengthen regional seas agreements

Regional seas agreements are already making an important contribution to the sustainable use of the oceans, despite wide variations in objectives, instruments and institutions in some cases (Section 3.4). Particularly positive examples are the Helsinki Convention for the Baltic Sea (HELCOM) – which regulates the amount of pollutants emitted into the Baltic Sea and has achieved a significant improvement in the condition of the Baltic's ecosystem – and the OSPAR Convention for the North-East Atlantic, which, among other things, has produced a network of marine protected areas on the high seas (Sections 3.6.2, 7.3.9.1). Analysis by the WBGU shows that the implementation of regional agreements can be improved by means of problem-related protocols, agreeing ambitious action plans and establishing regional seas commissions (Section 3.4).

Agree ambitious protocols and action plans

Protocols are legally binding. They make framework agreements more specific and therefore more effective. They can help avoid cross-border conflicts and assist member states in better organizing the use and protection of the marine region in question. The WBGU therefore recommends refining the contents of existing protocols and formulating new ones that ensure that problems that were not previously covered are tackled in a cooperative manner. In the spirit of a systemic approach, it is particularly recommended that ambitious protocols on land-based activities aimed at marine conservation are agreed, like those found in some existing conventions, for example the Barcelona Convention (Section 3.4.2). It should be investigated to what extent the principles outlined in the EU Marine Strategy Framework Directive should be included in the protocols to be agreed for other marine regions. Given the growing expansion of uses in and on the oceans, it should also be examined to what extent objectives and basic principles of marine spatial planning could be included in such protocols (Section 7.3.9.2).

Regional action plans enable ocean governance to continue developing dynamically. As such action plans are not legally binding, countries find it easier to agree far-reaching objectives backed up by concrete measures. Despite their non-mandatory nature, such action

Box 7.3-1

Regional focus on the Arctic: Comprehensive protection of a unique ecosystem

Unlike the Antarctic, which is an ice-covered continent surrounded by the sea, the Arctic is an ocean – much of which has been covered by ice all year round up to now – surrounded by land. According to the WBGU's vision, the Arctic Ocean should be assigned to the common heritage of mankind (Section 7.2). At the same time the Arctic, with its marine and terrestrial ecosystems, is a unique natural environment particularly worth protecting. Its use should be subject to very strict conservation requirements. It is particularly worth protecting because of its ecological significance, its special role in the climate system, and the fact that it is altering rapidly as a result of human-induced changes in the Earth system (Box 1.2-3).

The Arctic is home to communities of organisms that are able to survive in extreme environmental conditions. Compared to temperate latitudes the Arctic has a lower diversity of species, and the vegetation period is comparatively short due to the long polar night. These two factors contribute to the fact that Arctic ecosystems are much more fragile and sensitive than those at temperate latitudes. The Arctic Ocean has productive marine ecosystems with large fish stocks (Box 4.1-1).

The Arctic plays a special role in the global climate system as an early-warning system for changes. The ice cover usually reflects part of the solar radiation that falls on the Arctic, so as the Arctic snow and ice masses melt, darker land and sea surfaces are revealed that absorb the solar radiation, thus speeding up the process of warming. Along with other factors, this means that global warming is manifested in the Arctic as an increase in temperatures that is well-above average. We are already seeing an accelerating reduction in the size of the Arctic sea ice in the summer months and a stronger melting of the Greenland ice cap and the permafrost soils in the region. If the Arctic land ice melts, this leads to a considerable rise in the sea level. The Greenland ice sheet alone stores a volume of water that could raise sea levels by approximately 7 m in the long term (Section 1.2.7). Climate change has far-reaching effects on the Arctic ecosystems, including in fish stocks (Box 1-1).

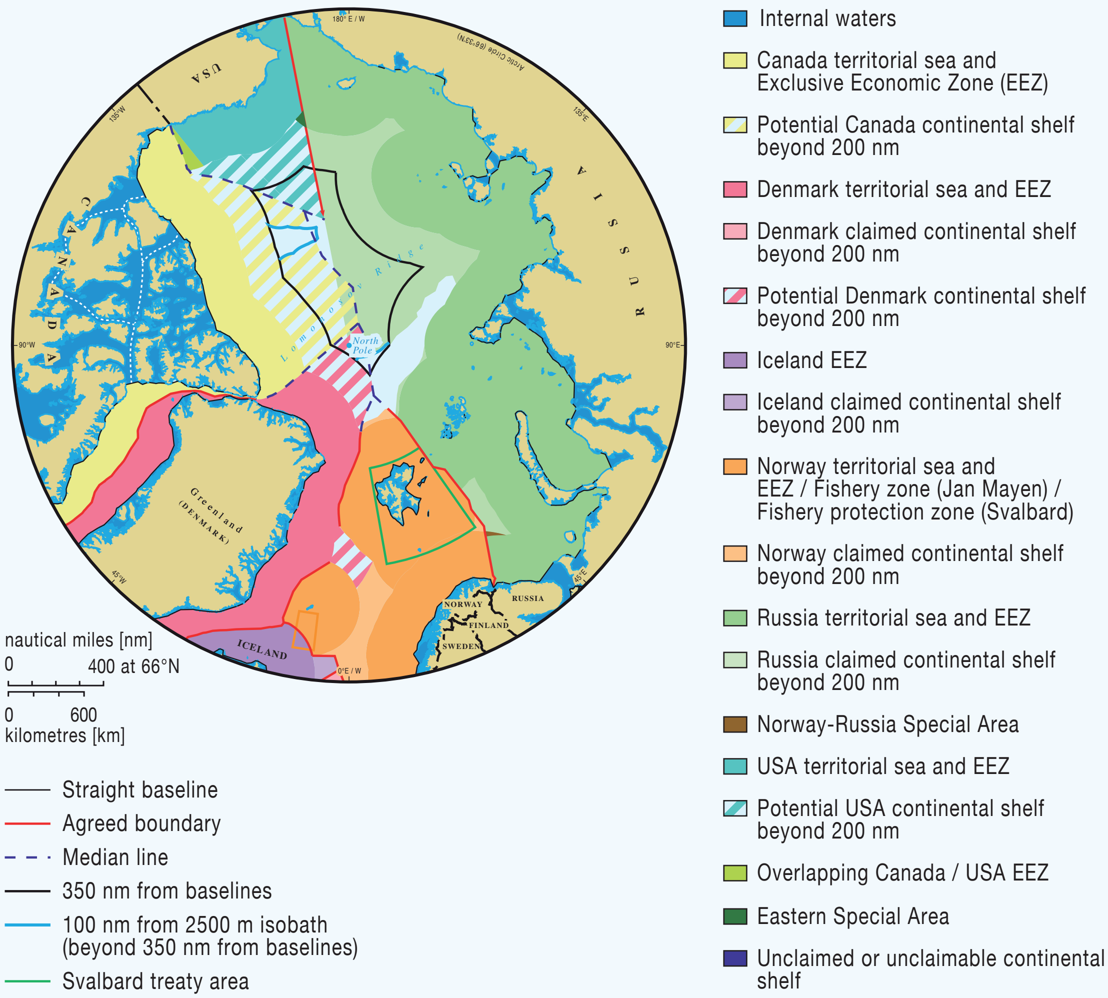


Figure 7.3-1
Maritime jurisdiction and boundaries in the Arctic region. For more detailed information see IBRU (2013).
Source: IBRU, 2013 (www.durham.ac.uk/ibru/resources/arctic)

For a long time, the Arctic Ocean and the sparsely population regions of Alaska, Greenland, Canada and Siberia have been spared intense economic exploitation due to the extreme climate, the year-round ice cover and the resulting difficult passage for shipping. Almost four million people live in the region, including many indigenous peoples who to some extent still practise their traditional way of life, which is well adapted to the Arctic region.

Access to such Arctic resources as oil, gas, gold, zinc, rare earth elements and fish stocks, as well as the passage of ships through the region's waters, have been made easier by continuous technological development and the retreat of the Arctic ice. The majority of the resources thought to be in the Arctic and the opening-up shipping passages lie either within the EEZs or in the area of the extended continental shelf, which can be claimed by the coastal states on successful application to the Commission on the Limits of the Continental Shelf (Figure 7.3-1). All the countries bordering the Arctic have announced that they intend to extract its mineral resources. Already a number of these countries are engaged in exploratory drilling with the aim of mining the oil and gas reserves. There are plans to construct regular production plants in the coming years. Pipelines, port and safety infrastructure, and processing industries are being further expanded. The volume of shipping in the region is also likely to increase if the passages are free of ice in the summer, as is expected. At the same time, we are seeing disagreements between the countries surrounding the Arctic over borders and the expansion of the continental shelf.

Increased use of the Arctic involves considerable risks for the fragile Arctic ecosystems. Resource extraction and the associated accidents (especially in the case of oil and gas production), the increased presence of industry, the growing volume of shipping and the risk of shipping accidents will lead to an increase in the amount of pollutants entering the Arctic. Depending on the severity of the pollution and accidents, this could cause irreversible damage to the Arctic's natural environment.

There are already plans for extensive economic use of the Arctic Ocean and its sea bed for oil and gas production and mining other resources. Nevertheless, the WBGU believes that the most appropriate instrument for protecting the Arctic, given the specific factors mentioned above, would be a comprehensive, cross-border marine protected area covering both the Arctic areas of the high seas and the adjacent EEZs. This Arctic protected area could be negotiated and implemented either by the countries bordering the Arctic via the Arctic Council or directly by the various states, and be expanded to include the share of the Arctic high seas under the terms of UNCLOS (Box 3.2-3). Exploration and mining of mineral resources, including oil and gas, should be banned in the protected area and large no-take zones set up for industrial fishery. Until a comprehensive Arctic protected area has been established, the following recommendations would represent steps in the right direction:

- *Arctic protected area for the High Arctic:* First, the High Arctic should be declared a protected area. Protected-area status involves restrictions on rights of use. This would represent an important step towards establishing a comprehensive Arctic protected area.
- *Extend and promote existing Arctic protected areas:* In 2004 a working group of the Arctic Council drafted a Marine Strategic Plan which aims to promote networking between existing protected areas. The German Federal Government should support the efforts of the working group. There are already a number of marine protected areas within the territories of the various countries bordering the Arctic, for example in Canada, Norway and Greenland. These efforts should also be honoured and encouraged.
- *Institutionalize the sustainable use of the Arctic Ocean and the sea bed:* The WBGU recommends that the international community in general, and the states bordering the Arctic in particular, should agree to protect the Arctic Ocean and its ecosystem. Within the EEZs and the extended continental shelf, too, the Arctic Ocean should only be used sustainably. Uses – especially the offshore production of oil and gas – should be allowed only subject to strict safety and environmental-protection standards that reflect the fragility of the Arctic ecosystems.
- *Implement a binding Polar Code:* Germany should support the efforts of the European Commission to develop a binding Polar Code on shipping in the region under the auspices of the International Maritime Organization (IMO). The aim here is to counter the environmental risks from growing shipping traffic in the Arctic and to implement corresponding safety measures.
- *Establish a liability regime:* To date there is no liability regime for the Arctic Ocean that could be applied in the event of significant environmental damage, for instance as a result of oil-rig disasters, collisions between ships, pipeline leaks or other incidents. A liability regime in the Arctic would have to provide a clear framework for action with liability provisions for the individual user groups and potential causers, such as countries, companies or other stakeholders.

plans can acquire considerable normative force, thus boosting the effectiveness of regional cooperation. This makes them a useful complement to binding protocols as an instrument of regional ocean governance.

Action plans already exist in some regional seas agreements such as OSPAR and HELCOM, and they are the central instrument in the UNEP Regional Seas Programme; indeed, all the regional programmes set up under the latter include an action plan. The WBGU recommends refining or reformulating action plans. The Baltic Sea Action Plan in particular, agreed in 2007 by the HELCOM member states and the EU – which explicitly calls for the implementation of an ecosystem approach, formulates environmental goals and tracks the development of corresponding indicators – demonstrates how the precautionary principle and adaptive management can be implemented. In the case of agreements primarily concerning economic activities, it would also be useful to adjust existing action plans, which often focus on specific sectors, to also include marine conservation.

Germany and the EU can help shape this process on several different levels. First, they should support the expanded use of protocols and action plans within the UNEP Regional Seas Programme. The EU in particular has further ways of exerting its influence as an active member of various regional seas agreements. In addition, German and EU development policy can support the agreement of ambitious protocols and action plans, as well as the creation of appropriate organizational capacity to help implement and enforce them.

Not least, the planned formulation of a global action plan for the seas as part of the Oceans Compact (Section 7.3.3.1) offers huge potential. Germany and the EU have great expertise in the subject matter thanks to their participation in sea agreements, some of which are very well developed (e.g. OSPAR, HELCOM), and their excellent, globally recognized marine research. It is especially important that the regional action plans are properly dovetailed with a future global action plan.

Set up and strengthen regional marine commissions

The WBGU recommends the further institutionalization of regional seas agreements by establishing regional marine commissions or offices with far-reaching powers. This could strongly promote the strengthening and extension of regional ocean governance (Section 3.4.2). In particular, the range of tasks carried out by regional marine commissions should be developed from purely sector-related powers (e.g. RFMO, Section 7.3.4.3) into an integrated approach covering all relevant uses as well as marine conservation. By bundling technical knowledge and promoting exchange between member states, regional marine commissions can then create a basis for more binding and flexible regional ocean governance. Furthermore, the WBGU recommends making decisions by the regional marine commissions mandatory. Particularly in the case of well developed collaborations such as HELCOM, it should be examined to what extent it might be useful to replace the unanimity rule with qualified majority votes.

7.3.5.3
Improve dovetailing in regional ocean governance

The WBGU particularly recommends cooperation between neighbouring or overlapping marine conservation agreements. Synergies can be generated here by improving coordination between stakeholders in a particular marine region, making objectives more coherent and improving their connection to governance mechanisms. For example, a positive effect has been achieved by the intensified cooperation on marine protected areas between the OSPAR Convention, which is not explicitly responsible for fishery, and the RFMO active in the same region (Section 7.3.9.1). This could be used as an example to drive the harmonization of objectives and measures in other regions, too, and to improve regional coherence. Germany and the EU should also use their influence to improve the regional integration of marine conservation and fisheries governance within the framework of the UNEP, the FAO and the Oceans Compact. Moreover, harmonization should be improved between international agreements signed up to by the EU on the one hand and the EU's off-shore and on-shore policies.

As technology develops and new uses of the oceans appear, new regulation is needed. Increased cooperation between different regions and sectors is also required. Relevant technical developments should be supported by policy-making at a regional level with regard to possible uses and conservation requirements. The technical developments currently taking place in the energy sector in particular require integrated regional evaluation because of their potential impact on the marine environment and their possible interactions with other uses. With regard to renewable marine energy, the WBGU holds up its earlier recommendations on international energy and technology policy (WBGU, 2011:332). At the regional level, for example, cooperation between IRENA and the UNEP's Regional Seas Programme would be possible, enabling the diffusion of renewable-energy technologies and ensuring the sustainable use of the oceans. Cross-border cooperation would also be possible in marine spatial planning, a forward-looking instrument that opens up possibilities for considering different interests in a cooperative fashion (Sections 7.3.9, 7.5.1.2).

Furthermore, the WBGU recommends strengthening collaborations between different regions. As demonstrated by the cooperation between OSPAR and the Abidjan Convention (Section 3.4.2), capacity building for monitoring, implementation and enforcement can be promoted by sharing knowledge, particularly in weaker economic regions. Cooperation between agreements with comparatively well-developed capacities (e.g. HELCOM and OSPAR) can be used to harmonize indicators and improve monitoring.

Existing inter-regional collaborations should be strengthened so that joint challenges can be addressed in an integrated fashion across sectors. This should be carried out using the principles and criteria suggested by the WBGU in Section 7.1 and in accordance with existing legal regulations (e.g. FSA, CBD, CITES). The development of further possible collaborations should be called for within the framework of the UNEP Regional Seas Programme, potentially also involving the Asian and Pacific marine areas.

Table 7.3-1
Compilation of the cost estimates from chapters 3 and 4, where available. There are no explicit estimates on one-off compensation payments, the one-off costs of establishing marine protected areas, or the global expansion of renewable energies from and in the oceans.
Sources: [1]UNEP, 2011b; [2]POGO, 2010, 2011; [3]Balmford et al., 2004; [4]WBGU, own estimates based on the HSTF, 2005, 2006 and Brooke et al., 2010

One-off costs		Annual costs	
[US$ bn]		[US$ bn]	
Fisheries reform[1]	190–280	Fisheries management[1]	10
		Maintenance of a network of marine protected areas[3]	5–19
Establishment of a monitoring system (GOOS)[2]	10–15	Maintenance of a monitoring system (GOOS)[2]	5
		Control and enforcement of ocean governance[4]	2–3
Total	**200–295**	**Total**	**22–37**

7.3.6
Develop concepts for the joint funding of ocean governance

The international cooperation required for a global, sustainable stewardship of the oceans should be supported by financial transfers between states. Reorienting fishery and aquaculture towards sustainability (Section 7.4), creating and maintaining marine protected areas (Section 7.3.9) and implementing and enforcing ocean governance (Section 7.1.5) generates costs in individual countries, while benefitting all countries. It is therefore important to seek out ways to distribute these costs fairly between all states.

The WBGU follows the precautionary principle and the principle of equality as its overriding principles with regard to burden-sharing. The precautionary principle emphasizes the responsibility of the community of states for the sea as a global collective good. As discussed in Section 3.5.8, the funding burden could be shared equally between all states by means of a per-capita distribution of costs. On principle, however, the varying ability of different countries to pay should also be considered when distributing costs. Transfers from economically strong countries to countries with smaller gross domestic products (GDPs) are often essential to enable the latter countries to comply with ocean-conservation regulations. Generally, transfers increase the willingness of the receiving countries to agree to a demanding governance regime for the conservation and sustainable use of the oceans.

One option for burden-sharing is to create international funds. The money for such funds should come from user charges, among other sources.

The costs of the conservation of the oceans and the transition to their sustainable use world-wide can only be roughly estimated in the context of this report. Table 7.3-1 presents the estimated one-off costs of fishery reform and the establishment of a global monitoring system. Total estimated costs are at least US$200–295 billion. Additional total ongoing annual costs of US$22–37 billion should also be taken into account (Table 7.3-1). There would also be other costs that are difficult to quantify, such as compensation payments for non-use of the oceans or for developing renewable energy from and on the sea (Section 7.3.7).

7.3.6.1
Strengthen international financing mechanisms

A number of international funds and programmes already exist that support sustainable fishery management, sustainable aquacultures, and the creation of protected areas. At present, funding for the protection of marine and coastal ecosystems via international financing mechanisms comes from various sources (GEF, World Bank and other UN organizations such as FAO and UNDP). However, these funds are distributed in a relatively uncoordinated way and are highly inadequate in terms of volume (Section 3.6.8). The available funding should therefore be bundled and increased in terms of its total volume.

The WBGU further recommends setting up two additional international funds: one to support national measures for the conservation and sustainable use of the oceans within the EEZs, and another to finance conservation on the high seas. Existing structures such as the Global Environment Facility (GEF) should be used to manage this money.

Funding mechanism for the sustainable use and conservation of the oceans within the EEZs

The sustainable management of the oceans within the EEZs is the responsibility of the respective coastal states and as such should in principle be funded by them. In the WBGU's vision, coastal states are accountable to the World Oceans Organization (WOO) for the sustainable use of the oceans within their EEZ (Section 7.2.2.1). A transfer mechanism would support primarily those coastal states whose economies are too weak to enable them to bear the costs that arise (e.g. for fishery reform, monitoring and reporting systems) on their own. This would increase the willingness of these states to meet their obligations. Following the equality principle, all states should participate in financing the fund; the size of payments by individual states should be based on their economic strength.

Funding mechanism for protecting the high seas

Money should be made available through an international fund to protect the high seas, in particular for monitoring and surveillance purposes and for creating a network of marine protected areas (Section 7.3.9.1). Following the equality principle, not just coastal states but all states should participate in the fund, whether they use the high seas directly themselves or not. Apart from anything else, all countries contribute to the endangering of the high-seas ecosystems at least indirectly (via trade, consumption, tourism and land-based activities) and they all benefit at least indirectly from the conservation and sustainable use of the high seas and the preservation of these ecosystems. The size of payments by different countries should depend on their respective economic strength.

7.3.6.2
Use the mechanisms of the Framework Convention on Climate Change for funding

Alongside the new funds for financing ocean governance to be set up as described above, it would also be possible to use existing funding mechanisms within the United Nations Framework Convention on Climate Change (UNFCCC) for the conservation and sustainable use of the marine ecosystem. The WBGU supports the idea of integrating the conservation of coastal forests storing carbon dioxide (e.g. mangrove forests) into the REDD+ mechanism of the UNFCCC. However, the WBGU does not consider it desirable to categorize coastal ecosystems as 'blue carbon' and to fund their conservation via carbon markets (Box 1.2-1).

It would be possible to support the funding of new renewable-energy-generating plants on the seas via the (funding) mechanism of the UNFCCC (Joint Implementation, Clean Development Mechanism, Climate Change Focal Area of the GEF Trust Fund, Green Climate Fund). The WBGU does not consider it necessary to create an additional international funding mechanism for renewable energy on the seas, since the advantages accruing from the use of the energy would be mainly national or regional and would largely benefit private companies. It would therefore be appropriate for the funding for new plants to come from those who stand to profit from them.

7.3.6.3
Utilize user charges as a source of funding

As with all international transfer payments, the question arises as to which is the best way to generate payment flows that are as substantial and reliable as possible into the new funds and transfer mechanisms proposed in Section 7.3.6.1. In the context of the seas and oceans, the WBGU recommends generating the necessary money from user charges, among other sources (WBGU, 2002). User charges can take on the incentive function described in Section 7.3.7. They can also make a significant contribution to funding ocean conservation, since the revenue generated – unlike taxes – can be ring-fenced.

Greater use should therefore be made of user charges in the international funding of sustainable management and the conservation of the oceans and their resources. In the future, they should apply first and foremost to areas that have hitherto been available free of charge. For example, nation states should charge for the use of oceans within their EEZs (e.g. fishery and aquaculture licences, charges for sporting and tourism-related activities with the EEZ; Section 4.1.3.6). In order to avoid competitive disadvantages for specific countries and to prevent users from moving elsewhere to avoid charges, it would be useful to have international agreements with the aim of harmonizing user charges.

7.3.7
Employ incentive instruments and funding structures

The institutional and political prerequisites described in Section 7.3.2 should ensure that investments in the sustainable use of the oceans are less risky than investments in non-sustainable uses in the medium to long term. In addition, targeted economic incentives such as user chargers, payments for ecosystem services or temporary subsidies should be used to support the conservation and sustainable, long-term-oriented uses of the oceans. The provision of additional investment capital by development banks, state hedging of risks and the establishment of new business models would facilitate access to affordable loan capital for potential investors.

7.3.7.1
Create economic incentives for sustainable uses

Targeted economic incentives such as user charges, payments for ecosystem services or temporary subsidies can be used to support sustainable and long-term-oriented uses. They increase the return on investments in sustainable as opposed to non-sustainable uses. In addition, they further reduce the associated risk. This makes investing in the long-term-oriented management of the oceans additionally attractive for both users and potential funders.

User charges for marine resources and ecosystem services

User charges are a way of charging users and polluters for the social costs of using the oceans – as manifested in the destruction or degradation of marine and coastal ecosystems; they also internalize these costs. They create an economic incentive to use the oceans in a resource-efficient way and avoid non-sustainable uses. All countries should therefore levy user charges within their EEZs, e.g. in the form of fishery and aquaculture licences, catch fees, taxes on by-catch, port fees or entry fees for protected areas. A bonus/penalty system could be used to grade the level of user charges depending on whether the user meets certain sustainability standards. This would also create further incentives for investments in fuel-efficient ships and sustainable fishing gear (Section 7.4.1). Importantly, user charges should be designed in a socially acceptable way. Other incentive systems, such as payments for ecosystem services, could be used in particular for small-scale fishery and aquaculture in developing countries (Section 7.4.1.8).

The German Federal Government should examine whether more user charges for direct ocean uses could be introduced in Germany. Under international agreements it should also push for the general introduction and harmonization of user charges for the seas. This would avoid competitive distortions and prevent users from taking evasive action to avoid charges (e.g. by moving to EEZs where there are no user charges) and the negative consequences of such actions.

Payments for ecosystem services

For small-scale activities – particularly where few alternative sources of income are available – payments for ecosystem services (PES) should be used to create positive incentives for sustainable use (Section 4.1.3.6). Payment for ecosystem services makes sustainable activities a source of income, putting individual actors in a position to do without non-sustainable uses and become involved in supporting ecosystem services. Payments in the fields of fishery and aquaculture could apply to using sustainable fishing methods, to the sustainable operation of aquacultures in connection with coastal conservation (e.g. conservation of mangroves), or to ceasing fishery or aquaculture activities altogether (e.g. in marine protected areas or during temporary fishing restrictions; Section 7.4).

Unlike user charges, payments for ecosystem services are particularly suitable for low-income regions where there are no alternative sources of income. Here, they can create incentives for reducing non-sustainable uses of the oceans and ensure that the seas and coastal areas continue to generate as varied a range of ecosystem services as possible in the future. For this reason, the German Federal Government should place a greater focus on this instrument, particularly in development cooperation. Payments for ecosystem services in the field of fishery and aquaculture would also be possible at the EU level, analogous to the compensation payments for agriculture made by the European Agricultural Fund for Rural Development. For example, payments could be made to fisheries and aquaculture farms that sign up voluntarily to management systems that are particularly environmentally friendly.

Compensation payments for non-use

In situations where the designation of protected areas or restrictions on catch volumes in certain fishing grounds suddenly and massively reduce the income opportunities of various stakeholders, public compensation payments should be used to cushion the losses in income and facilitate the transition to alternative methods of income generation (Section 4.1.3.6). Unlike payments for ecosystem services, compensation payments primarily serve the objective of burden-sharing and the fixed-term, one-off cushioning of social impacts (e.g. Sections 7.4.1.3, 7.4.1.8). Compensation payments for non-use can take the form of repurchasing fishing licences, boats or fishing gear. It is important to ensure that the catch volume and fishery activities as a whole are limited by regulation and that withdrawn licences and decommissioned boats and fishing gear are not simply replaced by new ones. Compensation payments can also include reimbursing and retraining people employed in upstream industries that are directly affected by non-use, as well as providing people with other services such as advice or consulting.

Certification of fishery and aquaculture products

Introducing voluntary or legally binding standards for the certification of fishery and aquaculture products (as is currently done by the Marine Stewardship Council) creates indirect incentives for sustainable activities.

See Section 7.3.8 for relevant recommendations.

Promotion of renewable marine energy

As far as the use of renewable energy from the sea is concerned, there is a great need for targeted public support of technology and innovation. In this context, the WBGU regards fixed-term feed-in tariffs and/or feed-in bonuses coupled with low-interest loans and loan guarantees by development banks (Section 7.5.1) as suitable instruments for strengthening long-term-oriented investments. At the same time, other innovative promotion instruments should also be sought with the aim of ensuring the effective and efficient diffusion of renewable marine-energy technologies. To promote offshore wind farms, for example, it would be possible to make use of tendering processes in which the level of payment is determined by a bidding competition (Section 5.4).

7.3.7.2
Develop funding structures for long-term-oriented investments

To increase investment in sustainable uses, it is not sufficient to create a clear political framework and suitable economic incentive structures; additional investment capital is also needed. Public funding mechanisms providing low-interest loans or loan guarantees and new business models can facilitate access to affordable loan capital for potential investors. With worldwide private financial assets thought to total around US$180 trillion (McKinsey, 2011), with suitable public support it should in principle be possible to raise the necessary funds for investment in the sustainable use of the oceans.

Make greater use of the funding instruments of development banks

Thanks to leveraging effects, the amount of money generated can, as a rule, be increased several-fold if public funds are used to support private investments. These are thus very efficient instruments for encouraging private investment. One option to support private investments is for development banks to offer cut-price loans and loan guarantees, or for the state to assume the risk of the investment. In Germany, for example, *KfW Mittelstandsbank* offers support for the funding of offshore wind farms in the North and Baltic Seas with its special 'Offshore Wind Power' programme. Loan programmes like this and others for funding sustainable fishery and aquaculture should be expanded and made permanent. Money is also needed to support innovative business models; this could be supplied through public-private venture-capital funds.

The state could hedge or assume risks by bundling private and public money in structured funds and then having development banks take on the riskiest shares, for example. National and international development banks should create more programmes and funds of this type for investing in the sustainable management of the oceans.

Promote new cooperative funding models

New cooperative funding models are also a good way of providing access to loan capital and, in so doing, reducing barriers to investment. One option is for a number of small-scale fisheries to join together to form a 'licence bank', bundling their own investments with seed capital from an investing partner or a national development bank. Using this start-up capital, they can then attract other private investors (Section 4.1.3.6).

'Fisheries trusts' are a similar model; they bundle funds from private foundations, low-price state loans and additional bank loans. The money accumulated in this way is used to purchase fishing licences which are then 'leased' by the fishermen for a fee. This allows small-scale fisheries with little capital, but a strong orientation towards sustainability, to use fishing licences. Part of the profits from fishery is then distributed to the external lenders – a precondition for their contributing capital in the first place.

In Asia, local aquaculture businesses sometimes group together to form 'aquaclubs'. Companies jointly adapt their business methods to make them more sustainable – something that neighbouring businesses would not be able to do on their own, because of the spread of pollutants in the water. The aquaclubs also offer cost benefits in terms of joint sourcing of fish fry and sustainable feeds. In addition, they make it easier to have sustainable aquaculture products certified, as the certification costs – especially the transaction costs – can be reduced by working as a group (Section 4.2.3).

Cooperative models such as licence banks, fisheries trusts and aquaclubs should be backed by loans from national development banks. Such approaches should also be supported more strongly in the framework of development cooperation and via international development banks.

7.3.8
Strengthen and expand private governance

Alongside public governance, private initiatives for the conservation and sustainable use of the oceans should also be promoted. The WBGU recommends strengthening forms of private governance in which different private stakeholders – mainly companies and non-governmental organizations (NGOs) – join together, develop regulations and commit themselves to upholding them. Private collaborations and initiatives of this kind can bring about changes in the management of the oceans without direct state intervention.

7.3.8.1
Introduce a standardized Europe-wide system of certification for wild-caught fish and seafood

Certification programmes such as those of the Marine Stewardship Council (MSC), Friend of the Sea (FOS), the Aquaculture Stewardship Council (ASC) and Naturland are examples of private governance in the sustainable use of the oceans (Section 3.5). The programme run by the MSC is the oldest and by far the largest. The number of fisheries certified by the MSC has grown sharply in recent years and is likely to continue growing. Certification enables consumers to tell whether a certified fishery is run according to certain environmental criteria.

However, if the criteria for certification are not ambitious enough or leave too much room for interpretation, this weakens the credibility of voluntary certification as an instrument of private governance.

Moreover, there are many young eco-labels at the national level, and more are likely to appear in the future. There has been very little research into whether these newer labels contribute to sustainable fishery. As their number grows, there is a danger that consumers will no longer understand the different levels of protection indicated by the different eco-labels. If this happens, the labels will no longer assist consumers' freedom of choice, and their significance for consumer decisions will become marginal.

The WBGU therefore recommends setting minimum requirements within the European Union on private sustainability standards for wild-caught fish and seafood products. While private standards can be selected at will, this minimum standard would have to be met by all suppliers of sustainability-certified fish and seafood products within the EU. Checks on minimum standards would clearly show whether private firms were meeting them or not, and sanctions could be imposed where appropriate. This would help improve the protective function of specific eco-labels and at the same time boost consumer confidence, given the large number of different labels. The standard should correspond to the FAO Guidelines for the Ecolabelling of Fish and Fishery Products from Marine Capture.

At present, there is no EU-wide sustainability standard for wild fisheries. A further step would therefore be to introduce a standardized EU quality label for fish and seafood products from sustainable wild fisheries.

7.3.8.2
Improve legal certainty on the WTO-conformity of sustainability standards

The conformity of voluntary – both private and public – sustainability standards and corresponding labelling systems with applicable international commercial law should be clarified in the context of the WTO negotiations (Section 7.4.1.7). With this in mind, clear criteria should be developed for deciding when process-related standards for resource and environmental protection and corresponding labelling systems conflict with existing trade-liberalizing regulations and when they do not. Adjudications by WTO arbitrators on this matter have been ambiguous up to now. To improve legal certainty in this area, the legal relationship between multilateral environmental agreements and/or the RFMO and WTO rules on the one hand, and the system of investigation in relevant cases of conflict should be fundamentally and conclusively clarified.

7.3.9
Considerably expand marine protected areas and spatial planning

Marine protected areas (MPAs) are an important component of marine spatial planning systems. They create and coordinate ocean zones allowing different intensities and types of use in order to resolve conflicts over use and implement a systematic approach (Section 3.6.2). Spatial planning should be based on scientific criteria and its effectiveness regularly checked. A number of graded conservation categories with different weightings of conservation and sustainable use also exist for marine protected areas, the most extreme being total protection and the complete exclusion of uses (e.g. no-take zones for fishery). As a rule, the core zones are more strictly protected than the peripheral areas. Marine protected areas should be organized into an overall system of protected areas to make them more effective, more representative and better connected. This requires international cooperation. Designations of protected areas should also be integrated into an overall concept of marine spatial planning (Section 7.3.9.2) and incorporated into the system of sustainable fisheries management (Sections 4.1.3, 7.4.1).

7.3.9.1
Expand marine protected areas

Protected areas are one of the most important instruments for maintaining biological diversity on both land and sea. The international community has on many occasions called for the creation or expansion of a network of marine protected areas (MPAs), most recently as part of the Biodiversity Convention (CBD) and in the Rio follow-up process (Section 3.6.2.1). The following recommendations on marine protected areas refer mainly to the global level. In the context of Europe, they aim primarily to have an effect beyond the borders of the EU and not specifically at a national or German level. The WBGU refers to the work of the SRU (2012a, b) for the European context, where the protected area designations under Natura 2000 (the Habitats Directive) and the Marine Strategy Framework Directive play a leading role, as well as for the German context. The WBGU reaffirms the recommendations made in its special report on 'The Future Oceans' (WBGU, 2006), particularly the objective that an ecologically representative and effectively managed system of marine protected areas should cover at least 20–30% of the total global marine area.

Implement and tighten international targets for protected area designations

The target agreed at the 10th Conference of the Parties to the CBD in Nagoya – 10% coverage for marine protected areas by 2020 – would not appear to be ambitious enough, although the emphasis on making such areas representative, well connected, effectively managed and integrated into the surrounding 'seascape' is to be welcomed (Aichi Target 11: CBD, 2010a). In view of the current level of protection – only 1.6% of the total global marine area, 4% of EEZs and 7.2% of coastal waters (Bertzky et al., 2012) – accelerating the knowledge-based implementation of existing objectives appears more urgent than increasing coverage targets (Section 8.3.2.2). Action is particularly required on marine conservation on the high seas (Section 7.3.4.2). The German Federal Government should strengthen its efforts to effectively implement marine protected areas in development cooperation (Section 7.3.6).

Use marine protected areas as an instrument for sustainable fishery management

Marine protected areas – especially zones with geographical or time restrictions on fishery – are not only vital for protecting biological diversity, they are also an important instrument for maintaining or rebuilding overexploited fish stocks. This is because more fish biomass is built up in protected areas, and larvae can be exported to surrounding fishing areas (Section 4.1.3.4). As a priority, large adjoining no-take zones should be established in areas where they can serve to protect important habitats (e.g. spawning areas) and lifecycle stages (e.g. young fish). However, they can also act as important reference areas for marine research, enabling a comparison with areas where fishery or other uses take place. Habitat-damaging uses such active bottom-contact fishing methods (Section 7.4.1.4) should not be permitted in marine protected areas.

Overcome blockades against marine protected areas on the high seas

Marine protected areas, including those on the high seas, are important instruments, not only for preserving biological diversity, but also for making fishery sustainable. However, they are even more under-represented on the high seas than in EEZs. The WBGU (2006) has already drawn attention to the urgent need for action and to the regulatory gaps relating to MPAs on the high seas, and derived appropriate recommendations. Since then, the OSPAR Convention for the North-East Atlantic has achieved a major breakthrough with regard to marine conservation on the high seas – in 2010 with the establishment of the first ever regional network of marine protected areas on the high seas to protect deep-sea habitats. The local RFMO (NEAFC) thereupon banned bottom-trawl fishing in large parts of these areas. Corresponding conservation agreements with the Seabed Authority are yet to be concluded. Despite the fact that implementing and enforcing these regulations remains a major challenge, these successes should be transferred to other regions wherever possible. The FAO's concept on vulnerable marine ecosystems (VMEs) and the FAO's guidelines on the management of deep-sea fisheries in the high seas (FAO, 2009b) offer valuable assistance in designating marine protected areas in the deep sea.

These positive experiences should also be used to overcome the blockades currently hindering negotiations targeting a new implementing agreement on biological diversity in the high seas (Sections 3.3.2.2, 7.3.4.2). The greatest efforts to create a network of protected areas on the high seas have been being taking place since 2004 in the UN General Assembly's informal Biological Diversity Beyond Areas of National Jurisdiction (BBNJ) Working Group. The Biodiversity Convention (CBD) does valuable preliminary scientific and technical work on behalf of the BBNJ Working Group, supplying criteria for selecting areas and initial lists of areas. The German Federal Government should make use of the need for action, which has been highlighted once again by the CBD, to exert greater pressure within the BBNJ Working Group with the aim of starting negotiations on the corresponding implementing agreement as soon as possible and bringing them to a swift conclusion (Section 7.3.4.2). In the meantime, collecting and disseminating positive examples of MPAs and results relating to them within a national or regional framework could help speed up international efforts to create MPAs.

The setting up of MPAs in the Antarctic region under the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) had to be deferred in 2013 due to opposition from certain countries. The next meeting will be hosted by Germany, giving the Federal Government a special opportunity – indeed responsibility – to bring the negotiations to a positive conclusion.

7.3.9.2
Expand cross-border marine spatial planning

In addition to the existing marine spatial planning in individual countries, a multilateral system that ensures cross-national coordination is required in order to realize large-scale uses and environmental-protection measures across zones in the future (Section 3.6.2.2). Current and future uses of the ocean and conservation interests have cross-border effects, so the planning of ocean uses should be increasingly supra-regional and international in order to avoid cross-border conflicts over use and not to interfere with marine ecosystem services. Positive examples of this are the EU-sponsored projects BaltSeaPlan and Plan Bothnia, under which cross-national spatial planning is being developed for the Baltic Sea.

The WBGU recommends strengthening marine spatial planning as an instrument, especially within the European Union, further developing the principles underlying the planning and the process, and anchoring them as mandatory elements in an integrated marine policy. To this end, the planning competencies of each member state should be transferred to the EU. To date, no such reallocation of competencies to the European level has been achieved, making consistent EU-wide marine spatial planning impossible. In the long term, for the sake of integrated ocean conservation and an integrated use of the seas, it might be useful to create a European planning authority for European waters. This body could ensure the sustainable use of the oceans in Europe.

Beyond the EU, marine spatial planning should also be strengthened by creating further sub-global confederations of states whose role would be to plan or re-plan adjacent areas of the oceans (regional seas) in a coordinated fashion. Cross-border spatial planning by sub-global confederations appears particularly meaningful in the case of regional seas, and in that context with respect to territorial seas and the EEZs.

Developing marine spatial planning is becoming a necessity for some European states as a result of their national energy strategies. Germany could play a pioneering role here, facilitating a European exchange of experience by organizing information events and conferences. More research is needed to determine the exact form that marine spatial planning should take. Given the current state of knowledge, it is not possible, for instance, to say which uses can be integrated or combined and which are mutually exclusive (Section 8.3.2.2). The ocean also makes particular demands on the spatial planning approach. On the one hand, the vertical dimension of the water column potentially allows for vertical or three-dimensional planning. At the same time, in designating useable areas it must be remembered that the sea, as a fluid medium, is in constant flux.

The EU could play a similar role in cross-border spatial planning, if joint spatial planning becomes established at the European level. This could potentially function as a best-practice example which could later be imitated by others.

7.3.10
Promote the harmonization of existing liability regimes

Where accidents – involving oil tankers or oil platforms, for example – have occurred in the past, regional and national liability mechanisms have revealed gaps and deficits in the current law on liability. At present, the only international liability standards exist in the field of oil shipping. Elsewhere, national liability regimes exist side-by-side without even a minimum of harmonization (Section 3.6.5).

The WBGU therefore supports the European Commission's intention to standardize the law on liability for offshore activities. On the basis of a proposal by the EU Commission (2011c), efforts are being made to establish a standardized liability framework for the EU's marine waters, including EEZs, which would make the causers of damage to the marine environment liable for the costs of preventive and remedial measures.

Moreover, the WBGU recommends that, at future meetings of the UN General Assembly (UNGA), the German Federal Government and the European Union's member states remind the parties to UNCLOS of their commitment to establishing effective liability systems under Article 235 of UNCLOS. A decision by the UNGA on this matter should again call for the implementation of UNLCOS by national states – a political signal indicating the importance of such systems for the marine environment.

7.4
Food from the sea

In many regions – particularly in developing countries – ocean fishing and aquaculture play an important role in food security, health, employment and income. However, most fish stocks around the world are still poorly managed today, both economically and ecologically. As a rule, too little attention is paid to the long-term perspective. Despite ever greater efforts by fisheries, global yields are now declining. Sustainable use is still a long way off for most countries and regions (Section 4.1.1).

Fishing has been impacting on the oceans for a long time and that impact is growing. Overfishing poses a serious threat to marine ecosystems and is one of the most important reasons for the rapid loss of biological diversity. At the same time, global demand for fish and seafood is on the increase – and with it the pressure on fish stocks. Since wild fishing cannot meet this demand, many people's hopes are directed towards aquaculture. However, the currently prevalent form of marine aquaculture focuses mostly on carnivorous species of fish and will not be able to meet these expectations: it requires large amounts of wild-caught forage fish to produce high-price fish such as farmed salmon, and this actually aggravates the overfishing of fish stocks. Nevertheless, sustainable aquaculture does have the potential to take some of the pressure off fishing by means of improved management and technological developments. To a certain extent, forage fish can be replaced by plant-based food, and other forms of aquaculture breeding, e.g. herbivorous freshwater species or mussels, avoid the problems outlined above (Section 4.3.3).

A fundamental shift towards sustainable fishing is required to avoid overuse, rebuild stocks, stabilize yields and protect marine ecosystems. Otherwise the contribution of the seas to the food security of a growing global population will be put at risk. If this transformation were to begin now, within a few decades – and in some regions even sooner – catch volumes could be even larger than today and remain so in the long term; biomass could increase substantially and stocks could become more resilient. For this to happen, the fishing pressure has to be greatly reduced for a period of time. This is a political challenge: such a turnaround would involve immediate political, social and economic costs during the transition period, while the profits from rebuilt fish stocks cannot be harvested until later.

Parallel to this there should be a transformation towards sustainable aquaculture that operates in a socially acceptable and environmentally responsible way. Currently, large sections of aquaculture operate in a non-sustainable manner (e.g. polluting waters, using large amounts of antibiotics, endangering wild populations). In many cases this could be reduced using existing technical solutions. Systemic interrelations also merit closer investigation: not only should aquaculture's dependency on marine fishery be drastically reduced, the impact on land use of substituting increasing amounts of fish meal and fish oil with vegetable materials (e.g. soya) should also be taken into account. For aquaculture to take some of the pressure off fishing, technological innovations are not enough: consumer behaviour also needs to change. In poorer coastal regions, the key issue will be to come up with regionally or locally adapted solutions for sustainable aquaculture production. Internationally, the main task is to refine and implement the voluntary agreements on aquaculture that already exist.

The good news is that important prerequisites for the transformation towards sustainability in fishing und aquaculture already exist. Although some international regulations are in place on aquaculture, much stronger foundations have been laid with regard to fishing: the UN Fish Stocks Agreement, the FAO Code of Conduct for Responsible Fisheries, the Biodiversity Convention and the results of the Rio summits provide ambitious international regulations and political objectives – e.g. to stop overfishing, rebuild fish stocks and reduce 'ecological risks and side effects' by 2015. The technical instruments and management options for sustainable fishing are also known. If existing knowledge and instruments are used consistently, these objectives are achievable for many fish stocks. What is needed now above all is the effective implementation and enforcement of these ambitious rules and objectives – including effective sanctions – and the closing of the remaining gaps in international legislation. From a global perspective, the long-term benefits far outweigh the costs of the transformation and justify the necessary investment in the long run (Section 4.2.5).

The transformation towards sustainable fishery is challenging, but possible. However, one should not underestimate the barriers to a complete shift of fishery towards sustainability. It is easy to say that there is a lack of political will to implement the change, but actually overcoming the path dependencies and removing the barriers is much harder, as it is difficult to bring stakeholders on board who are pursuing a strategy of short-term profit maximization. Nevertheless, in some countries the redirecting of fishing towards sustainability has already begun – and positive developments in ocean fishery are visible. In the EU most stocks are still overfished, but work is underway on a reform of the EU's Common Fisheries Policy, and the target is sustainability (Section 7.4.1.7).

The overall legal framework and incentive systems are important starting points. At present they often still offer misguided incentives, such as subsidies for expanding fishing capacity or for fuel. This makes it cheaper to hunt stocks and fails to internalize the ecological damage. In political decision-making processes, the long-term interests of society are often given less weight than the short-term interests of individual stakeholder groups. As a result, existing legal regulations are being hesitantly implemented. The current EU fisheries reform is one example among many of how difficult it is to overcome the blockades against transformation.

Section 7.4.1 initially outlines the most important overall elements of a global transformation of fishery towards sustainability. This is followed by some recommendations for action on particularly relevant topics. Section 7.4.2 presents recommendations for action on aquaculture as well as recommendations based on an integrated view of fishery and aquaculture. Further below, Section 8.3.3 identifies research gaps in how these transformations should be managed.

7.4.1 Recommendations for action on marine fisheries

The WBGU's analysis and recommendations on fisheries relate primarily to the global situation. Fisheries in Germany and the EU are not the focus of the WBGU's recommendations for action (see e.g. SRU, 2012b on this) with the exception of the cross-border impacts of fisheries agreements and imports (Section 7.4.1.7). Recommendations on fisheries as part of the development or reform of UNCLOS can be found in Section 7.3.4, which also offers recommendations on global fisheries governance. Section 7.3.8 contains recommendations on private governance, including certification. Marine protected areas – which are not only of critical importance for preserving marine ecosystems, their ecosystem services and their biological diversity, but can also serve as an instrument of fisheries management – are discussed in detail in the context of marine spatial planning in Section 7.3.9 and therefore only briefly touched on here.

7.4.1.1 Overall recommendations for a change of course in fisheries

Effective instruments of sustainable fisheries exist, but they need to be adapted to widely differing local and regional stocks and conditions. Furthermore, they must be intelligently combined and applied in order to avoid overfishing, rebuild stocks and minimize undesirable by-catch and damage to marine ecosystems (Section 4.1.3). An important precondition for implementing these objectives is creating as broad an understanding as possible in society that without a change of course in fisheries, substantial ecological damage, diminishing individual profits and economic losses are inevitable in the long term.

The WBGU's general recommendation is a combination of traditional approaches (fishing quotas, co-management, etc.) and spatial or temporal restrictions on uses, embedded within a system of marine protected areas (Section 7.3.9), with environmentally friendly fishing techniques and incentives for sustainable fishing management. The effective participation of local fishermen, non-governmental organizations and scientists in decision-making processes, and shared responsibility for implementing the agreed management system offer a good basis for sustainable management (Section 4.1.3).

The following points are particularly important for sustainable fisheries management:

- *Apply the ecosystem approach and precautionary principle:* The ecosystem approach should be rigorously applied in fisheries on the basis of the best scientific data (Box 4.1.3.1). Applying the precautionary principle is particularly important for safeguarding stocks and hence securing the future of fishing, given the frequent scientific uncertainties and information gaps (Section 7.1.3).
- *Set sustainable yield limits:* For most regions and stocks, managing fisheries on the basis of scientifically determined maximum sustainable yields (MSYs; Box 4.1-5) would in itself represent considerable progress; current yields are regularly in excess of these limits, sometimes significantly. When setting catch volumes, the MSYs should be regarded as the upper limit. Actual catches should remain below this level – i.e. there should be a safety margin – to take into account the impact of fishing on marine ecosystems (food webs, habitats, biodiversity, etc.), natural variability in marine ecosystems and future adaptation requirements caused by climate change or the acidification of the oceans, among other things (Section 4.4). Moreover, where stocks have already been decimated, catch volumes should initially be set much more conservatively to enable a swift recovery of stocks. For environmental reasons, a particularly large safety margin should be set for forage fish stocks (Box 4.3-1). This new role of MSYs – as an absolute upper limit, not a target level – should be enshrined in all levels of fishery governance through both legislation and intergovernmental agreements. Ecosystem-based plans for managing and rebuilding stocks should be drawn up and adhered to on this basis. These management plans should stretch across several years and be adapted to the region in question.
- *Observe sustainable yield limits:* The scientifically-based recommendations on permissible total catch volumes should be adhered to as closely as possible. Today they are regularly exceeded for the sake of

private interests. Instead, the fishing of overexploited stocks should be reduced until the stocks have recovered and sustainability requirements are met.

- *Reduce the level of global fishing effort:* A critical precondition for meeting yield limits is a significant cut in total global fishing effort by reducing overcapacity (Section 7.4.1.3). Measures aimed at reducing overcapacity should be promoted. For example, laid-up industrial vessels should be scrapped and not allowed to be exported or flagged out.
- *Ensure effective monitoring:* Institutions should monitor compliance with use and access rights (e.g. by means of inspectors on board or in harbours, satellite positioning systems or cameras). This is critically important for ensuring that management plans are adhered to.
- *Minimize ecological risks and side effects:* Current fishing impacts on ocean ecosystems not only by removing marketable fish, but also through by-catch and destructive or wasteful fishing methods (Sections 4.1.2.3, 7.4.1.4). Sustainable fishery should reduce these impacts to a minimum and make use of existing technical solutions.

7.4.1.2
Improve the preconditions for knowledge-based fishery

Marine and fishery research are preconditions for knowledge-based fishing. Whatever approach or indicator is chosen, it will be necessary to improve the scientific basis for monitoring fish stocks and yields and assessing the state of marine ecosystems. The basis for this is sufficient knowledge about the biology and ecology of the target species and the ecosystem, and also about the key drivers of the use of this resource (Section 7.3.1). Corresponding research recommendations can be found in Section 8.3.3.1. Efforts should be made to improve cooperation between scientists, and between scientists and fishermen.

- *Advance indicators:* Traditional fishery management aims primarily at maximizing the yield of target species. It neglects ecosystem factors such as the state of habitats or the interactions with other species. In line with the ecosystem approach, indicators that not only cover species that interact with target species (ecosystem-based multispecies approach, including non-target species), but also indicate the overall condition of the ecosystem should be gradually introduced into fishing management. There are a number of interesting approaches that should be examined and refined by research and development (Section 8.3.3.1) so that they quickly become available for application.
- *Improve data:* Many regions lack reliable data about fish stocks and catches. Here, the first step is to create or improve the scientific basis (monitoring, stock data, models; Section 8.3.3.1). Countries should commit to carrying out high-quality, regular, transparent surveys of fish stocks, landings and by-catch in their EEZs so the FAO has access to much better global data.
- *Ensure consistent transparency:* Data on fishing models, results, recommendations, quotas, yields and so on should be shared between researchers and used jointly. This data should also be published as early and in as much detail as possible to enable scientific and societal discourse.
- *Take into account the special situation in developing countries:* Developing countries need approaches that enable the sustainable management of fish stocks without detailed analysis. Simple initial methods that can produce good results on MSY even with limited data have already been discussed (Section 4.1.3.2). As long as countries rigorously apply the ecosystem approach and precautionary principle, and do not allow fishing right up to the limit of the MSY, these simple methods can bring about rapid progress in countries with weak management capacities. The methods should be further developed and their application promoted through development cooperation. Particularly in the case of small-scale fishing in developing countries, participatory monitoring and evaluation can help involve the local population in the governance of natural resources and promote democratic participation (Section 4.1.2.4).
- *Promote capacity building:* Development-cooperation organizations (e.g. World Bank, regional development banks, BMZ, KfW, GIZ) should focus on building up capacity (scientific, institutional, technical) for knowledge-based, sustainable fisheries management. The priority should lie with regions where fishery (mainly small-scale fishing; Section 7.4.1.8) plays a key role in food security. To be especially effective, large and overfished stocks in particular should be monitored. Another theme for development cooperation is how to cushion the social effects of fishery reforms by means of compensation payments. Positive examples exist around the world where a suitable mix of instruments has been used to rebuild stocks (Boxes 4.1-6, 4.1-7). The exchange of information about such positive examples should be improved and increased collaboration promoted, also on an international basis.

7.4.1.3
Reduce subsidies

The most important approach for reducing overcapacity is for the state to adjust overall conditions to the needs of sustainable fisheries, and especially to abolish subsidies (Sections 4.1.4.7, 7.3.2, 7.3.7). The Biodiversity Convention's target of abolishing subsidies harmful to the environment by 2020 (Aichi Target 3, CBD, 2010a) also applies to fishery. At the 'Rio+20 Conference' it was once again agreed to abolish subsidies that promote overfishing and overcapacity (UNCSD, 2012). The faltering WTO negotiations on fisheries subsidies should be swiftly brought to a conclusion that is in line with these decisions.

- Subsidies that have a harmful impact with respect to sustainable fishing should be quickly phased out worldwide, especially subsidies that are aimed at maintaining or increasing fishing capacity (e.g. building new fishing vessels or reducing fuel prices).
- The money saved by abolishing subsidies can be used to fund the necessary investments in sustainable fisheries management – e.g. by expanding or improving scientific and institutional capacity, such as fisheries research or improved monitoring of compliance with fishing regulations. In this way at least part of the necessary transformation of fisheries can finance itself through redirected subsidies (Section 4.1.4.7).
- The money saved should be used where necessary to cushion cases of economic hardship or create alternative sources of income for fishermen.
- Data on direct and indirect support for the fishing industry should be publicly available.

7.4.1.4
Stop wastefulness

Minimize and use by-catch

By-catch of undersized fish, non-target species, bottom-feeding organisms, marine mammals, sea turtles, seabirds and so on that are caught unintentionally and usually thrown straight overboard again should be reduced. To this end, the WBGU recommends gradually introducing a ban on discards, as well as a binding, total landing obligation for all target and non-target species (as in Norway, for example; Section 4.1.3.4). Endangered and protected species should be excluded from this obligation and returned to the ocean unharmed wherever possible. To reduce the losses to marine biodiversity caused by by-catch, mandatory ecosystem-compatible (i.e. environment-friendly) fishing gear and practices should be introduced. Fishing methods which, for technical reasons, inevitably involve large proportions of by-catch of non-target species – not just fish but also seabirds, sea turtles, marine mammals, etc. – should be banned and replaced by other methods. A landing obligation also reduces uncertainty with regard to estimated stocks. By-catch that cannot be avoided by technical measures should not just be landed on principle but also made use of, if possible for direct human consumption. Where this is not possible, it can be processed to fish meal or oil as a source of food for sustainable aquaculture, thereby reducing forage fishing (Section 7.4.2.2). The framework conditions should be structured a way that creates an incentive to minimize by-catch, so that the by-catch of non-target species also stays within sustainable limits. The challenge here is not to create incentives to increase the level of by-catch, despite making the best possible use of it. Further research is necessary on these key issues (Section 8.3.3.1).

Ban destructive and wasteful fishing and enforce bans

Destructive fishing techniques should be banned in territorial seas, exclusive economic zones (EEZs) and on the high seas. These bans must be effectively enforced. This includes not only fishing with dynamite or poison, which is still practised in territorial seas in the Tropics, but also fishing that damages habitats, such as bottom-trawl fishing and beam-trawl fishing in sensitive ecosystems such as reefs, sea-grass beds, sandbanks and marine protected areas. This applies particularly to deep-sea areas with fragile habitats and rich biodiversity, such as cold-water coral reefs and seamounts. The FAO guidelines on deep-sea fishing on the high seas should be implemented as a matter of urgency (FAO, 2009b). More environment-friendly alternatives to bottom-trawl fishing should be researched and applied (e.g. electrofishing, pulse fishing; Section 8.3.3.1).

There should be a ban on wasteful fishing methods in which only a small fraction of the biomass captured is used. One example is shark finning, which involves the removal of sharks' fins for use in soup; the fatally wounded shark is then thrown overboard again unused. Here, the rules issued by many countries (including the EU and USA) and institutions (RFMO, FAO, CITES) should be expanded into a global ban: sharks play an important role in marine ecosystems and many species of shark are in acute danger due to fishing (Section 4.1.3.4). The EU Commission's proposal (2011d) to ban shark finning at sea without exception should be swiftly implemented. The Bonn Convention's Memorandum of Understanding on Migratory Sharks (CMS, 2010) has agreed a conservation plan for the subgroup of migratory shark species. However, the countries where shark fishing plays a major role and the key Asian importing countries have yet to sign up to the Memorandum.

Regulate forage fishing

Approximately a third of the total marine catch volume is used to produce fish meal and oil, primarily for animal feed. A large proportion of this is turned into aquaculture feed for carnivorous fish, which involves a considerable efficiency loss ('reduction'; Section 4.3). Catching wild fish for use in aquaculture operations focusing on carnivorous fish ('reduction fishery') does not contribute significantly to food security and so should be scaled down. Alternatives should be developed and promoted in its place (Section 7.4.2.2). Conservative, ecosystem-based catch restrictions for reduction, forage and industrial fisheries at a low trophic level should be agreed, implemented and enforced. This would safeguard the food supply for natural predators in the food web and make provisions for unknowns, e.g. the possible effects of climate change (Box 4.3-1). In addition, initiatives are needed to certify forage fisheries as fully as possible with regard to their sustainability and origin. Depending on the local situation, it may also be desirable to build up local fishmeal industries for local aquaculture farms. As an alternative to turning these yields into animal feed, research, development and infrastructure should be promoted to find new ways of using forage fish stocks directly for human consumption, as already happens to some extent (Section 8.3.3.1).

7.4.1.5
Combat illegal, unreported and unregulated fishing

Between one seventh and a third of the global fishing catch is down to illegal, unreported and unregulated (IUU) fishing (Section 4.1.4.5). The political objective of ending IUU fishing, particularly on the high seas, has enjoyed international consensus for many years and was reaffirmed at the Rio+20 Conference.

The recommendations for fighting IUU fishing should focus on its key causes: insufficient governance capacity in many coastal states (e.g. inadequate monitoring of fishing) and sanctions that are much too weak. First, stronger international cooperation is needed to build a better information base on fishing on the high seas. This can be achieved by expanding the International Monitoring, Control and Surveillance Network and setting up a global information system on high-seas fishing vessels, as well as by other measures. Widespread acceptance of the UN Fish Stocks Agreement and resolute reforms to the Regional Fisheries Management Organizations (RFMOs) would make IUU fishing on the high seas much more difficult (Section 7.3.4.3). Some RFMOs have already taken steps against IUU fishing, such as negative and positive lists of ships, ship-monitoring systems, transhipment rules, inspection programmes, port controls and landing bans for IUU ships, or requiring all fishing vessels to have an IMO number. Some of these measures have been effective and should be adopted by other RFMOs.

The FAO's international plan of action to combat IUU fishing has been in existence since 2001 and specifies many necessary measures. However, few countries have come up with national action plans to date. Strict controls by flag and port states, and checking species and origins indications – which are often false – are considered particularly effective. The FAO Port State Measures Agreement on combating IUU fishing could be an effective instrument as it aims to prevent IUU fish from reaching the market. For this reason it is important that it comes into force quickly and is effectively implemented by countries and the RFMOs. The introduction of strict processes for checking origins (e.g. based on DNA analyses) should be promoted (Section 8.3.3.1). The need for EU action on IUU fishing with respect to the import of fish products is discussed in Section 7.4.1.7.

7.4.1.6
Take into account climate change, ocean acidification and other systemic effects

Environmental changes such as ocean warming, ocean acidification and dead zones may have a significant future impact on fishing if emissions of greenhouse gases and the release of nutrients and pollutants are not restricted (Section 4.4). The fight against the causes of these problems is largely beyond the realm of fisheries management; it must take place on land through changes in the energy, transport and land-use systems (e.g. WBGU, 1995a, 2005, 2010). Keeping within the 2°C guard rail would probably sufficiently limit the impact of climate change and acidification to prevent overstraining the ability of ecosystems and fisheries to adapt, although there is still considerable uncertainty on this question (WBGU, 2006). If this is not achieved, climate change and ocean acidification are likely to have a major impact in the medium term (Sections 4.4.1, 4.4.2).

But the fishing sector must also take action. Here, too, a transformation towards low-carbon practices is needed (Section 4.1). Fishing practices with high specific emissions, such as bottom-trawl fishing and fishing in distant areas requiring long journeys, should be reassessed – not least on grounds of climate protection. Low-impact and fuel-efficient (LIFE) fishing (Suuronen et al., 2012; FAO, 2012b:205) offers an interesting approach to identifying win-win strategies for low-carbon sustainable fisheries and should therefore be promoted. This approach is consistent with fishing with yield targets well below the MSY, which not only has ecological and economic benefits (Box 4.1-5) but also produces fewer emissions thanks to the favourable ratio of fishing effort to yield. In the long term, however, fishing – and shipping in general – must find a way to do without fossil fuels. The WBGU's flagship report 'A Social Contract for Sustainability' presents recommendations on this issue (WBGU, 2011: 151 ff.). In the longer term, the gradual introduction of climate compatibility as a criterion for certifying sustainable fish products should also be considered.

Overfished stocks are more sensitive to environmental changes like climate change than sustainably used stocks (Section 4.4.5). Fishery faces significant challenges to which it must adapt, if it is to overcome the unavoidable impact of global environmental changes. This increases the level of uncertainty for fisheries management, making the implementation of the ecosystem approach and the precautionary principle in fishing even more urgent (Section 7.4.1.1). A strategy of proactive adaptation is important, and this includes looking at climate scenarios and scenarios for ocean acidification as well as other factors (WBGU, 2006). If the overall recommendations in Section 7.4.1.1 are consistently observed, stocks will also be better able to adapt to anthropogenic environmental changes.

7.4.1.7 Reform the European Union's Common Fisheries Policy

A sustainable EU fishing policy should take an overarching approach, i.e. not just covering fishing in EU waters but also incorporating the external dimension through Fisheries Partnership Agreements with third countries and import policy. Based on its global perspective, the WBGU focuses in the following on the direct effects of European fisheries policy (the 'external dimension') on third-party states, as well as on the indirect effects of imports of fish products from third-party states.

Reform of the EU Common Fisheries Policy

The EU's fish stocks are in a poor state because the scientific recommendations on catch volumes have been considerably exceeded for decades. The situation is exacerbated by overcapacity, destructive fishing methods, large by-catches, lack of monitoring and illegal fishing (SRU, 2011b). However, recent years have seen greater efforts to move to fishing methods based on maximum sustainable yield (MSY; Box 4.1-5). This objective, reaffirmed at the Rio+20 Conference, is supposed to be achieved by 2015 (UNCSD, 2012). Accordingly the situation has improved in the past few years. In the period between 2005 and 2009 overfished stocks (i.e. stocks fished at a level above MSY) in the Northeast Atlantic and neighbouring waters averaged around 90%; by 2012 this figure had fallen to 47%. Exceeding sustainable catch volumes has also decreased: in the period from 2003 to 2009 it averaged almost 50%, compared to 11% in 2012 (EU Commission, 2012a: 13ff.). In some regions, however, the situation remains very bad. In the Mediterranean, for instance, 80% of the investigated stocks were overfished. Moreover, the EU Commission (2012a) says that there is insufficient data on almost two-thirds of stocks – a situation which it quite rightly describes as worrying. If international targets and commitments are to be met, the reform must be resolutely enforced. Initially this would result in a sizeable reduction in catch volumes and the closure of some fisheries. But within a few years it would probably lead to even greater yields than before (Section 4.5).

The reform process of the Common Fisheries Policy (CFP), begun in 2009, is to be strongly welcomed. It offers grounds for hope that, following approval by the EU Parliament in early 2013, the necessary changes can be initiated in the course of 2013. The reform aims to create a framework for the sustainable management of stocks and to contribute to the conservation of the marine environment. The EU Commission (2011c) had previously proposed a reform of the CFP that included some good proposals for improvement, but did not go far enough in the view of the German Advisory Council on the Environment or SRU (SRU, 2011b). The SRU's recommendations are in line with the WBGU's overall recommendations (Section 7.4.1.1), translating them into concrete terms for the current European situation. The WBGU supports the SRU's recommendations. In particular, the WBGU agrees with the overall objective that the future CFP should ensure the sustainable management of fish stocks and give high priority to environmental objectives. The most important points are as follows:

- An end to overfishing and a transition to the sustainable management of fish stocks, with the objective of achieving a stock biomass above that necessary for the MSY; management plans for all stocks covering several years.
- Introduction of a general ban on discards and a landing obligation, backed up with adequate controls.
- Reduction of overcapacity and in particular the phasing out of subsidies that might support or increase overcapacity.
- More effective controls and sanctions, including more effective punishments for illegal fishing and a review of whether the measures already in place are effective.
- Regionalization of fisheries management and increased participation by fishermen.
- Marine protected areas with large adjacent no-take zones and the closure of selected areas.

- Gradual introduction of transferable fishing concessions to support the sustainable management of stocks, if the recommended ban on discards is introduced. The impact of transferable fishing concessions should be carefully monitored.
- Sustainable bilateral fishing agreements with partner countries – this is discussed in more detail in the following section.

The external dimension of EU fisheries

The so-called 'external dimension' of European fisheries policy, in the form of Fisheries Partnership Agreements (FPAs) with third countries, has been heavily criticized with regard to its environmental and social impact. The at times disastrous impact of FPAs on fish stocks due to overfishing and on small-scale national fisheries in partner countries due to competition with EU vessels is scientifically well documented and has been accepted by the European Commission (Section 4.1.4.6). Nevertheless, delays persist with regard to the political implementation of suitable measures. This problem requires urgent action. The reform of the EU's CFP, begun in 2009, is an important step in the right direction and should be used to gradually end the destructive practices of the EU fleet in non-European waters.

Fundamental strategic changes to FPAs are needed to guarantee their sustainability and rebuild their credibility. In the context of its role in providing the basis for livelihoods and food security, the objective should be to support the fishing sector in the respective partner country in its transformation towards sustainability, and to build effective institutions there. For this reason, the WBGU welcomes the European Commission's suggestion that FPAs should in future be known as 'sustainability agreements'. To ensure that food security is given top priority, FPAs should include mention of human rights, in particular the right to food (Article 25, paragraph 1 of the UN Universal Declaration of Human Rights). The WBGU's overarching recommendations on fisheries should also be taken into account in the reformed FPAs (Section 7.4.1.1). Environmental and social standards for European fishing activities should be implemented in partner countries and accountability obligations and sanctions increased on both sides. With regard to FPAs, it is essential that non-European fisheries policy is much better coordinated and agreed within both the European Commission and the Federal Government. For example, issues related to development policy should be adequately reflected in the CFP. The WBGU's detailed recommendations are as follows:

- *Improve data:* Improving the pool of data on fish stocks in partner countries is a key prerequisite for ensuring the sustainability of the CFP. The financial, technological and institutional capacities of partner countries for monitoring fish stocks and setting sustainable catch volumes need to be strengthened. FPAs should only be agreed where a sustainable usable catch volume has been shown to exist and scientifically quantified. Strengthening fishing administrations in partner countries, combined with creating (or strengthening) regional partnerships across different countries, can help establish trans-national monitoring systems for fish stocks.
- *Create transparency:* Both the EU and its partner countries should publish figures on their total fishing effort, catch volumes and the actual market value of the fish caught. Partner countries should also publish the size of the total surplus passed on to the EU and other partner countries through licences. In addition, the documentation on the FPA negotiation processes should be published. To prevent IUU fishing by the EU fleet, the indications of origin made for landings should be strictly checked (Section 7.4.1.5).
- *Preserve and promote sustainable small-scale fishing:* In addition, the sustainability of national fishing sectors, many of which are small-scale, should be promoted, as is already formally laid down in FPAs. The recommendations for small-scale fishing made in Section 7.4.1.8 also apply to FPAs. Payments for building up sustainable local fisheries should be unrelated to payments for access by the EU fleet (Section 4.1.4.6). Moreover, ship-owners and the fishing industry should contribute a larger share of the payments. Fish stocks located close to the coast are of primary importance for income and food security in developing countries. Accordingly, the EU should structure FPAs in such a way that small-scale fishermen are given priority access to fish stocks close to the coast, and that EU vessels interfere with these stocks as little as possible (e.g. a ban on bottom-trawl fishing in areas close to the coast, the creation of a 20-nautical-mile zone exclusively for small-scale fishermen; Section 4.1.4.6). The landing obligation and investments in local value chains are vital for supporting economic and social development in partner countries.
- *Introduce an exclusivity clause:* Where an FPA exists, EU fishing vessels – including vessels where European capital is involved but which sail under a different flag – should not be able to receive licences outside of this agreement. The EU should implement effective measures to prevent fishing vessels getting round this clause by means of re-flagging.
- *Initiate joint learning processes:* A systematic evaluation of existing best practices could improve the knowledge basis for policy options. With the sup-

port of development cooperation, this joint learning process could be organized across different countries, thereby also contributing to regional cooperation.

Imports of fish products to the EU

Besides fishing in EU waters and the external dimension (i.e. EU fishing in third countries), imports into the EU from third countries are the EU's largest source for fish products. Some 60% of fish consumed in the EU is now imported, and its share continues to grow. At the same time the EU accounts for 26% of all imports from third countries, making it the world's biggest import market for fish products, ahead of both the USA and Japan (Markus, 2012; Section 4.1.4.8). Through global trade, the EU thus exerts a major indirect influence on fisheries in other waters.

Whatever the potential positive or negative impact of trade in fish products and the possible distributional effects in export states, it is clear that properly functioning stock-management systems in exporting states are important in order to avoid a negative impact on local marine ecosystems (Section 7.4.1.1). Sustainable fishery is a basic prerequisite for sustainable trade in fishing products. The analysis presented in Section 4.1.4.8 raises the question of whether the EU can make an additional contribution to the sustainability of global fishing through its trade policy. The following are possible starting points and options for action:

- On a regular basis, the EU – perhaps in cooperation with the FAO – should analyse developments in trade flows for fish products into the EU and their impact on export states. This analysis should look not just at exports of goods, but also at the impact of direct investments, third-country agreements, and maybe also private fishing activity in third-country waters that takes place outside of third-country agreements.
- Although the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a sharp instrument in the field of trade law and can be used as a basis for issuing effective trade and import bans, it has very little impact when it comes to sustainable fisheries. Its reactive approach means that it can only protect species whose survival is threatened, which only applies to a fraction of the fish species that are harvested non-sustainably. Nevertheless, the Federal Government should continue to actively support the expansion of protection of fish species under the CITES. Particular support should be given to efforts to protect endangered species of sharks and rays.
- In the fight against IUU fishing, trade-restricting measures are being considered which would also affect imports to the EU (e.g. measures by RFMOs or under the FAO Port State Measures Agreement; Sections 4.1.4.5, 7.3.4.3, 7.4.1.5). The IUU Regulation has been in force in the EU since 2010. It contains an impressive list of measures and potential sanctions for fighting IUU fishing, although it is too early to draw conclusions as regards their effectiveness in the member states. To this extent, the enforcement of the IUU Regulation should be scientifically investigated (Section 8.3.3.1). The WBGU believes that including trade-policy measures in the efforts to prevent IUU fishing is the correct approach. The WBGU's recommendations for avoiding IUU fishing can be found in Section 7.4.1.5.
- The EU is currently in the process of enacting a regulation on "certain measures in relation to countries allowing non-sustainable fishing for the purpose of the conservation of fish stocks". This regulation supports the implementation of international rules on the management of fish stocks under UNCLOS, the FSA and RFMOs (Section 7.3.4). To ensure compatibility with WTO rules, the regulation is limited to certain shared, straddling and highly migratory fish stocks for which a 'joint interest' arises. Based on ambitious sustainability targets, in its current form it contains a series of measures vis-à-vis third countries affecting the entire flow of goods into the EU. The WBGU recommends that the German Federal Government actively campaigns for the swift adoption of the regulation.
- The EU's fishing-trade policy is embedded within the World Trade Organization (WTO) framework, under which fish products are considered industrial commodities (Section 4.1.4.8). Exceptions to the principle of non-discriminatory trade are generally possible to protect the environment or fish resources (GATT Article XX b and g). However, the interpretation of these exceptions is always a matter of disagreement. The WBGU therefore recommends a systematic, far-reaching contractual agreement on the legal relationship between international environmental and resource-protection agreements on the one hand and WTO trade law on the other (in particular with regard to subsidies and certification; Sections 7.4.1.3, 7.3.8.2).
- The existing or proposed import restrictions described above (e.g. CITES, the fight against IUU fishing) only affect a small proportion of fishing stocks. The decisive factor, however, is that legal fishing is not synonymous with sustainable fishing in all exporting states. For this reason, further steps should be considered that would make a proactive, directive approach possible. Due to the difficulty of ensuring conformity with the WTO, it will not be

easy to close the gaps that exist in trade law (Section 4.1.4.8). It is therefore questionable whether, in the long term, it will be sufficient to strengthen (or implement) current international and national regulations protecting the environment and fish stocks through trade policy. For this reason, the WBGU makes recommendations on closing these gaps within the framework of its vision of a fundamentally reformed UNCLOS (Section 7.2).

7.4.1.8
Marine small-scale fisheries in the global context

In developing countries where fish account for a large share of protein in the diet, marine small-scale fisheries play a major role in food security, as well as having considerable socio-economic significance (Section 4.1.2.4). The contribution made by small-scale fishermen should be given greater recognition and emphasis in global and national policies. Food security should always be given top priority in policies on small-scale fishing. These policies should be embedded within broader economic, environmental and socio-political programmes and agreed across all levels of administration. They should include clear regulations on the potential competition between industrial and small-scale fishing. Indeed, one additional argument for reducing subsidies for industrial fishing is that they place small-scale fishing at a disadvantage (Section 7.4.1.3). Social policies should ensure that small-scale fishermen can be compensated where, for example, temporary catch restrictions are unavoidable for the sake of preserving or rebuilding fish stocks (Section 7.3.7).

The WBGU therefore calls on Germany and the EU to increase their support for the interests of small-scale fishermen in developing countries, primarily within the framework of the reform of the Common Fisheries Policy (Section 7.4.1.7) and in development cooperation. To do this, the data pool must first be improved at a national and global level. In addition, the definition of 'small-scale fishery' should be standardized to ensure the comparability of the data. Moreover, capacity should be built supporting value chains for small-scale fishermen in developing countries (e.g. associations, infrastructure) in order to strengthen the national and international competitiveness of small-scale fisheries. Regulatory frameworks (e.g. laws, administrative structures) should be strengthened and cooperation between the state and fishing companies extended. Organizations of small-scale fishermen should be supported so that they can play a meaningful role in political processes.

Co-management is a highly promising approach to managing the difficult balancing act between regulatory frameworks and adaptability to local contexts. Key success factors include continuous self- and co-determination by local communities and in particular the preservation of traditional access rights. 'Territorial Use Rights in Fisheries' (TURFs) have often proved successful in small-scale fisheries (Section 4.1.2.4). When making adaptations to fit local contexts it is important to draw on local knowledge – with regard to monitoring, say, or the seasonal use of specific fish species.

The WBGU also recommends actively supporting the negotiations on the FAO International Guidelines for Securing Sustainable Small-scale Fisheries (FAO, 2012c; Box 4.1-3). Here, the long-term goal should be first to have the guidelines added to the FAO Code of Conduct for Responsible Fisheries, and then to anchor them in national legislation in all countries.

7.4.2
Recommendations for action on aquaculture

Aquaculture is the fastest-growing food sector. It is widely assumed that, with catches stagnating, the growing demand for fish products will be met mainly by aquaculture (Section 4.2). However, where there is a lack of regulation and control, aquaculture can also be associated with environmental pollution – in the form of nutrient discharge, the endangering of wild populations through mixing with specially bred forms, and intensifying conflicts over coastal land use. A significant burden on the oceans at present comes from the intensive breeding of carnivorous fish (e.g. salmon), as these species are mainly fed with wild-caught fish – small pelagic species such as sardine and anchovy. To produce high-price carnivorous fish, this method requires several times as much wild-caught forage fish (Section 4.3.3). This places increased pressure on these fish stocks in the oceans, and sometimes also on some local markets where these forage fish are important for human consumption (Section 4.3.2).

There have long been calls at the international political level for a system of sustainable aquaculture management that would help protect ecosystems and biodiversity while improving food security and safeguarding livelihoods (Aichi Target 7: CBD, 2010a; UNCSD, 2012; Section 4.2.3). Alongside these objectives, there are a number of ambitious but non-binding guidelines and strategies at the international and EU level, first and foremost the FAO Code of Conduct for Responsible Fisheries (FAO, 1995: Article 9). To date, however, these objectives and recommendations have not been adequately implemented. From a global perspective, aquaculture urgently needs to be redirected towards sustainability and responsibility – especially as it is currently growing on a massive scale, particularly in areas where regulation is weak or not strongly enforced.

The WBGU makes the following general recommendations (to be explained in greater detail on the following pages):

- The recommendations in the FAO Code of Conduct for Responsible Fisheries, and later agreements that are relevant for aquaculture, should form the basis for developing ambitious standards in aquaculture at the international and EU level. They should be anchored by countries in their national law in the form of effective, enforceable regulations.
- The ecosystem approach should serve as a basis for developing sustainable aquaculture around the globe.
- The additional pressure placed on wild fish stocks by feed production for the aquaculture sector should be stopped. Aquaculture should be put into a position to relieve the burden on wild fish stocks.
- Environmentally damaging and destructive production methods should be phased out and replaced by environmentally friendly procedures.
- Supply and demand for sustainably produced aquaculture products should be promoted, particularly in industrialized and newly industrializing countries, with the help of incentives and information campaigns.

7.4.2.1
Improve knowledge and data resources

Reliable data is needed to develop sustainable aquaculture and the associated governance and management structures: production data, data for development planning, data on environmental and ecosystem burdens, etc. However, such data is lacking in many countries. Databases should therefore be developed and the financial resources they require made available. It would be advisable to evaluate different methods of collecting data (e.g. by aquaculture farmers themselves, by representatives of the authorities) and implement the methods found to be the most cost-effective. An important precondition for ensuring better data on the environmental impact of aquaculture – and ultimately for effective management measures – is developing a long-term, comprehensive system of environmental monitoring that is appropriately financed and staffed. Germany could help developing countries to build up effective databases and monitoring programmes by means of financial and technical cooperation and capacity-building in the field of staffing or institutions. Germany should lobby in international and European bodies for more reliable data collection. Related research recommendations are given in Section 8.3.3.2.

7.4.2.2
Promote the development of sustainable aquaculture systems

To make aquaculture sustainable and environment-friendly, it is necessary to break the link between aquaculture and wild fishing as a supply of forage fish and substantially reduce the damage to the environment caused by aquaculture operations. Action is needed both to counter the growing pressure of use on coastal areas, where most aquaculture plants are located, and to respond to the changing environmental conditions which are caused by climate change and require an adjustment of aquaculture.

Replace fish meal and fish oil in aquaculture feed

Some biological and technical solutions for partially substituting fish meal and fish oil with vegetable matter, for example, are available and in some cases already being implemented (Section 4.3.3). More research on substitutes is needed, however (Section 8.3.3.2). It is important that this transformation is carried out on the basis of an environment-friendly and, as far as possible, regional approach to agricultural production in order to avoid environmental problems simply being shifted to land use. In the long term, the use of fish meal in livestock farming and herbivore and omnivore aquaculture should be phased out. It is also important that the ratio of feed used to units of fish produced – i.e. the food-conversion ratio – is improved in countries with deficits in this area. One way to achieve this is by optimizing feeding techniques so as to reduce feed waste. Given the problems of BSE in the past, educational measures aimed at users would be helpful in increasing acceptance for the use of by-products from livestock farming as a feed source in aquaculture (Section 8.3.3.2).

Increase the farming of species at a low trophic level

Carnivorous fish and crustaceans cannot be completely adapted to fish meal, and especially fish-oil substitutes. In future the necessary cultivation of feed substitutes such as soya will increasingly be competing with water and land for agricultural food production. Aquaculture should therefore focus more on breeding organisms at a low trophic level – such as mussels, snails, herbivorous crustaceans, fish and algae – as food for human consumption and as feed supplements.

Reduce environmental damage from aquaculture

To reduce the negative impact of aquaculture on the environment (e.g. through the discharge of nutrients and pollutants), integrated systems, multitrophic production systems and land-based closed-cycle technologies (Section 4.2.2.4) should be further investigated, technically optimized and their use promoted (Section

8.3.3.2). Other important measures include preferring native species in open systems in freshwater, coastal and offshore areas so as to reduce the risk to the gene pool of wild populations, and introducing compulsory risk analyses for aquaculture management. Sustainable aquaculture techniques already exist in the EU. Germany could lobby at EU level for the creation of incentives to develop environment-friendly aquaculture technologies and to market the technology on the global market. This recommendation is already contained in the Communications of the EU Commission (2009a) on the strategy for sustainable aquaculture in Europe.

The destruction of mangrove forests by shrimp farming is one of the main causes of mangrove loss, especially in Asia. To protect these valuable areas, incentive mechanisms and regulations should be developed in developing countries, such as payments for ecosystem services (Section 7.3.7.1). In parallel, help should be given particularly to small-scale farmers to develop mangrove-friendly aquaculture farms and integrated forestry, fishing and aquaculture systems. Such help can be given within the framework of development cooperation. Germany could offer the necessary support in the form of microcredits and support for regional associations. To promote monitoring of the ecological damage – and consequently potential social and economic damage – caused by aquaculture, Germany could also help set up procedures for environmental impact assessment and environmental monitoring within the framework of development cooperation.

Examine the potential of offshore aquaculture

Sustainable offshore aquaculture can ease the competition for space in coastal areas. For a future possible combination of aquaculture with offshore wind farms, it is essential to critically examine and evaluate both the advantages (e.g. synergies, multiple use of space) and the potential disadvantages (e.g. greater safety risk due to increasing shipping traffic in the plants). The WBGU recommends introducing marine spatial planning as an instrument (Section 7.3.9) with the aim of promoting offshore aquaculture and reducing competition between different uses of the oceans. Clear-cut legal regulations should be drawn up involving all affected stakeholders. These regulations should take into account the best available technology and environmental conservation standards, socio-economic factors (e.g. socially fair employment contracts), the FAO Code of Conduct for Responsible Fisheries and the ecosystem approach. For the potential long-term expansion beyond national waters, it would be advisable to develop binding international regulations for aquaculture management based on the principle of sustainability and taking into account competing uses, such as fishing, the extraction of mineral resources and shipping.

Adjust marine aquaculture in line with climate change and ocean acidification

As a result of climate change and the growing pressure on natural resources such as freshwater and soils, the conditions for aquaculture are also likely to change regionally. Strategies for adjusting aquaculture to climate change should be integrated into aquaculture policy, especially on a regional level, to safeguard the future of marine aquaculture and direct it along the path of sustainability. The WBGU recommends strengthening regional authorities and research institutes (Section 8.3.3.2) and stepping up regional cooperation, for example in the joint monitoring of diseases and foreign species and in joint data collection. Here, Germany can support developing countries with knowledge and technology transfer as well as institutional advice.

7.4.2.3
Implement international and EU-wide recommendations

At present only generally formulated guidelines and recommendations for aquaculture exist at the international and EU level. In the medium to long term, ambitious, more specific standards are needed in order to globally develop an environment- and resource-friendly, socially responsible and economically sustainable system of aquaculture based on the ecosystem approach.

Make the ecosystem approach the basis for sustainable aquaculture

The ecosystem approach should be accepted worldwide as the principle governing aquaculture. It should be reflected in policy instruments, strategies and development plans. Besides regulatory measures such as rules and standards, economic incentives such as user charges, taxes and payments for ecosystem services (Section 7.3.7) can be used to promote sustainable aquaculture. Measures in other areas can also be used for this purpose, for example spatial planning (Section 7.3.9) and the development and restructuring of the aquaculture sector on the basis of the ecosystem approach. Germany should lobby at the international and EU level for this approach to be implemented.

Adopt, implement and refine international standards in national law

In addition to the voluntary FAO Code of Conduct for Responsible Fisheries, there are also the far-reaching recommendations of the Bangkok Declaration and Strategy (2000) which were developed later, the

Phuket Consensus (2010) based on them, the recommendations of the CBD on marine aquaculture and the technical guidelines of the FAO, which translate the FAO Code of Conduct into concrete terms and offer suggestions on implementation. Many countries that already practise aquaculture have relevant legislative frameworks and legal regulations in place, but these are often inadequately enforced (Section 4.2.3). Within the framework of development cooperation (e.g. technology and knowledge transfer, building effective administrative structures), Germany and the EU should push for stronger legislation, the incorporation into national law of key recommendations that are currently lacking, and above all better enforcement. The 'polluter pays' principle should be enshrined in legislation and regular monitoring and evaluation enabled, backed up by sanctions where necessary. In states with less effective structures for implementing ambitious regulations, market-based mechanisms such as co-management measures, voluntary commitments and responsible self-management by producers can represent key steps, alongside economic incentives.

In the medium term, recommendations and standards should be tightened up at the international and EU level and implementation methods further developed and fleshed out. In so doing it would be advisable to check to what extent ambitious, binding standards for aquaculture might be incorporated into such regional agreements as HELCOM for the Baltic Sea and the OSPAR Convention for the North-East Atlantic (Section 7.3.5). However, the long-term objective should be to establish a core of binding standards at the international level. Binding international regulations could be a good idea, particularly if aquaculture expands into EEZs and the high seas in the future. The WBGU recommends that Germany – as a member of the EU and the FAO and a country that imports aquaculture products – should lobby for the further development of European and international standards.

7.4.2.4
Strengthen economic policy supporting sustainable aquaculture

Given the rapid growth of the aquaculture sector, it is essential that its economic development be guided by the sustainability principle. Companies involved in trade, as well as consumers, also bear considerable responsibility, to which they should live up much more.

Establish national aquaculture authorities

Where no responsible 'aquaculture authority' exists, such a body should be set up at the national level, particularly in newly industrializing and developing countries, to improve the planning, coordination and implementation of specific regulations on aquaculture. The task of this body should include improving the integration and coordination of development strategies for aquaculture with the requirements of other political areas. In addition, it could oversee the introduction and implementation of environmental regulations and monitoring in the aquaculture sector and support relevant areas of research (Section 4.2.3). Within the framework of development cooperation, Germany can provide significant support for the creation of organizational and administrative structures.

Promote sustainability in small and medium-sized aquaculture businesses in newly industrializing and developing countries

While large aquaculture companies often find it easier to implement environmental and sustainability standards, thanks to their greater resources, small producers frequently need financial aid, technical knowhow and support in hedging risks when switching to sustainable production. If they intend to supply regional, national or international markets they also require market access, infrastructure, larger shares of the value chains and the ability to meet specific quality, hygiene, environmental and social standards (Section 4.2.2.2). Germany can live up to its global responsibility by expanding its current development-cooperation in the field of providing political and economic advice for regional and municipal authorities as well as for small and medium-sized businesses in the aquaculture sector. Germany and the EU should offer small-scale aquaculture businesses more help with implementing sustainability standards, for instance by setting up microfinance markets, supporting self-organization in producers' associations (e.g. aquaclubs; Box 4.2-2) and promoting group certification – or by providing direct technical support and capacity-building. German and European development-cooperation institutions could also strengthen the involvement of international and national development banks and insurance companies with regard to loans, micro-financing and micro-insurance promoting sustainable aquaculture, by giving these organizations advice.

Create incentives for changes in behaviour by suppliers and consumers

Particularly in developed countries, appropriate action should be taken aimed at consumers (e.g. product information, education, certification) to boost demand for sustainable products (e.g. omnivorous and herbivorous freshwater fish, mussels, snails, macro-algae; Section 7.3.8) and reduce demand for carnivorous fish. At the same time, retailers should assume more responsibility for the sustainable stewardship of the oceans and offer more aquaculture products that are certified according to sustainability criteria. Support for environmental protection organizations and government information campaigns are possible ways of achieving this. In the medium to long term, a public debate – similar to that about eating meat – would be useful on the question of how far the constantly growing global demand for fish and seafood can be met by environmentally responsible aquaculture production (both freshwater and saltwater), or whether we should actually be consuming less fish and seafood in the first place except in regions where food supplies are problematic (Section 8.3.3.2). Moreover transparent, objective communication and information on the part of companies, authorities and governments on the possible environmental and health risks, as well as all other aspects of aquaculture, is to be recommended.

In addition, the WBGU suggests introducing a national online information system in high-income countries like Germany. This would provide both producers and consumers with species-specific biological, ecological and economic information on the different types of aquaculture. It would also enable an independent evaluation – by NGOs, say – of production conditions from the angle of sustainability (perhaps in the form of 'aquaculture traffic lights'). The WBGU recommends a lifecycle analysis that covers all stages of the value chain, from the production of fry to the final product reaching the supermarket shelves, to make it possible to assess environmental damage and the use of resources and energy (Section 4.2.3.2). Parameters such as CO_2 emissions and water consumption should be included in this analysis.

Refine certifications for sustainable aquaculture

It is recommended that the existing certification systems promoting environmentally and socially responsible aquaculture (Sections 4.2.3.2, 7.3.8) should be refined and extended to include aquaculture products that are currently not covered. Producers in developing countries should be given particular support here. Fortunately, this process is already underway; it should now receive greater support. Certifications should cover both domestic and foreign products so as to counter any shifting of production-related environmental damage to other countries and subsequently higher levels of re-imports. Germany should campaign among the FAO member states that the FAO's voluntary technical guidelines on certification in aquaculture (FAO, 2011d) be more strongly implemented and contribute to the further development of fact-based certification criteria (Section 8.3.3.2). In addition, the WBGU recommends at some stage in the future unifying the existing quality labels, certifications and guidelines under a single, generally applicable quality label backed by strict, standardized requirements, thereby increasing transparency and comparability for consumers (see also the recommendation for an EU-wide quality label for wild-caught fish; Section 7.3.8.1). It should be examined whether the existing EU organic farming logo, which can be used for aquaculture products but has been criticized by NGOs as not being strict enough, could provide a starting point. Furthermore, appropriate procedures and measures should be developed for improving the traceability of products which often come from small or micro-businesses in developing countries. Certification processes could be strengthened by supporting group certifications for small businesses. Efforts should also be made examine to what extent Germany can further expand its support for sustainable production methods and value chains, as well as their certification, in its development-cooperation work.

7.4.2.5
Promote cooperation, prevent conflicts

Most aquaculture facilities are located in coastal zones that are also strongly in demand for other uses. Aquaculture can cause or aggravate conflicts with other users by causing environmental damage and making demands on space. Stronger cooperation between affected stakeholders, particularly in border areas between neighbouring countries, and appropriate measures to reduce conflicts over use should be further developed and implemented.

Improve cross-border and international cooperation

The recommendations of the FAO Code of Conduct for Responsible Fisheries should be implemented more strongly where there is cross-border cooperation in aquaculture production. To avoid conflicts between countries as a result of environmental damage to ecosystems close to borders, special care should be taken when choosing locations for aquaculture farms, selecting species and managing the farms. Cooperation with neighbouring countries should be sought. Coordinated overall management by countries bordering on certain marine regions would be necessary here in order to contain the environmental consequences of aquaculture.

The WBGU recommends increasing support for international collaborations with potential aquaculture production countries within the framework of development cooperation. Capacity building and technology transfer should ensure that basic scientific and technical knowledge about effective, environment- and resource-friendly production methods is provided and exchanged.

Define ownership and access rights

The increasing spatial expansion of aquaculture farms can lead to conflicts with traditional uses in coastal areas (e.g. agriculture, fishing), often placing a burden on local communities. Ownership rights relating to land or in the form of access to the sea should therefore be clearly defined, especially in developing countries. On a local and regional level, ensuring territorial ownership rights for local communities is an important measure to counter conflicts of interest and use, and to strengthen sustainable development. Germany could further strengthen such approaches by supporting rural development in the context of international cooperation.

Promote spatial planning and coastal-zone management

In developing, newly industrializing and industrialized countries, marine spatial planning (Section 7.3.9.2) and integrated coastal-zone management (ICZM) are prerequisites for developing marine aquaculture in as conflict-free a manner as possible, especially given the increasing number of uses on coasts and in the oceans. Marine spatial planning and ICZM reduce the number of conflicts over use and strengthen opportunities for stakeholder participation. In the medium to long term, aquaculture should therefore be integrated into a forward-looking, cross-border system of marine spatial planning in which both the interests of use and environmental protection are taken into account (Section 7.3.9.2). By involving all relevant stakeholders, ICZM can contribute to conflict reduction through a process of dialogue and mediation, especially at the local or regional level; it should therefore be supported. Germany could evaluate its experience in ICZM processes and marine spatial planning and make this experience available through knowledge transfer at the EU level and in an international framework.

7.4.3 Fishing and aquaculture as elements of integrated strategies for food security

Demand for fish products and competition for fish are likely to grow strongly. However, this should not mean that we automatically decide to meet this demand from the fishing and aquaculture sector without looking at the systemic implications. Analysis of increased demand should distinguish between industrial and small-scale fishing, and between fishing for high-price markets in industrialized countries and subsistence fishing for coastal regions in developing countries. If increased demand and reduced production (on sustainability grounds) causes rising prices in markets in developed countries, this does not limit food security – unlike in developing countries, where it can have precisely this effect. A strategic perspective on the functions and distribution of marine contributions to nutrition is therefore essential in order to integrate strategies on food security.

- *Contribution of aquaculture:* To date, most aquaculture activities have not led to a reduction in the burden on fishing (Section 7.4.2). The various aquaculture systems and their systemic interrelations with fisheries and land use therefore need to be carefully distinguished from each other. Landing and reusing by-catch and waste products from the fish-processing industry should be introduced on a mandatory basis to reduce pressure on forage fishing. Replacing fish meal and fish oil with vegetable or algae-based materials should be promoted, whilst taking into account the new demand that this creates for land use and ensuring that this demand is met in a sustainable fashion. Preference should be given to breeding filter feeders (especially mussels), suspension feeders, algae, herbivorous fish and crustaceans in aquaculture. Numerous environmental problems can be avoided by promoting integrated and multitrophic systems as well as land-based, closed systems. In many cases, the systemic impacts of aquaculture and their relationship with sustainability are still unknown; much more research is needed here (Section 8.3.3.2).
- *Food security in low-income coastal communities:* Demographic developments can be expected to lead to increased demand and therefore incentives for overfishing in the coastal communities of developing and newly industrializing countries. Technical developments such as motorized boats add to these incentives. Moreover, the combined pressure of small-scale fishing and industrial fishing often contributes to overfishing. Low-income population groups who cover a large proportion of their animal protein intake from fish and seafood should be compensated for possible losses of yield in the course of the transition to sustainable fishing (Section 7.4.1.8). This will involve both substituting the considerable marine contribution to their protein intake with alternative plant and animal products, and either compensating them for lost income or creating alternative sources of income. Food-security strategies should be developed in collaboration with the affected local communities. Germany should get involved in this field through its development-cooperation work.
- *Systemic perspective:* It is becomingly clear that an integrated perspective is needed on global food security and the contribution made by the oceans to

this goal. There should be a greater focus on the systemic connections between fishing, aquaculture and land use. The WBGU reiterates its recommendation to establish a Global Commission for Sustainable Land Use (WBGU, 2011) that would develop such a systemic approach in cooperation with the responsible UN institutions (especially the FAO).

7.5 Use of energy from the sea for the energy-system transformation

Building a low-carbon and sustainable energy-supply system requires a corresponding national energy policy; an international energy policy is also beneficial (Section 5.5; WBGU, 2011). Using renewable-energy technologies in the sea (e.g. offshore wind, waves, tides, sea currents, ocean-temperature and salinity differences, biomass, sun) is becoming an increasingly important option for the transformation of global energy systems (Section 5.2). The use of energy from the sea is currently dominated by mineral-oil and natural-gas production, and accidents that take place during mining and transport can have catastrophic consequences for marine ecosystems. At the same time, releases of methane during extraction or after accidents, and the CO_2 released when oil and gas are used, are contributory factors to climate change. This is why a low-carbon energy policy also requires low-carbon, sustainable energy generation using offshore-wind and marine-energy technologies on and in the sea. Since some of these technologies are still at an infant stage, they should be supported by a targeted innovation policy. At the same time the present and future use of the oceans to generate energy requires an overall legal framework that protects the marine ecosystems and in this way ensures an environment-friendly use of the seas.

In offshore exploration for fossil fuels there is a trend towards working at ever greater depths. Floating platforms, underwater robots and horizontal drilling systems make it possible to extract fuels even at great depths and in difficult-to-access marine areas such as the Arctic. Fossil-based offshore energy generation must be expected to expand further, given that deposits are expected to be large and the global demand for energy is rising.

In addition, technological progress and the demand for energy could turn the mining of marine methane hydrates into an attractive business. However, the risks involved are still largely unknown at present. Methane hydrates are not needed either for a future low-carbon global energy supply or for the phase of transforming the energy systems, since existing reserves and resources of conventional gas are more than sufficient (Section 5.1.7). From the point of view of a responsible climate and marine policy, the WBGU advocates abandoning efforts to mine marine methane hydrates.

The WBGU also recommends applying stricter environmental conditions when issuing drilling permits, and establishing an international liability regime for companies operating offshore oil and gas installations, as well as for marine mining. There should be international cooperation to research the environmental risks of all marine technologies – including renewable marine-energy technologies – develop new regulations and standards, and agree international treaties on environmental protection. It is essential in this context for the development of regulations to keep pace with the speed of development of marine technologies and energy systems.

The key to a low-carbon and sustainable use of the oceans for energy generation is the expansion and development of offshore wind technologies, renewable marine-energy technologies and transnational offshore power grids (Section 5.3). Some countries are already successfully operating offshore wind farms for generating power, while others are still in the test phase. Wind energy can reach higher levels of capacity utilization offshore than on land, because winds are stronger and more constant there. Offshore wind farms could potentially be operated in deeper waters and further away from the coast. The more renewable-energy technologies are transferred to the sea, the less energy needs to be generated on land, releasing space on land for other purposes. When appraising possible uses, the WBGU recommends using the instrument of marine spatial planning (Section 7.3.9) and assessments of the effects of plans and programmes on the environment. The WBGU believes that the advantages of offshore wind energy justify the high upfront investments, especially in deeper waters. For this reason, relevant technological developments and market integration should be given political backing. The costs can be expected to fall significantly in the future as a result of learning effects. However, this requires continuous expenditure on research and development and the diffusion of the technologies.

The risks posed by renewable-energy technologies at sea are lower than those of marine oil and gas extraction. Even so, there are potential dangers, for example from rotating rotors, noise during the construction phase, and electromagnetic fields generated during the transmission of electricity (Section 5.2.3). The WBGU therefore recommends intensive accompanying research. This could then provide a source of recommendations for statutory requirements on the construction and operation of offshore wind farms and marine-energy technologies (Section 8.3.4.2).

In the future the sea will also be used for other forms of renewable energy generation. Although offshore bioenergy production – using algae for example – is still in its infancy, it seems to have considerable potential.

Multi-use platforms – the combination of several energy-generating technologies on a single platform – can offer considerable economic and ecological advantages for the global marine-energy system of the future, since they combine both the generation and the storage of sustainably generated energy. This requires a marine energy-transmission system which is integrated into the transport systems on land. In addition to oil and gas pipelines, other networks will be needed in the future to transport electricity and CO_2 (Section 7.5.2). Some of these transmission technologies could be combined. It is conceivable in the long term, for example, that superconductive power lines could be coated with refrigerated liquid methane or oxygen, thus transporting both energy carriers in a single system. However, these solutions still require a considerable amount of research (Section 8.3.4.1).

7.5.1 Integrated energy, marine and innovation policies for the energy-system transformation

7.5.1.1 Energy policy

The WBGU recommends developing national energy strategies all over the world with development targets for renewable-energy technologies and therefore also targets for offshore-wind or renewable marine-energy technologies (WBGU, 2011, 2012). Companies should be legally guaranteed entry to the market and access to the grid to ensure free competition, i.e. competition that is not distorted to the advantage of fossil fuels (WBGU, 2011). In addition, marine planning and approval processes should be developed for erecting and operating offshore technical installations, as well as liability regimes (Sections 7.3.2, 7.3.10). Temporary, degressive support schemes or support strategies are necessary for the roll-out phase and for the integration of renewable-energy technologies into existing electricity-supply systems and electricity markets (Section 7.3.7.1). The WBGU recommends temporary, technology-specific feed-in tariff schemes that efficiently encourage rapid capacity building (WBGU, 2011, 2012). German experience shows that the expansion of grids and energy sources needs to be coordinated.

Within the European Union, a coordinated support scheme for offshore-generated renewable energy would raise the efficiency of promotion. Power from renewable sources could then be generated at the most favourable locations, i.e. at low cost. The realization of a single energy market is an important precondition for this (WBGU, 2011).

It is necessary for investments in renewable marine-energy technologies and offshore wind energy that the overall conditions of climate, energy and legal policy offer long-term investment security and guarantee appropriate returns (Section 7.3.7; WBGU, 2012). The WBGU therefore recommends CO_2 pricing, as this would make the use of fossil energy more expensive and lower the price of low-carbon technologies. Simultaneously, for CO_2 prices to develop their full impact, the subsidies enjoyed by fossil energy should be phased out worldwide to minimize the cost advantage of fossil fuels (WBGU, 2011).

7.5.1.2 Marine policy

Establish marine spatial planning

In the foreseeable future the oceans will be used as an energy resource in the coastal waters and the EEZ, so that the coastal states will be responsible for designing and establishing a regulatory framework (Section 5.4.2).

Since marine renewable-energy systems require space and compete both with other uses of the oceans, and with ocean and coastal conservation, the WBGU recommends using and enhancing the instrument of marine spatial planning (Section 7.3.9.2). In the development of marine renewable-energy technologies, marine spatial planning is necessary to be able to establish legal force for designated areas and issue permits for private investors quickly. Synergy effects generated by shared uses – e.g. renewable energy generation and sustainable fishing, or renewable energy generation and designating protected areas – should be taken into consideration in this context. For coordinated and coherent marine spatial planning it is important to get all the government ministries concerned involved in the process, so that different interests in the use of space can be integrated and given appropriate consideration.

In many cases the development of marine renewable-energy systems has cross-border effects on ecosystems and shipping, so that cross-border cooperation in spatial planning is necessary for the EEZs in regional seas (Section 7.3.9.2). Similarly, cumulative effects on ecosystems can arise when all coastal states develop their marine energy systems on the borders of their respective area of jurisdiction. The WBGU therefore recommends coordinating marine spatial planning at the level of regional marine agreements such as OSPAR or HELCOM (Section 7.3.5).

Strengthen environmental monitoring and control

In order to give proper consideration to the risks that the use of marine renewable or fossil energy can cause to the environment and to people, the government should make greater efforts to monitor the environment and control installations.

As is already being practised by some states parties to UNCLOS, installations for generating energy should on principle be subject to a preventive ban under which the supervisory authority reserves the right to grant authorization. The required approval process, in contrast to subsequent control measures, has the advantage that the risks that such an installation might involve can be assessed and evaluated before the plant is built and commissioned. The process used in this context should be adaptive in order to make use of the latest knowledge from research. Adaptive management requires long-term research accompanying it, targeting the areas where there is still a lot of uncertainty about the possible interactions both between technologies and ecosystems, and between different technologies (Section 8.3.4.2). An official approval process to be carried out by the coastal states would also ensure that the public can get involved. Approval should also include obligations on the part of the plant operator to conduct regular environmental monitoring of the surrounding marine area and to supervise the plant. The WBGU recommends that this information be made accessible to the public, so that civil society is enabled to enforce marine conservation.

Coastal-state monitoring after the approval of an installation can only be effective if the government institutions have sufficient expertise, infrastructure and personnel. The WBGU therefore recommends making more funds available. Regular information and reporting obligations of the plant operator should be made legally binding to make supervision easier. A coastal-state regulatory framework should also make it possible to issue subsequent rules and constraints, especially to be able to meet new requirements derived from scientific findings or experience with the installations.

Germany could be a role model for other countries on such coastal-state licensing and monitoring regimes with its regulations on offshore installations (*Seeanlagenverordnung*). They provide for a comprehensive licensing regime covering the construction and operation of installations for generating energy from water, currents and wind; in particular the regime aims to protect the marine environment, takes objectives of spatial planning into account, and insists on a regular environmental impact assessment being carried out. However, even in Germany the public control regime is not extensive enough; e.g. there is a lack of effective powers of intervention.

Regulate oil and gas production

The offshore production of mineral oil and natural gas will continue to play an important role in the use of the oceans in the medium-term, given the ongoing development of deep-sea extraction technologies, as well as new discoveries (e.g. in Brazil and the Arctic) and their importance for national energy security. Since gas accidents and especially oil spills can cause grave damage to the environment and do not stop at national borders, the WBGU believes that the regulatory framework must be strengthened for all existing and future mining activities, since it can reduce the risk of accidents, improves damage-repair capabilities and regulates the liability of polluters. The WBGU recommends stricter regulation of fossil technologies and the establishment of an international liability regime for the operators of offshore oil and gas installations, as well as in marine mining; this raises the cost of oil and gas production and prices-in the environmental risks to the marine ecosystems.

To avoid the risk of accidental leakages of methane, CO_2 or oil, the WBGU proposes giving companies the obligation to prove the absence of damage and introducing a regular reporting requirement. This change in the burden of proof could create incentives to develop safe extraction techniques, necessary measuring technologies and security techniques.

At the European level, the European Commission has submitted a 'Proposal for a Regulation of the European Parliament and of the Council on safety of offshore oil and gas prospection, exploration and production activities' (EU Commission, 2011a). The aim of the proposal is to expand the EU's environmental liability regime to cover all waters of Member States, including the EEZs and, possibly, the extended continental shelf. A liability regime would be set up for offshore activities within the EU which includes, in particular, an obligation to remedy environmental damage. The WBGU supports this initiative for this reason.

In addition, the WBGU proposes agreeing internationally uniform technology standards, as well as regulations on use and liability and embedding these in national law. The European Union could promote such proposals in international bodies and push for corresponding international agreements.

7.5.1.3 Innovation policy

In addition to formulating legally binding development targets for offshore renewable-energy technologies as a political signal to potential investors, an innovation policy to support these technologies is required; after all, both offshore wind energy and, in particular, the various marine electricity-generating technologies are still far from mature (Sections 5.4.3, 7.3.7.1; WBGU, 2011, 2012). Public support for research and development can provide incentives for innovations by businesses via temporary subsidies or tax concessions. Public-financed cooperation between science and industry and international research and technology collaborations – like the Implementing Agreement on Ocean Energy Systems of the International Energy Agency (IEA) – could ensure that sustainable marine-energy technologies are internationally diffused and deployed as quickly as possible. Governments should create an environment that is attractive to venture capitalists. Public demonstration projects, or public provision of infrastructure, could also minimize the risks for private investors. In the diffusion stage, access to private capital can be improved by providing soft loans and temporary credit guarantees, thus helping to facilitate the commercialization of the corresponding technologies (Section 7.3.7.1; WBGU, 2011).

7.5.2 Build an offshore supergrid

The WGBU believes that an offshore power grid interconnecting the various marine power-generating plants and different countries has more advantages than individual, direct connections to land. In a similar way to a continental, transnational power grid, it improves market integration and facilitates the integration of fluctuating power-generating systems by smoothing the output generated, thus reducing the need for balancing (e.g. using storages).

At the same time the development of a transnational offshore grid involves a number of challenges. Planning one requires the coordination of both the grid and the offshore power-generation plants between different countries and different national authorities. Furthermore, the terrestrial grids need to be modified and adapted.

A key challenge is the creation of investment incentives for private companies. In addition to a national energy policy, a transnational energy policy is needed for countries with regional-sea coasts that want to connect their power grids by means of an offshore grid.

Only in exceptional cases have EU Member States planned for a transnational offshore grid at the national level up to now, and this planning has also been rather cursory. The current practice consists of point-to-point links, which are disadvantageous for the WBGU's vision of combining all power-generation options (Section 5.3). The current arrangement will lead to higher future costs and lock-in effects, which are preventable. Although individual connections – such as the Dutch-Norwegian 700 MW cable or the planned 1.4 GW connection between Germany and Norway – are economically very attractive, they cannot include all the North Sea offshore wind farms. The WBGU therefore recommends that the Federal Government should go ahead and build an offshore grid in the North Sea as soon as possible – as announced in the *Energiekonzept* (Energy Concept) and the *Entwicklungsplan Meer* (Development Plan for the Sea). The vision of a transnational offshore power grid should already be included today in the national plans for the development of offshore grids in the EEZs. In addition, offshore grid planning should be taken into account in the national planning of terrestrial grids and transnational grid connections to enhance transmission performance between the countries. The relevant North Sea countries should coordinate their actions on this basis.

The WBGU supports the European initiatives and plans to develop a marine supergrid and suggests that offshore wind farms should initially deliver power to land together via marine cables, as currently provided for in the North Sea offshore grid plan for Germany. The next step should then be to make transnational plans on developing a meshed grid, which can link up with the European Energy Programme for Recovery if the EU promotes three pilot projects as building blocks of a future offshore grid: a submarine cable between the Netherlands and Denmark (COBRA Cable), the offshore Kriegers Flak wind farm, which is connected with the German and Danish power grids, and a high voltage DC distributor (HVDC hub) off the Scottish coast.

The WBGU recommends EU-level harmonization of national support systems for renewable energy and the creation of harmonized terms for investment in a transnational offshore grid. Furthermore, more support should be given to the offshore grid initiative and the implementation of the Kriegers Flak pilot offshore wind farm.

7.5.3 Refrain from marine methane hydrate mining

Mining marine methane hydrates is associated with environmental risks that have not yet been quantified. They include landslides, sea-floor subsidence as a result of sediment destabilization, uncontrolled escape of methane into the sea, unknown effects of solvent use in certain mining techniques, and damage to marine ecosystems (Section 7.1.5).

At this stage, therefore, the WBGU is against mining marine methane hydrates. Nevertheless, research should continue on the deposits, their stability and the environmental risks. However, since some countries, e.g. Japan, look likely to start the commercial extraction of methane hydrates within the next few years, the WBGU reiterates its previous recommendation that the risks of methane hydrate mining should be carefully examined in each individual case (WBGU, 2006). In the WBGU's view it is necessary to carry out an environmental impact assessment and to monitor the state of the ocean according to universal standards. Both of these instruments should form part of marine spatial planning. At the same time, these instruments should be in place before mining licences are issued.

The International Seabed Authority is responsible for methane hydrate deposits outside the EEZ. Here, too, the WBGU is in favour of a ban on mining, for the reasons stated above. Moreover, this fossil energy carrier is not needed worldwide for the future low-carbon and sustainable global energy supply (Section 5.1). As stated in Section 7.2.3.1, the 'common heritage of mankind' principle, a systemic approach and the precautionary principle should be applied to 'the Area', i.e. the ocean floor seaward of national jurisdiction. Given the likelihood that methane hydrates will soon be mined, the WBGU recommends, as a minimum solution, that the signatories to UNCLOS agree on international standards for the marine mining of methane hydrates; the Seabed Authority could then make these a requirement for licensing. In addition, the WBGU recommends interdisciplinary research to develop suitable standards for sea-floor mining (Section 8.3.4.2).

The danger of CH_4 release from methane hydrates also exists in principle in other sea-floor mining activities. As recommended in Section 7.5.1.2, in this case, too, it should be incumbent on the companies to prove the absence of damage; this would create incentives to develop the necessary measurement technologies. As called for in the case of monitoring and the supervision of installations (Section 7.5.1.2), marine-mining companies would also be under an obligation to report releases of methane, other greenhouse gases or substances that damage or destroy marine ecosystems.

7.5.4
Develop regulations for sub-seabed CCS

The WBGU already examined the option of storing CO_2 both in the ocean and under the sea floor in its special report 'The Future Oceans – Warming Up, Rising High, Turning Sour' (WBGU, 2006) and explained why the injection of CO_2 into sea water is not a sustainable option, i.e. due to uncontrollable risks and the insufficient retention period.

The situation is different when it comes to storing CO_2 in geological reservoirs under the ocean floor which have already served as stores in nature, such as partially emptied gas and oil fields. There are leakage risks, although these can be minimized by selecting suitable storage sites. Retention times of 10,000 years, which the WBGU considers necessary in the large-scale use of CCS (carbon capture and storage), should also be used here to ensure that the technology also contributes to long-term climate stabilization. If countries want to continue using fossil fuels in the long term, the combination with CCS represents a possible application to prevent anthropogenic climate warming of more than 2 °C. However, permanent monitoring and contingency plans are essential.

The WBGU's assessment of the sub-seabed storage of CO_2 is that it is less risky than storage in land-based locations; it therefore recommends focusing research on this form of use (Section 8.3.4.2). CCS in the seabed could potentially also be combined with the use of aquatic biomass for energy generation, thus creating an additional sink for CO_2 from the atmosphere (Section 5.2.2). The current arrangements under the London Protocol allow the storage of CO_2 under the sea floor in principle, whereas the injection of CO_2 into the water column is not permitted. They also contain guidelines – but no binding liability rules – for evaluating and monitoring potential CO_2 storage activities in the seabed. There is room for improvement here. The regulations were also adjusted under OSPAR, so that CO_2 storage in the seabed has been allowed since 2007.

CO_2 is already being stored under the ocean floor in individual cases, e.g. in the Sleipner project in Norway (Section 1.1.5). However, certain technological and legal conditions still need to be clarified before this technology can be used on a large scale. Current experience with CO_2 storage is limited to relatively small-scale installations. 1 million tonnes of CO_2 is stored per year in the Sleipner project, which is less than one-tenth of the amount of CO_2 that could be released annually by one large coal-fired power plant with CO_2 capture. To date CCS on the relevant scale is an unproven technology, although the individual components are already being used on a large scale by the oil and gas industry – e.g. the injection of CO_2 into oil and gas fields, although up to now this has mainly been done to increase production (Enhanced Oil Recovery, EOR) and does not target the long-term storage of CO_2. CO_2 compression and CO_2 transportation in pipelines have also been tested on a large scale.

The WBGU recommends continuing to examine doubts on the retaining ability of CO_2 stores (Sections 5.1.5, 8.3.4.2). CCS technology should not be used on a larger scale until it can be proved in scientific studies that the required retention period of at least 10,000 years can be guaranteed. Before it is used, it should also be clarified how long-term monitoring can be implemented. Another prerequisite should be an (international) legal framework regulating not only liability for the escape of CO_2 over a period of decades, but also the climate-relevant question of long-term escape over thousands of years. The WBGU refers here to its 2006 report, in which it already gave comprehensive recommendations on how this could be organized under the UN Framework Convention on Climate Change (WBGU, 2006).

Recommendations for Research and Education 8

8.1 Research in the context of the transformation towards sustainability

The WBGU has presented extensive evidence for the necessity of a 'Great Transformation' towards a sustainable society and demonstrated its feasibility with the example of climate change (WBGU, 2011). The WBGU defines this Great Transformation as moving the economy and society worldwide towards sustainability, with the goal of safeguarding humanity's natural life-support systems.

The Great Transformation will require leaps in technology, new concepts of welfare and knowledge, a wide range of innovations and an unprecedented level of international cooperation. By 'innovations' the WBGU means both sustainable technologies (and the societal parameters needed for their global application) and sustainable production, lifestyles and consumption patterns.

Research plays a key role in this transformation process, as the Great Transformation towards sustainability is an open, societal search process characterized to a large extent by action under conditions of uncertainty (WBGU, 2011). Although objectives can be named and structural options revealed, it is not possible to describe the precise, ultimate goal or the paths that might lead there.

Sustainable stewardship of the oceans therefore also depends on support from research accompanying the process – to help make it possible to develop sustainable solutions and derive guiding principles for systematically safeguarding the future.

The WBGU has furthermore underlined the importance of education in the context of a Great Transformation (WBGU, 2011). Achieving a high level of education for as many citizens as possible is a basic prerequisite for enabling people to form their own judgments, and hence for achieving a desirable broadly based participation in shaping a sustainable future.

Education should critically convey the latest scientific findings so that people gain a well-founded understanding of the current state of the oceans and a systemic understanding of what action is possible. Society should be regarded as a stakeholder in the transformation process and allowed to participate in the education process itself in future. People need to see themselves as actors in the historical process if they are to take on responsibility for their actions. Corresponding educational structures are an essential precondition for this (Leinfelder, 2013).

Germany has a dual responsibility with regard to a sustainable stewardship of the oceans in the context of the Great Transformation. First, Germany is a highly developed industrial nation. This means that it has a particular responsibility for ensuring that its own interactions with the oceans are driven by considerations of sustainability – not just in the North Sea and the Baltic but, as a flag state, also for the other oceans. Second, Germany is responsible as an important centre of research. Germany has outstanding capacity in the field of marine research and should use this to address the scientific questions relating to the sustainable stewardship of the oceans. The country's significance as a centre of scientific marine research should be safeguarded and extended so it can support the sustainable stewardship of the oceans.

In the following chapter the WBGU describes the two types of research which it considers relevant – transformation research and transformative research – and gives recommendations on each. The recommendations on transformation research are divided into the following key research themes: societal transformation processes and transformation ability, transformation paths, acceleration, and global cooperation. The recommendations on transformative research cover the themes of global-change research, governance research and the focal themes of this study: food and energy from the sea. This is followed by the WBGU's recommendations on research policy.

8.1.1 Key types of research

To improve the scientific basis for the transformation towards sustainability, the WBGU has proposed the creation of a new field – 'transformation research' – and described the potential role of traditional research under the heading 'transformative research' (WBGU, 2011). The demands to be made on restructuring research outlined by the WBGU (2011) have contributed to the discussion on the development of policy-relevant sustainability research (UBA, 2012).

Research on the 'transformation of human interaction with the oceans' first requires transformation research, that is to say the interdisciplinary scientific analysis of societal transformation processes as such, and in particular the identification of the 'conditions of possibility' (to use Kant's phrase) of social and technological innovations and their potential effects on the Earth system and society. This calls for a comprehensive understanding of the interactions between societal, technical and natural systems – in other words close collaboration between the social, natural and engineering sciences. In addition, research on the 'transformation of human interaction with the oceans' requires transformative research, i.e. all scientific activities that can collectively generate the decisive innovations in the sectors relevant for transformation, thus enabling the transformation. Recommendations on both types of research in relation to the oceans are made in Sections 8.2 and 8.3.

Transformation research and transformative research do not call into question the necessity of basic research or the freedom of research. Among other things, freedom of science is a prerequisite for a person's ability to form his or her own opinion and hence a condition of functioning democracies. Basic research can be complemented by transformative aspects and thus become transformative research itself. Basic research in marine sciences can be combined with other disciplines such as economics, social science or history to create a novel interdisciplinary approach. In this way it can contribute to both transformation research and transformative research.

To expand and further substantiate its research recommendations, the WBGU has discussed them with representatives of marine research in Germany. It did so at a workshop with representatives of the German Marine Research Consortium (*Konsortium Deutsche Meeresforschung*, KDM), a body covering all the major research institutes and university departments in the field of marine, polar and coastal research. It has also held hearings, conducted reviews and had external expert opinions written on selected topics in the area of marine research. The results have been incorporated into the WBGU's research recommendations.

The representatives of the German Marine Research Consortium have also argued for an extension of the existing institutes involved in German marine research, which are currently strongly focused on the natural sciences, to include the fields of economic, jurisprudential and social-science disciplines. They also considered a more interdisciplinary approach in both basic and applied research to be a prerequisite for any science that aims to find solutions to problems, as well as a prerequisite for developing options for the sustainable use of the oceans.

On the international front, the International Council of Science (ICSU, 2010) has identified five Grand Challenges for Earth system science with regard to global sustainability. In Box 8.1-1 the WBGU discusses the relevance of these Grand Challenges for the oceans and assigns each of them to the relevant WBGU category – transformation research or transformative research.

8.1.2 Innovative approaches in German marine research

Much of the marine research in Germany is basic research carried out from a natural-science perspective. The research is mainly in the areas of physical oceanography, marine and atmospheric chemistry, biogeochemistry, biological oceanography, marine biology, biodiversity research, marine geology, geophysics and sea-ice physics. Research projects examine the interactions between the oceans, the atmosphere, the cryosphere and the geosphere, study the changes that are occurring in them and predict future changes. Another major area of research focuses on how marine ecosystems function and the ways in which they are changing, sometimes with an explicit focus on coasts and the land, as well as on material cycles, biodiversity and the organismic biology of marine life, including marine microbiology. There is also research on the state of the oceans, on marine pollution and ecotoxicology. On the technical side, marine research in Germany generally focuses on technologies for measuring and monitoring. However, research is also conducted on the development of technologies for purposes such as the exploitation of marine resources, geoengineering and nature conservation.

Individual research institutes focus on economic questions, as well as on issues relating to management and the law of the sea, mainly with reference to fishing. Social-science research and environmental economics are not well represented. Interdisciplinary research is

Box 8.1-1

Research recommendations relating to the ICSU Grand Challenges

In 2010 the International Council for Science (ICSU) identified five broad topics of global sustainability as Grand Challenges to Earth system science (ICSU, 2010). These are:

1. *Forecasting:* Improving the usefulness of forecasts of future environmental conditions and their consequences for human societies.
2. *Observing:* Developing, enhancing and integrating the monitoring systems needed to shape global and regional environmental change.
3. *Confining:* Improving the way we recognize, anticipate, avoid and manage disruptive global (environmental) change.
4. *Responding:* Determining institutional, economic and behavioural changes towards global sustainability.
5. *Innovating:* Encouraging innovations in developing technologies, policies and social strategies in order to attain global sustainability.

The WBGU endorses the ICSU Grand Challenges. To illustrate their importance for the oceans, the WBGU has concretized and assigned them to the WBGU's categories of transformation research and transformative research. By way of example, the WBGU recommends tackling the following research questions relating to sustainable interaction with the oceans:

Transformation research

Forecasting

Develop a theory of global transformation towards sustainable interaction with the oceans and develop interdisciplinary scenario techniques:

- How do human behaviour, institutions and technical systems impacting marine ecosystems interact with each other?

Confining

- What institutional structures are needed to reduce the negative and possibly cumulative effects of multiple marine uses at the local and regional levels? How can they be set up?

Responding

- What strategies, instruments and mechanisms for avoidance, adaptation and transformation are possible from the local to the global level, and which ones are effective in dealing with gradual or abrupt environmental changes in the oceans?
- What changes in human behaviour make sustainable interaction with the oceans possible? How can they be brought about?

Responding and innovating

- How can effective, legitimate, binding, equitable and comprehensive solutions to marine environmental problems be implemented on a large scale?
- How can the necessary changes be rapidly triggered at the economic, institutional and behavioural levels?

Innovating

- What changes in economic uses of the seas could contribute most to improving the ecological state of the oceans and to promoting sustainable interaction with the oceans? How can this be achieved?
- How can the need to place interaction with the oceans on a sustainable footing be reconciled with other challenges, such as the need to eradicate poverty, resolve regional conflicts, distribute income equitably and establish security?

Transformative research

Forecasting and observing

Develop instruments, methods and indicator systems for forecasting the impact of human activity and technical systems on the oceans, and develop appropriate monitoring systems:

- What aspects of marine socio-ecological systems harbour risks that are exacerbated by positive feedback?
- How can discontinuities and tipping points in marine ecosystems be identified, and how can we determine how much time remains before they are reached?
- What significant environmental changes result from human activity?
- How do these changes influence human well-being and how do people react to them?
- What impact do technical systems have on the state of the oceans?

Observing

- What threats do changes to marine ecosystems pose to vulnerable human communities? On what time scales are they to be expected?
- What indicators of socio-ecological systems must be monitored to enable an appropriate response to changes in the marine environment? What would a suitable information system look like?

Confining and responding (examples)

- What role can be played by marine renewable energy sources in global energy security? How can marine ecosystem services sustainably improve living conditions for the very poorest people?
- What technological, institutional or social innovations are most effective at reducing and preventing damage in the context of marine uses? Which ones open up sustainable development trajectories?

Innovating (examples)

- How can learning processes increase individuals' and decision-makers' capacity to act and give research a more practical orientation?
- How can different forms of marine use be integrated in technical and spatial terms (e.g. by combining sustainable energy generation with aquaculture)?
- How can integrated assessment analyses in scenarios make better provision for context-specific factors such as culture, specific institutional structures, norms and values?

Box 8.1-2

Structural challenges to marine research

Since humans do not live in the sea, they often lack any direct experience of developments that take place far from the coasts. It is therefore all the more important to step up both research and systematic monitoring, because our knowledge of the links between human activity and the state of the oceans is still limited, and gathering data is a laborious task.

Adopting an interdisciplinary approach is important to transformation-related research. It is also a prerequisite for problem-oriented, transdisciplinary research (UBA, 2012). At present, marine research specializes primarily in the natural sciences and technological disciplines. Yet activities that harm the environment touch on all kinds of different aspects of marine ecosystems and cannot be understood in isolation from terrestrial ecosystems and terrestrial activities. Harmful activities have repercussions both in the sea and in the atmosphere, on land and in the many and varied facets of human societies. The causes and continued existence of grave environmental problems, such as climate change and the loss of biodiversity, are too complex to be grasped by observation from the perspective of any single discipline, as are their effects and interdependencies.

The impact of solutions to problems can likewise only be understood on a systemic and interdisciplinary basis, because the solution to one aspect of a problem often interacts with other aspects. Interrelated and extensive changes to technologies, societal institutions and individual modes of behaviour lead to far-reaching transformations. Only systemic, interdisciplinary research can adequately model such contexts and develop effective intergenerational design proposals. Relevance to society and the incorporation of practical (e.g. local, traditional or indigenous) knowledge can be ensured by integrating transdisciplinary stakeholders when research questions and objectives are being defined, as well as by involving them in the research process and getting society to discuss research outcomes. Making interdisciplinary and transdisciplinary research more effective will require a new generation of researchers who not only excel in their chosen fields, but are also able to speak and understand the language of other disciplines.

Despite promising approaches, efforts to increase interdisciplinarity in science face a number of structural barriers. The scale, organization and structures of faculties and departments and, in particular, their incentive, accreditation and evaluation mechanisms are not appropriate to give interdisciplinary approaches the weight they need in transformation-relevant research.

The duration of research funding presents a further challenge. Scientists should be given an opportunity to engage in long-term interdisciplinary research in order for them to have sufficient time to devote themselves to what are mostly complex issues. Especially when researching complex marine issues, three-year funding periods for research projects are too short, as they preclude long-term observation and the chance to build up suitable structures. Marine-research institutes require appropriate overall conditions and should be endowed with sufficient funds to build up permanent capacity.

conducted mainly between different disciplines within the natural sciences. The structural barriers to establishing a comprehensive interdisciplinary approach are summarized in Box 8.1-2.

Some initial, highly promising approaches to interdisciplinary, more problem-based research and academic training are also found, however. One example is an excellence initiative called GLOMAR (Global Chain in the Marine Realm), a graduate school for the marine sciences at the University of Bremen. The school's aim is to combine training for doctoral students in the natural and social sciences and to offer an at least partially interdisciplinary education for future academics by means of joint events and mandatory introductory lectures in different disciplines. The INTERCOAST (Integrated Coastal Zone and Shelf-Sea Research) international research training group operates in a similar way, combining research on coasts in the fields of both the natural and social sciences. The Kiel-based excellence cluster 'The Future Ocean' (*Ozean der Zukunft*) also takes an explicitly interdisciplinary and problem-based approach, combining marine sciences in various integrated research fields such as sustainable ocean management and scenario research. The aim of this cluster is to investigate the past, present and future changes in the oceans in an interdisciplinary manner and by so doing contribute to sustainable ocean management.

The Leibniz Centre for Tropical Marine Ecology (*Leibniz-Zentrum für Marine Tropenökologie*, ZMT) in Bremen has set itself the goal of creating a scientific basis for the conservation and sustainable use of tropical coastal ecosystems. The centre has its own social-sciences department and strives to develop interdisciplinary solutions for preserving threatened ecosystem services which take the socioeconomic realities in tropical coastal states into account.

Innovative, interdisciplinary research approaches are also found in marine technology development. One example is a research group called 'Marine Aquaculture, Maritime Technologies and Integrated Coastal Zone Management' at the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, which develops platforms for integrating marine aquaculture and offshore wind power. It also investigates their acceptance by various user groups and organizational aspects of co-management.

Another positive example of an application-oriented project is 'Offshore Site Selection for a sustainable and multi-functional use of marine areas in heavily utilized seas as exemplified by the North Sea (OSS)', a project funded by the Federal Ministry of Food, Agriculture and Consumer Protection. The aim of this project is to develop criteria for choosing sites for offshore aquaculture farms in conjunction with offshore wind power.

German marine research institutes are also participating successfully in innovative projects within the European Union's Seventh Framework Programme, for example with a programme called 'Vectors of Change in Oceans and Seas Marine Life (VECTORS)'. This programme studies how the distribution and productivity of fish stocks change as a result of changing uses and anthropogenic pressure. The programme also plans to look at how these changes impact on ecosystem services, to estimate further socio-economic consequences, and to develop political strategies to avoid negative impacts.

8.2 Transformation research for the oceans

8.2.1 Conceptual background

The term 'transformation research' is used by the WBGU to mean the scientific analysis of societal transformation processes, in particular identifying the 'conditions of possibility' (in the Kantian sense) of technological and social innovations and their interactions. Transformation processes are only possible if the interactions between societal, technical and natural systems are properly understood:

1. Transformation research sets out to investigate the institutional parameters, key players, drivers and obstacles in transformation processes and their relevance both now and in the future. The history of technology and institutional theory play important roles in this. Also of significance are the scientific, cultural, psychological, social, economic, political and technological prerequisites for, and barriers to, transformations. Since these transformation processes occur from the local level right up to the global level, they should be analysed as interdependent multi-level dynamic forces.
2. Transformation research, in cooperation with the natural sciences, aims to identify the interactions between past, present and future transformation processes and the natural environment. It works on the assumption that, in the Anthropocene, societal parameters – in particular the organization of economic activity – strongly determine the state of the natural environment and the perception of ecological crises. For this reason, cooperation between the social and natural sciences is required in order to record, understand, evaluate and predict the effects of human activity, and to make it possible to communicate these effects to others.
3. On this basis transformation research, assisted by the engineering and technical sciences, designs and evaluates technological systems that respond to the ecological and social challenges. Future uses of the oceans – and redesigning existing uses – often requires the application of extensive technologies and infrastructures, as in the case of integrated renewable-energy systems (Sections 5.3, 7.5). Due to path dependencies, once established these have far-reaching and sometimes unintended consequences for society and the environment; they are also very difficult and sometimes expensive to change. Interdisciplinary reflection on the future development of technology helps reduce such unintended consequences.
4. Whereas the analysis of societal transformation processes primarily draws on knowledge about historical and current transformation processes, transformation research also works with knowledge about the future. Since it has been scientifically shown that, in the Anthropocene, staying within planetary guard rails requires a comprehensive societal transformation, transformation research further investigates the possibilities and boundaries of future developments (Box 1-1). It draws up visions and goals, contextualizing them within the Anthropocene by indicating the possible consequences of alternative visions for the natural environment. In addition, it suggests how the transformation should be structured to enable visions to be implemented.

As yet no comprehensive, detailed theory exists of the multifaceted interactions between the anthroposphere and the natural world (biosphere and geosphere) – a theory that could serve as a heuristic equally well for the natural, technical and social sciences. The WBGU recommends that such a systemic perspective be developed as a matter of priority in the natural, technical and social sciences and in the humanities. This perspective should interlink and integrate knowledge from the various disciplines and strengthen compatibility between them.

Various international scientific organizations also draw attention to the importance of a better understanding of transformation processes in order to be able to avoid or reduce harmful human influences on nature and society. In 2011 the International Social Science Council (ISSC) recommended increasing the role of the social sciences in international research into global change. According to the ISSC, such research should primarily address questions relating to transformation, looking at aspects such as the societal conditions for a transformation towards sustainability, the corresponding transformation of markets, the policies required, the role of change agents and the transformation of consumer behaviour (ISSC, 2012). The international global change research programme 'Future Earth' also stresses the necessity of transformative change and scientific support for this transition to a globally sustainable society. One of its three key research themes will therefore probably be called 'Transformations towards Sustainability'. Research recommendations on global change can be found in Section 8.3.1.

8.2.2 Research recommendations

The WBGU has suggested four Key Research Themes for transformation research (WBGU, 2011) and bases the following proposals for ocean-related transformation research on them.

Key research theme 1: Societal transformation processes and transformation ability

The focus here is on analysing historical and current transformation and upheaval processes. The objective is to gain a better understanding of transformations and their impact on the Earth system, so as to draw conclusions about how to develop policies that can actively shape transformations.

There are very few long-term interdisciplinary studies or regional models of change in the oceans. Nevertheless, enough knowledge about the relationship between human use of the oceans and the damage it causes is usually available to make it possible to transform specific uses and make them sustainable. What is often lacking is integrated solutions for transforming the multiple uses of the sea and activities on land into a sustainable form of ocean stewardship, while avoiding or minimizing conflicts of objectives and tradeoffs. The key questions are whether changes in human behaviour that would permit a sustainable stewardship of the oceans are possible, and whether and how the political will to create suitable parameters for this might develop.

Particularly important in this context are studies on the appropriate design of institutions and their capacity for innovation. Global governance research has neglected the oceans in the past. What is needed is an understanding of which effective, non-hierarchical, polycentric governance structures are likely to be needed in order to handle future multiple uses. This leads to the additional question of what form the transformation of the existing governance regime should take. Particular focus needs to be placed here on the role of change agents, participatory procedures and the distribution of resources to promote or block change. Research should also include looking for second- and third-best solutions.

Particular attention should be paid to the significance of the oceans as the connecting and transport route between the continents – a bridge in the development of the global society. Despite the *de facto* importance of the seas for the emergence of the global society, the various forms of international ocean governance have so far been paid little attention by attempts to theorize the global society. A key component of these studies should be the interaction between the emerging global society and the natural environment – especially the oceans – and the question of which aspects, if any, of the global society react to threats to the natural life-support systems.

The WBGU therefore proposes a systematic study of the role of the oceans in the formation of the global society, or of the interdependence between the world's oceans and the global society. Historical analyses could examine major changes in the use of the oceans (from artisanal to industrial fishing; the use of the oceans for intercontinental travel; the laying of the first telegraph cables for communication purposes; the beginnings of oil and gas exploration, and so on) and the related effects on ecosystems and societies. The same goes for historical efforts to protect oceans and coastal areas. The role of key locations and infrastructures in transformation processes should also be analysed more closely, as well as the significance of ports and islands. The historical co-evolution of technology and ocean governance and the resulting state of the ocean ecosystem is also a relevant area for research.

The increase in environmental damage to the oceans is closely related to the emergence of the global society and the global economy. With this in mind, research into the global society should be linked to Earth-system research. In this way, researchers could identify the repercussions of the many transformations associated with the emergence of the global society on the natural foundations of human life and consider the effectiveness of existing governance systems.

A related question is the influence of key global societal trends and the associated environmental impact on current, fast-changing uses of the ocean – and the resulting demands on (global) governance.

Such trends include the perception of global environmental change, new markets like aquaculture and their contribution to the global food supply, the growing demand for food combined with reductions in the amount of available farmland, new resource shortages (e.g. rare earths), economic growth in Asia, shifts in power between the old and new powers, the rapid growth of urban populations, the expanding middle classes worldwide and the strong growth of cruises as a sector of tourism.

International research into the stewardship of the oceans and coastal areas would be a further component of this key theme of transformation research. Research priorities here include how the sea is treated by different cultures, what it means to them and what are the resultant environmental effects. Also especially relevant is the question of how interactions with the oceans, and hence the environmental impacts, have changed over time, paying special attention to technological change. An important area for research is how prevailing cultural conditions affect people's understanding of transformations and, in a second step, how they then affect related policy-making with respect to the oceans.

Identifying barriers to implementing the existing governance structures for nature conservation and environmental protection is also particularly important, especially with regard to the high seas (Section 7.3.4.2). Equally important are rules for the sustainable management of fisheries (Section 7.4.1) and certain areas of environmental protection in international shipping (e.g. ballast water, grey-water, organic waste). Moreover, there is a lack of risk and technology-impact assessments – e.g. on the extraction of oil and gas, deep-sea mining or the large-scale use of carbon capture and storage (CCS). With regard to both historical and current changes in humanity's interaction with the oceans, it should be investigated what enables different actors (countries, companies, associations, NGOs) to become change agents. Studies are needed of the overall framework governing action by players and the specific capacities of individual players, as well as regional and global cooperation between them. Another relevant area of transformation research is examining the particular constellation of actors or change agents needed for transformation processes. One key question, for example, is how the functional importance of different groups of players for the use of the oceans is currently legitimized. Studying obstacles to the move towards sustainability is also vital.

On the basis of the analyses described above, transformation research studies the prerequisites for policy-making with regard to the road towards a sustainable stewardship of the seas, and the extent to which societies can or do meet these prerequisites. Closely related to policy-making options is the question of the transformation ability of coastal states and countries that use (or damage) the ocean indirectly. Here, specific resources and capacities should be identified which allow conclusions to be drawn on the ability of a country to transform. This leads to questions about measuring (using a new set of indicators yet to be developed) and potentially increasing a country's ability to achieve transformation. Appropriate indicators from the natural sciences should be identified and monitoring systems developed to make the effect of transformative developments visible and to readjust them where necessary.

Key research theme 2: Transformation paths

Developing and evaluating visions for a sustainable future stewardship of the oceans, describing possible paths and making suggestions about related policy-making form the core of this key research theme.

Improved research into the normative basis for human interactions with the oceans is a prerequisite for evaluating visions and transformation paths. Fundamental ethical and normative questions arise from the perspective of the Anthropocene about humanity's responsibility for the future of the Earth system and for global public and common goods, including the oceans. A key element of transformation research is developing theories of responsibility and justice for the preservation of global public and common goods – including future options such as the use of genetic diversity for new materials and processes. Gaps in research also exist when it comes to evaluations of the oceans in cultural studies. There are some initial analyses of the ecosystem services of the oceans and their monetary significance, but only isolated examples of corresponding investigations into the cultural significance of the oceans. Yet even a superficial examination shows that the function of the oceans for humanity cannot be reduced to material and utilitarian aspects. Interdisciplinary research is needed here, too, to show the extent to which cultural differences influence a society's relationship with nature and hence its interaction with ecosystems. The WBGU therefore also recommends promoting marine research in the cultural sciences.

At present there are no visions for a sustainable stewardship of the oceans involving different, long-term uses. Within the framework of interdisciplinary marine futurology, researchers should use both traditional foresight methods and model-based scenario-development approaches to draft visions, models and concepts for the sustainable stewardship of the oceans in the context of the Great Transformation (WBGU, 2011). This field should take an integrated approach to different uses (e.g. energy generation, tourism, resource exploitation), describing the conflicts and synergies between them and examining relevant interac-

Box 8.2-1

Research as a 'laboratory of the future' – the Anthropocene and global ocean governance

Since the oceans have been greatly underrepresented as an object of global governance research up to now, we lack answers to the question of what forms of global governance are needed to support sustainable stewardship of the oceans within the framework of the Great Transformation. Nor do we know how such forms might be implemented.

The WBGU recommends an increase in funding for research that analyses the significance of the oceans as a global public good in the Anthropocene and develops forms of polycentric global governance which are commensurate with the systemic challenges.

Research with such a focus would see itself as a kind of 'laboratory of the future'. Its role would be to analyse past developments in, and forms of, global ocean governance, identify weaknesses and draft options for new ocean-governance structures that include, but also go beyond, nation states. Long-term, visionary research of this nature will initially be accused of being an ivory tower that has nothing to do with political realities. This criticism in no way undermines the importance of such approaches to research, however. On the contrary, the history of science has seen several examples of visionary designs without which the dynamic developments that followed would never have occurred. As early as the end of the 18th century, for example, Immanuel Kant formulated important basic principles of international law in his essay 'Perpetual Peace', introducing the concept of world citizenship long before the notion of a global society had found its way into established scientific and political discourse.

Research on how a systemic approach to a global governance regime might be designed faces the challenge of outlining a coherent multi-level concept of ocean governance for all the seas of the world and for all relevant uses. The WBGU sketches what ocean governance might look like in the future in Section 7.2. Research is needed both into the WBGU's vision as outlined there, and into alternative visions of transformative ocean governance. Research is also required into the guiding principles of a form of global ocean governance that could meet the challenges of the Anthropocene (such as the systemic approach), into the ethical and legal-philosophy foundation for the application of guiding principles (such as the common heritage of mankind principle), and into the material design of these guiding principles. Moreover, especially in relation to the material design of guiding principles – such as the formulation of a level of conservation for the marine environment that does justice to our intergenerational responsibility – there is a need for further research into the design of the institutions and instruments that this will require (Sections 8.3.2.1, 8.3.2.2).

Furthermore, there should also be studies on how ocean governance based on this kind of guiding principle might be linked with existing use and conservation regimes at the national and regional levels. This also touches on other environmental regimes (e.g. CBD, UNFCCC) in addition to ocean-governance regimes. Investigations in this context should focus on how the impact of suitable principles for the conservation and sustainable use of the oceans can be realized as fully as possible, while at the same time harmonizing them with other environmental regimes.

tions between land and sea and their interdependencies with ecosystems. This will require scientific research into the 'tipping points' of marine ecosystems – which are defined as the maximum possible levels of stress before far-reaching and irreversible changes to the marine ecosystem are triggered. Progress on determining such tipping points will make it possible to discuss concrete transformation paths in more specific terms, partially because environmental tipping points limit the scope for 'safe' human activity. Closely related to this is global governance research, the role of which is shown in Box 8.2-1.

A better understanding of the affected ecosystems and the interactions with alternative transformation paths will make it possible to identify guard rails and outline development corridors for transformation processes. Building on the vision of a sustainable stewardship of the oceans, researchers should develop potential transformation paths and evaluate their sustainability impacts. To this end they should draw up various scenarios, e.g. on different theoretically possible models or systems – global institutions, local steering by the markets, polycentric models, etc.

It is decisive for this key research theme that the description of the various transformation processes includes a discussion on the interactions and interdependencies between them. For example, the road to sustainable urbanization of coastal areas raises questions not just about the coastal cities themselves, but also about the required hinterland infrastructure, potential competition between different uses and the necessary institutional and legal parameters. Estimating different interactions with ecosystems should also form part of research into different transformation paths.

Key research theme 3: Acceleration

Apart from defining the societal preconditions for successfully structuring and influencing transformation processes, it should also be examined what options exist for accelerating such processes. Particular focus should be placed on examining societal tipping points and key initiation points, as identified above under key research theme 1. In addition to a historical and sociological understanding, technical expertise is relevant here, as are insights into socio-psychological and intercultural processes, not least in terms of the global reach and legitimacy.

Key research theme 4: Global cooperation

The transformation towards a sustainable use of the oceans is necessarily a global process which must be supported by adequate institutions and global governance mechanisms. In this context, the yet-to-be-developed field of transformation research should examine whether and how global governance can support the processes investigated in the three key research themes elaborated above. This means that transformation research should examine the role of global governance and global cooperation in historical transformation and upheaval processes: learning from the past in order to shape the future.

One key problem is that the existing processes and institutions of global cooperation are inadequate for protecting the seas as a global public and common good and as a life-support system for human life.

Examining the systemic aspects of ocean governance has revealed that social, legal and economic aspects are often neglected in natural-sciences research and poorly integrated into interdisciplinary references. It has also revealed that in the areas of legal, economic and political sciences, research into global governance and public and common goods in one field often neglects research in the other fields; indeed in terms of topics, methods and concepts there is often no interaction between the different fields at all. In terms of research policy, interdisciplinary connections should therefore be strengthened: what is needed is an integrated perspective on global public and common goods.

Major efforts are needed in the field of transformation research, not only with regard to analysing and solving problems, but also to communicating them. Societies that live near the oceans and rely on them for their survival differ greatly in terms of their cultures, and their cultural ties to the sea also vary enormously. Moreover, there is a very widespread notion that the oceans are an 'uncomplicated', often uncontrolled store of resources and a dumping ground.

8.3 Transformative research for the seas

Transformative research promotes the transition to sustainability by means of problem diagnosis and by developing solution approaches and innovations in relevant sectors. It includes the development of social and technical innovations. In addition, it implies a systemic view: first, by aligning innovation activities to the results of transformation research; second, by trying to systemically anticipate possible effects of innovations. Research on innovations covers not only developing and assessing innovations, but also determining the societal prerequisites and developing political strategies and instruments for their dissemination.

8.3.1 Research on global change

Research on global change focuses primarily on changes in the subsystems of the Earth system, on humanity's role in the observed changes, and on the effects of global change on human societies. Global-change research is conducted at an internationally excellent standard in Germany. It makes an important contribution to understanding the complexity and vulnerability of the Earth system, also in relation to the oceans.

No detailed recommendations on marine global-change research are given here, since the WBGU's priorities in this report are ocean governance, and food and energy from the sea. However, some references to core topics are made below because of the great importance of global-change research for the transformation. The three most important methodological pillars in this context are (1) targeted measurements and experiments at sea and in the laboratory, (2) regular monitoring (among other things as part of the Global Ocean Observing System) and (3) the development of modelling and forecasting capabilities.

Climate change

The world's oceans are involved in climate change in many ways (Section 1.2). The most important research questions include the following:

- How quickly are surface sea temperatures rising and how does the warming signal penetrate into the deeper ocean layers? How much thermal energy is stored in the ocean in this process?
- How are ocean currents changing?
- How is the sea level changing, both globally and regionally?
- How do the ocean and the cryosphere interact in terms of both the change in sea-ice cover and the influence of ocean warming on the ice shelves and continental ice sheets in Greenland and Antarctica?
- How are natural variability modes of the ocean changing, e.g. El Niño/Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO)?

Material cycles

The chemistry of the ocean is increasingly and considerably changing, because humanity has become an important factor in the global material cycles in the Anthropocene. This leads to a number of important research questions:

- How are CO_2 storage in the world's oceans and ocean acidification due to CO_2 input developing?
- How do the oxygen-deficient zones in the oceans spread?
- How big is the danger of global warming causing the release of methane from hydrate deposits in the ocean floor?
- How do pollutants – plastic waste, oil pollution, radioactive substances – spread in the oceans?

Marine ecosystems and biodiversity

Life in the sea is exposed to multiple stress factors simultaneously in the Anthropocene: warming, acidification, pollution, overfishing, etc. (Chapter 1). Further research is urgently needed to find out how the marine ecosystems cope with this, how they influence each other in the process, and where critical load limits are being exceeded. The overarching research questions listed below are specified in Section 8.3.3 in relation to the relationships between fisheries and aquaculture:

- What effects are the increasing warming of the sea water, changes in the currents and interventions in natural sedimentation having on marine ecosystems and their biological diversity?
- How are the acidification and spreading of oxygen-deficient zones impacting on the ecology of the oceans, e.g. on coral reefs and microplankton?
- What effects are the spread of invasive, non-native species having?
- How does ocean pollution affect the marine ecosystems?
- What influence does fishing have on the marine ecology?
- What measures (e.g. marine protected areas) are best suited for making marine ecosystems more resilient towards climate change, acidification and fishing pressure?
- How can the yields and services of marine ecosystems be evaluated in economic terms (Section 8.3.3.1)?

The three above-mentioned key areas – climate change, material cycles and marine ecosystems/biodiversity – which are superficially assigned to the fields of marine physics, chemistry and biology, should not, however, be considered in isolation, but in the context of a systemic approach which incorporates their interactions.

The question of the economic valuation of marine ecosystem services points beyond classical global-change research in the direction of indicators for governance. No comprehensive valuation has yet been carried out of global marine and coastal ecosystem services. Although individual valuation studies have been made on selected ecosystem services, mostly in certain subregions of the Earth, there is still a long way to go before a comprehensive inventory can be made of the value of the global marine and coastal ecosystem services. This would require more complex national and global estimates and would have to be based on corresponding models mapping a large number of relevant interactions. Projects and organizations attempting such a comprehensive valuation of marine ecosystem services, e.g. the international TEEB project (The Economics of Ecosystems and Biodiversity; Beaudoin and Pendleton, 2012), should be supported.

In addition, more support should be given to valuation studies looking at ecosystems that are hitherto largely unexplored. At present, valuation studies exist primarily on coral reefs, mangroves and coastal ecosystems, while hardly any efforts have been made to conduct an economic valuation of other marine ecosystems in general and deep-sea ecosystems in particular – not least because of the associated methodological challenges. As long as the economic importance of these ecosystems is unknown, we lack an important basis for making decisions on the protection and use of the oceans.

8.3.2 Ocean governance

Research on the governance of the oceans is broad and well-developed in individual sectors, particularly in the fields of jurisprudence and political science (e.g. on regulatory and economic instruments in the field of fisheries and on individual institutions and regulations of UNCLOS). Less research has been conducted in other fields. For example, there are hardly any scientific findings on political, legal and economic design options for such forms of ocean use as renewable marine energy or aquaculture (Sections 8.3.3, 8.3.4). Global governance research on the oceans is underdeveloped compared to other fields (such as the climate, forests or international financial markets). Overall there is a lack of cross-sectoral and coherent analyses and assessments of governance structures, or on legal and economic conditions and requirements relating to the current and future use of the oceans. At the same time, given the challenges of the Anthropocene there is a need to intensify cooperation between global governance research in the fields of social sciences and jurisprudence on the one hand and the natural sciences and engineering on the other. Only if there is a better understanding of the interaction between the ecosystems, the socioeconomic systems, and the technical systems can governance patterns be developed that are able to meet the challenges involved.

The WBGU believes that developing governance research in this way is indispensable on the road to a sustainable stewardship of the oceans. This research should go hand in hand with laying down the theoretical foundations of – and drafting and developing – potential global guiding principles, such as the 'heritage of mankind' principle, and possible institutional and instrumental designs of governance based on such guiding principles.

8.3.2.1
Ocean governance for the transformation towards sustainability

Existing ocean governance is already well developed in some sectors, for example in fishing (Section 4.1.4). In some cases there are promising approaches for a further development towards a transformative form of governance (e.g. the designation of marine protected areas on the high seas under OSPAR; Section 3.4). Measured against the challenges of the Anthropocene, however, there are considerable deficits and gaps. In this context, research on ocean governance committed to the systemic approach should contribute to a better understanding of the design, functioning and shortcomings of existing governance. A better understanding of existing ocean governance is essential for developing a coherent transformation policy at the local, regional and global levels. The WBGU therefore recommends funding both research into understanding the status quo and research that reveals the prospects of systematic interaction with the transformation towards a sustainable society. Ideally, this research would dovetail closely with the research on societal visions outlined in Box 8.2-1.

Global level

In the field of ocean governance at the global level, there is also a need for research on individual steps towards a transformation. For example, not enough work has yet been done to determine to what extent future global implementing agreements could develop a transformative effect under UNCLOS, the Convention on Biological Diversity (CBD) or the UNFCCC. The first question to be asked here is what topics would be particularly important for further agreements in relation to the transformation and how might those that are currently under discussion – for example on biodiversity on the high seas (Section 3.3.2, 7.3.4.2) – be fleshed out? Secondly, there is need for research into the likely effects of additional global agreements at the regional and national level. For example, there should be studies on what possibilities would be opened up, e.g. as a result of additional competencies. In this context, the WBGU recommends also examining how global agreements should be designed to encourage the further development of regional ocean governance and to ensure better interaction between regional and global governance.

There are also gaps in research on the institutional fragmentation of global ocean governance and on further developing it towards an integrated form of governance. Studies in this field should first look at how the activities of the various players at the United Nations can be better integrated institutionally (Section 3.3). In the context of current efforts under the Oceans Compact (Section 7.3.3.1), for example, interdisciplinary governance research should here investigate how such integration might take place and how coherence can be encouraged – e.g. between UNEP, FAO and IMO (Section 3.3). The aim is furthermore to examine the advantages and disadvantages of a unified form of ocean governance that brings together the existing and future institutions into a World Oceans Organization (WOO; see Section 7.2.2.1).

Regional level

Numerous regional governance structures exist worldwide, both for protecting the oceans (e.g. the Helsinki Convention for the Baltic Sea) and for improving sustainable use (e.g. RFMOs in the fishery sector). Up to now, these regional governance structures, most of which are specifically enshrined in international law, have not been fully researched from a political or legal perspective.

The existing social-science research conducted under the UNEP Regional Seas Programme is largely concerned with environmental, socioeconomic and cultural aspects, as well as detailed management questions (Section 3.4.1).

Developing a coherent policy of transformation requires better answers to overarching governance questions at the regional level. Research is needed primarily into institutional conditions for the success of regional governance concepts for the seas. Comparative research on the individual mechanisms of existing agreements and programmes would be appropriate in this field in order to identify best-practice solutions and make concrete suggestions on how to overcome the fragmentation of ocean governance and improve cooperation and coherence.

There should also be research into the extent to which regional marine agreements not only meet their agreed objectives, but are also appropriate in view of the real challenges of the Anthropocene. This requires a more interdisciplinary direction of research involving the natural sciences. In this way, the effects of regional agreements can be assessed on the basis of scientific findings on the targeted state of the respective marine region, rather than with reference to political objectives that have been formulated by the players to be evaluated.

Research on EU trade policy

Trade policy plays an important role within a systemically oriented marine policy. These issues are particularly relevant for the EU because of its rising imports of fishery products. An improved understanding of the economic interests and their relationship to existing governance is required in order to make trade policy more sustainable. There should also be studies on trade flows and their relations to direct investments and agreements with third countries, on the strategies of retailer corporations, the effects of subsidies and the role of sustainability certification. Research is also needed on the compliance of minimum standards with WTO rules when issuing sustainability labels. The same applies to fishing subsidies, where there is a particular need for clarification with regard to the current round of negotiations (Doha round).

8.3.2.2
Policy instruments for new challenges

The rapidly expanding number of ways of using the oceans – e.g. resource extraction in the deep sea, access to Arctic resources, new Arctic shipping routes – potentially involve considerable and, in some cases, incalculable effects on the marine ecosystems, as well as on existing uses (Chapter 1). To ensure a future-oriented, sustainable stewardship of the oceans, instruments of governance should be developed which address the global challenges of the Anthropocene. Corresponding interdisciplinary research in the national and European context should also include the global level.

At the same time, intensified research on the effect of the combined use of different instruments and policies is necessary with the aim of achieving an integrated form of ocean governance. There should also be studies on what a player-specific mix of instruments for the respective policy areas might look like. This would also include research on the effects of private standards, such as eco-labelling in fisheries.

Global evaluation system on environmental effects of ocean uses

The WBGU believes that the effects of ocean uses on the marine environment require a global evaluation in line with the systemic approach. A globally applicable evaluation methodology should be developed to this purpose that links up with global-change research (Section 8.3.1) and existing evaluation systems. Among other things the development of an integrated and coherent system of indicators for evaluating the global, regional and local effects of the most important uses of the sea should be funded which also takes interactions and interdependencies into account. The WBGU also recommends developing political target indicators – e.g. for fisheries (Section 8.3.3.1) – as a frame of reference for future ocean governance.

The development of such an evaluation methodology should build on existing national and European assessment procedures (e.g. strategic environmental assessment, environmental impact assessment; Section 7.2.4) and – for the political target indicators – on existing experience, also in the context of regional marine agreements. The WBGU also recommends examining how marine aspects can be incorporated into the United Nations Sustainable Development Goals (SDGs), which are currently being developed (Section 7.3.3.1).

Spatial planning and marine protected areas

As a forward-looking instrument for balancing different users' interests and coordinating conservation and use, marine spatial planning can make an important contribution to sustainable coastal governance. Analyses have shown that only a small proportion of this potential has been used to date (Section 3.6.2). Alongside the comparative analysis and evaluation of existing spatial planning on the sea, especially in the EEZs, there is a need for research above all on the possibilities and requirements of spatial planning on the high seas (Section 7.3.9). Studies here should focus on how global marine spatial planning based on the systemic approach – including the material and procedural design of the instrument – can be developed and implemented. The focus here is on questions relating to conservation standards, integration and formulating environmental, use-related and political target indicators, as well as transparency and how best to involve actors. Accompanying socioeconomic, ecological, political-science and jurisprudential research should also be funded.

Marine spatial planning is in its early stages. Research should be conducted into possible ways of adjusting marine spatial planning to land/sea interactions (material flows, etc.) and to how the instrument of spatial planning can be made operational in regions that are outside national jurisdiction. Only a better understanding of these special characteristics will make it possible to enhance marine spatial planning and turn it into an instrument that can meet the challenges of the Anthropocene.

There is also a need for more research on marine protected areas (MPAs). The questions to be asked here relate to the design and implementation of an effective network of MPAs in the context of marine spatial planning dedicated to sustainability. Research should be intensified into how much potential there is for regeneration and adaptation in areas that have already been damaged. Initial results, for example in coral reefs, indicate that the highest adaptation speeds can occur in reefs that are already damaged, which would need to be taken into account when designating protected areas. In this context, the WBGU recommends funding studies on the effectiveness of MPAs, also looking at selection, conception, protected status and enforcement. There is also a need for research on the use of MPAs as an instrument of fisheries management (Section 8.3.3.1). Here, too, there is a need for inter- and transdisciplinary accompanying research. In addition, there should be research on how the granting of rights of use and the designation of protected areas on the high seas can be integrated with existing or yet-to-be-developed evaluation systems (e.g. under NATURA 2000) or environmental impact assessments. Marine spatial planning in the German EEZ in the Baltic and North Sea can serve as a starting point for this research

User charges

With reference to the collection of user charges on the high seas, research is needed on aspects of practical implementation and legal form. The range of possibilities in terms of legal form should be explored more closely in various uses, especially in fishing. Decisions on the type and amount of user charges should furthermore be based on studies on the economic implications of introducing user charges. It should also be clarified who could impose user charges and how these charges should be used.

8.3.3 Food from the sea

8.3.3.1 Fisheries

The current problems caused by overfishing (Sections 1.2.2, 4.1.1) have their roots not so much in inadequate knowledge about the sustainable management of fish stocks as in the inadequate application of existing knowledge. Nevertheless, there are gaps in knowledge about the structure and function of marine ecosystems, and about the effects on these ecosystems of different fishing methods, climate change and ocean acidification. Research findings in this field are a prerequisite for implementing the ecosystem approach to fisheries (Sections 4.1, 7.4.1).

Marine ecosystems

- The implementation of the ecosystem approach in fisheries depends on broadly based background knowledge. A strengthening of research aiming at a better understanding of the structures and functions of marine ecosystems, including their biodiversity, material flows and productivity, is therefore recommended to provide a scientific basis for the more specific research recommendations on fisheries and aquaculture made below. Studies of historical states of marine ecosystems and their relations to fishing and fishery governance can help in this context.
- In the context of the TEEB study, research on the economic valuation of biological diversity and ecosystem services provided by the seas should be extended to improve our estimates of the costs of overfishing and global environmental changes (climate change, acidification, oxygen-free zones). These findings can also serve as input for the new scientific advisory panel IPBES (Intergovernmental Science-Policy Platform on Biological Diversity and Ecosystem Services).

Methods, indicators and data

- The effects on biodiversity and ecosystems of different fish-catching methods and their intensity should be researched more closely, especially to develop and scientifically evaluate solutions for more sustainable fishing. Studies on the effects of different selective catching methods, as well as on protected zones and ecosystems should be intensified.
- Research should be funded on the technical improvement of fishing gear in order to avoid bycatch, to be more selective in catching the respective target species, and to minimize the harmful effects on marine ecosystems and habitats (e.g. passive fishing methods). One focus of research should be the replacement of methods that damage or destroy the marine habitat, for example substituting fishing gear that touches the sea floor by alternatives such as pulse fishing. The possible ecosystem effects of these alternative methods should also be examined.
- The data basis on many stocks, which is required for modern, knowledge-based fisheries management, is poor even in developed countries, but the situation is particularly serious in developing and newly industrializing countries. For these 'data-poor stocks' research should develop instruments and indicators that make it possible to estimate the maximum sustainable yield and a sustainable management system despite a lack of available data. In parallel, research collaborations should be stepped up to improve knowledge about the biology and ecology of the target species.
- Research on the sustainable management of fish stocks should be intensified. In particular, efforts should be made to improve the models and enhance indicators and monitoring concepts in relation to ecosystem linkages (maximum economic yield, optimum sustainable yield, multispecies maximum

sustainable yield and other multi-species approaches, cascading effects, etc.). Furthermore, workable concepts should be developed on how the ecosystem approach can be integrated into fisheries management.

- The scientific basis of the widely cited FAO analyses of the expected demand for fish should be significantly improved. In particular, the options for responding to the projected increase in demand are insufficiently differentiated. Different strategies should be used for dealing with growing demand (e.g. regulation via the price, substitution strategies) depending on the region and the level of economic development (developed country, emerging economy or developing country).
- Reliable proof-of-origin systems for fish and fish products would be very helpful for establishing effective port-state controls to combat illegal, unreported and unregulated (IUU) fishing and illegal trade, as well as for sustainability certifications. Studies on the development of corresponding monitoring procedures and controls, including the use of genetic methods (DNA bar coding), should be funded, as should the creation of corresponding databases and communication structures for consumers.
- Fishing for forage fish for use in aquaculture concentrates primarily on species at low trophic levels. Research results show negative effects of this 'reduction-fishing' on food webs, marine ecosystems and the natural predators such as tuna, seabirds and marine mammals. Research should be intensified on sustainable management methods for forage-fish species.
- Research should aim to find out how fish species that up to now have been used only as forage fish can be made usable as a food for direct human consumption in order to raise the efficiency of fish farming. The development of non-perishable products from these stocks is important, especially for markets in developing and newly industrializing countries.

Governance of fisheries

- Socioeconomic research on framework conditions and incentive structures for sustainable fisheries management at the local and regional levels should be further strengthened. In particular, research is needed on the suitability of different arrangements on ownership and access rights under different local conditions, as well as on methods for reducing bycatch and other ecosystem stresses. In this context studies should concentrate on how rules on the compulsory landing and use of bycatch can be designed in such a way that there are no incentives to increase the amount of bycatch.
- Research is urgently needed on drawing up the scientific principles for a sustainable EU fisheries policy based on fisheries partnership agreements with third countries (the 'external dimension'). Moreover, there should be studies on which economic, political and legal incentives are particularly effective in promoting the enforcement of agreements by the EU Member States. Comparative analyses of best-practice examples could provide helpful insights.
- Research should be conducted in the fields of political and social science to examine the various options and instruments for overcoming the barriers hindering the transition to sustainable fisheries.
- Monitoring of stocks and fishing activities should be improved and intensified to gain a better overview of illegal, unreported and unregulated (IUU) fishing. The aim should be to uncover deficits and gaps in regulation and implementation in local, national and global governance, particularly in relation to developing countries. Furthermore, there should be studies on which policies and measures might be most effective in addressing these deficits. In particular, they should examine how effectively the EU's IUU Regulation is being implemented. Transdisciplinary research, for example in cooperation with the authorities, could contribute to a better understanding of the interactions between regional, national and international fishery and trade policies, and thus to more effective and more efficient coordination between the action levels.
- Research on the implementation and design of an effective network of MPAs in the context of sustainable marine spatial planning should be intensified. Studies on the effectiveness and success factors of MPAs should be funded (Section 8.3.2.2). In the fishery context there is above all a need for research on the use of MPAs as an instrument of fisheries management.

Fisheries and global environmental change

- Research is needed on the systemic effects of global environmental change (warming, acidification, oxygen-free zones, biodiversity loss, increase in the numbers of invasive species, etc.) on marine ecosystems in general and fish stocks in particular – especially on the regional effects on the transformation of fisheries and aquaculture towards sustainability. This research should increasingly pursue interdisciplinary approaches and integrate physical, biological, (geo)chemical, social-science and economic disciplines (Section 4.4.5). The effects of environmental changes on marine organisms and ocean ecosystems should be studied in greater detail by developing realistic scenarios (e.g. warming, lack of oxygen, acidification). Efforts should be made to improve science's understanding of climatic effects on fisheries and protein supply – and of the subsequent effects on societies around the world, e.g. on economic performance, prosperity, employment and food security.

- The effects of climate change on fish species should be researched. Changes in the composition and occurrence of species could have a serious adverse impact on the livelihoods of small fishermen. For this reason, corresponding adaptation strategies and measures should be developed.
- The concept of LIFE (low-impact, fuel-efficient) fishing can provide interesting ideas on the low-carbon development of fishing. In particular, there should be further research on the use of win-win effects in terms of sustainability and reducing CO_2 emissions, and on designing framework conditions and incentives accordingly.
- Small-scale fisheriesThe available data should be urgently expanded at all levels to promote small-scale fisheries. In addition to the scientific collection of information on fish stocks, more data should be gathered on the societal benefits of small-scale fisheries, for example in relation to food security or ecosystem services. In many developing countries, it is currently not possible to estimate the sustainability of small-scale fisheries due to a lack of research. In parallel, research on the management of data-poor fish stocks should be promoted. In this field it is especially important to integrate local knowledge on fish-stocks monitoring into the research.
- Since there is no scientific consensus on which governance mechanisms are most effective for promoting sustainable small-scale fisheries, the research on this topic should be intensified. A comparative analysis of existing incentive mechanisms could be a meaningful area in which to start. Since local, informal rules play an important role in small-scale fisheries in developing countries, the analysis should take the participation of small-scale fishermen into account.
- There are few studies on optimizing the value chains of small-scale fisheries in developing countries. The key issue is what investments are most effective there in order to generate the maximum possible value creation in developing countries. Since there is no consensus on whether small-scale marine fishermen can be meaningfully incorporated into certification systems, comparative research could shed some light on what potential and risks exist in this context.
- Small-scale fishermen are sometimes forced to use non-sustainable fishing methods under certain circumstances (e.g. competition from industrial fishing or falling prices) to ensure their survival. The question arises as to which structures are suitable for safeguarding the social security of small-scale fisheries, preventing such over-exploitation and promoting sustainable fishing. What possibilities are there for improving the socioeconomic situation of local communities, while simultaneously reducing the pressure on fish stocks by extending and raising the competitiveness of local value chains and alternative sources of income?
- Another gap in research relates to the interactions between small-scale and industrial-scale fisheries. Such an analysis would be necessary to share ecologically and socially sustainable catch quotas between industrial fishing and small-scale fisheries and to develop suitable zoning concepts. In addition, there is hardly any research on the effective coordination of fisheries governance across different levels of political action (local, national, regional).
- The specific contribution of small-scale fisheries to combating malnutrition, so-called 'hidden hunger', has been insufficiently quantified. Filling this gap in research should complement knowledge about the role of small-scale fisheries in developing countries.

8.3.3.2
Aquaculture

Aquaculture is a fast-growing sector with a great need for research, especially in the field of sustainable production methods. The rapid development of aquaculture also requires research to be conducted into any adverse effects it might have on the environment and society.

Intensify research on forage-fish substitution

- The aquaculture of carnivorous and omnivorous species remains dependent on catching forage fish (reduction fishery), which are used as feed in the form of fish meal and fish oil or raw fish/fish waste, and this aggravates the overfishing of the oceans. Research is in progress on technical solutions for substituting fish oil and fish meal, and has already met with some success; nevertheless, the problem of substituting of fish oil in particular has not yet been satisfactorily solved. Work is already in progress on extracting proteins and oils from protozoa (single-cell oils, SCO). This has great potential, so funding for it should continue, especially with a view to a broader and less cost-intensive application. Possible synergies with the bioenergy sector should be explored with the aim of reducing costs. Research is also currently in progress on the genetic modification of agricultural crops such as soybean and rapeseed, which are supposed to produce unsaturated omega-3 fatty acids. Before they are used, possible ecological risks should be taken into account by making careful environmental risk assessments. Other feed alternatives include the use of residues from terrestrial animal production and from the processing of fishery and aquaculture products, as well as bycatch from fishing; their usefulness as feed and any negative effects (e.g. obstruction of a desired bycatch reduction) should be assessed, and they can be further developed where appropriate. Further research into the use of algae as a source of lipids could also be profitable.

- There should be research into whether, and to what extent, Antarctic krill could function as a possible substitute for forage fish; the findings should be critically evaluated from an ecological perspective. In addition to collecting data on populations and abundance, it is imperative in the sense of the precautionary principle to analyse the possible effects of extensive krill fishing on food webs and marine ecosystems, since krill is at a low level of the food chain (Section 4.3.3). Furthermore, a comprehensive risk assessment should be conducted, and its results should serve as a basis for the further use of krill.
- Research is also needed on the interactions between expanding the production of plant-based aquaculture feeds (such as soya and oil palms) on the one hand and alternative land uses on the other, especially in view of the growing pressure on land from the rising food needs of a growing population, which is increasing competition for land use. The potential of a regional, environment-friendly agricultural production of plant substitutes should be measured and evaluated.

Expand research on sustainable and environment-friendly aquaculture systems

- The ecosystem approach should be the basis for developing sustainable aquaculture. In particular, interdisciplinary research into designing and implementing this approach should be intensified. Research on various assessment frameworks based on this approach (e.g. the ecological footprint) should be further intensified.
- The distinguishing feature of land-based aquaculture recirculation technologies is that they are a resource- and space-conserving production method; however, they are relatively expensive due to their high production and operating costs and their complex technology. The aim must be to improve these technologies by means of interdisciplinary cooperation and to conduct market evaluations for them. Existing research on integrated multitrophic systems should be expanded and intensified because of their possible contribution to an environment-friendly form of production, above all in developing countries.
- Fish larvae are often taken from the sea for breeding purposes for fish aquaculture. This primarily affects species that are seriously endangered but economically very interesting, such as tuna, eel or grouper. In Germany, biological knowledge is limited on the early egg and larval stages and their application for a technically successful rearing process. There is a need to catch up here in terms of making progress in breeding, primarily with the medium-term aim of no longer needing to take larvae from the wild. In parallel to this, however, there should be support for research into breeding suitable new herbivorous and omnivorous species and into their sustainable production and humane husbandry, since such species are hardly – or not at all – dependent on fish meal and fish oil in their feed. The research should include changes in consumer behaviour and marketing strategies to promote new species.
- The development of offshore aquaculture, and the exploitation and promotion of synergies between offshore installations, such as wind power and aquaculture equipment or other multifunctional platforms, might be the ways to go forward in view of increasing competition for the use of space in coastal regions. Research on offshore aquaculture should be expanded to clarify what breeding types and technologies are best suited for environment-friendly aquaculture production. Multitrophic aquaculture systems should take priority in funding, since they can ensure an optimal use of the nutrient and energy cycle. Research on breeding filter feeders such as mussels and algae, which hardly pollute the marine environment at all, should be intensified with this in mind. Work should also be done on how to optimize possible synergies, also in terms of risk assessment and safety, e.g. in view of increasing shipping traffic in and around wind farms. Also, the impact of offshore aquaculture on marine ecosystems should be thoroughly investigated by continuous accompanying research and monitoring. Research should be funded on the development of the infrastructure required both on land and offshore, coupled with comprehensive economic feasibility studies. Furthermore, there is a great need for research on the overall socioeconomic conditions into which the offshore aquaculture projects are embedded.
- In addition to the technical aspects, research should also be conducted on sustainability issues and the macroeconomic assessment of land-based recircula-

tion systems and integrated multitrophic aquaculture systems in offshore wind farms. These are priority research questions for Germany, since the country only has very few locations suitable for near-coastal marine aquaculture. Efforts should be promoted to optimize the hitherto very expensive recirculation systems (e.g. by means of a market evaluation of the products, a feasibility estimate of the facilities, securing sales, determining the impact of rearing on the animals, forage-fish substitution), which offer great potential.

- Research on environment-friendly, resource-saving, socially acceptable and economically viable aquaculture techniques should be intensified (both at the small-scale and at the industrial level), particularly in developing countries where there are frequent conflicts between aquaculture and other uses and aquaculture is growing rapidly. Issues relating to the socioeconomic impact of aquaculture development, acceptance and conflict-reduction measures should be integrated.
- Another research field is the combination of aquaculture candidates from different trophic levels, e.g. fish with algae, mussels and polychaete, and the reduction of eutrophication on coasts. Eutrophication and oxygen deficiency can be reduced – and management programmes to reduce nutrient inputs into waters supported – by the bioextraction of nutrients like nitrogen. Existing research should be further expanded, in particular research on the effects of bioextraction on the marine ecosystems and their ecosystem services, as well as on the transferability of the results to other ocean regions.

Intensify research on the environmental effects of aquaculture

- Aquacultures can threaten the ecosystems surrounding them with chemical substances, antibiotics, superfluous nutrients, excrement, pathogens and gene transfer from escaped aquaculture organisms. In particular, the effects of genetically modified breeding organisms on wild populations and ecosystems need to be further explored and possible risks analysed. Potential effects on biodiversity should also be analysed when cultivating new species.

Promote research on governance in aquaculture

- Studies should be conducted on which governance approaches are most likely to promote ecologically, economically and socially responsible aquaculture and under what societal and political conditions. There should also be research on how regional governance can take future resource pressure and changing environmental influences on aquaculture into consideration so as to make sustainable adaptation possible. In this context, existing deficits in governance and barriers to the implementation of suitable governance measures should be included in the analysis. Since the conditions are very region-specific and context-dependent, case studies might be a suitable starting point.
- There should be studies on how measures for implementing ecologically sustainable aquaculture can be designed in a way that is also socially sustainable and can thus make a simultaneous contribution to poverty reduction. Factors such as market access and market distortion, which put small businesses at a disadvantage, should be documented accordingly and compensation possibilities identified. Ways to build value chains that are compatible with aquaculture should be examined.
- Having different certification schemes, criteria and labels for sustainable aquacultures makes marketing more difficult and complicates matters for consumers. Research should be funded with the aim of unifying criteria and labelling schemes and improving comparability.

Promote research on yield potential in aquaculture and food security

- There is hardly any data to date on the global yield potential of different aquaculture scenarios (intensive versus semi-intensive versus extensive, sustainable versus conventional production). Research on this subject should be encouraged, particularly on whether and to what extent the steadily growing demand for aquaculture products can be covered in the long term – worldwide, and particularly in regions with a difficult food situation – by ecologically sustainable and resource-conserving production methods. This also includes the question of how well sustainable and environment-friendly aquaculture can compensate for the reduced catches that will be experienced on the road to sustainable fishery. Research on potential yields should also consider issues like the amount of space available for the possible expansion of aquaculture, a potential expansion of agricultural land for growing forage-fish substitutes like soya, and possible resultant conflicts over land use and other resource conflicts (e.g. availability of fresh water for agriculture versus freshwater aquaculture).
- Direct and indirect contributions by aquaculture should be studied and quantified in relation to food security and poverty reduction. Case studies show that mechanisms like microcredits can be useful initiatives for generating self-sufficiency or creating

new sources of revenue. Even so, the effect of expanding aquaculture production on poor sections of the population has been insufficiently studied and quantified up to now (Section 4.2.2.2). Although existing case studies are already delivering information, this is often not scalable or unequivocal. A more profound understanding of the mechanisms causing certain effects in different markets and value chains can reveal regionally and culturally specific support mechanisms for combating poverty and allow the prevention of undesirable developments that are not socially sustainable. This includes an analysis of the respective political and cultural framework.

- As a contribution to food security in urban areas, studies could be conducted on the extent to which the decentralized eco-friendly breeding of omnivorous and herbivorous species in urban and semi-urban areas is possible and can be promoted.

Intensify research on the effects of environmental influences on aquaculture

- Aquaculture is influenced by changing environmental factors and will have to face future challenges caused by such environmental effects as climate change and associated warming, ocean acidification and sea level rise, as well as extreme weather events. There is a need here for research on the effects of these changes on the aquaculture sector in different regions. In addition, studies should be carried out to determine which adaptation options are likely to be the easiest to implement and how possible land-use conflicts could be mitigated by any relocations that become necessary.
- Climate change may have an adverse effect on the availability of plant-based feed materials such as soya, since many of the corresponding plants are grown in tropical regions, and agriculture there could increasingly suffer from regional water shortages. Studies are needed to investigate the price changes of feed materials, as well as access to them and their availability, and to develop adaptation strategies.
- Higher water temperatures and ocean acidification can have a negative impact on breeding organisms. There is a need for research on effective feeding methods at higher temperatures. The mussel industry, which accounts for about 75% of marine aquaculture production volume, is especially vulnerable. There is a lack of research into the physiological effects of higher temperatures and acidification, particularly on crustaceans. Research is also needed to better analyse the effects of toxic algal blooms on shellfish production sites and human health.

Strengthen the research infrastructure

- The Bangkok Declaration calls for more investment in aquaculture research. Public-private research partnerships and greater cooperation between national and regional institutes have already generated stimuli for research and research funding and should continue to receive funding. Furthermore, the development of international research partnerships (e.g. between developing, emerging and developed countries) should be intensified in order to support the aquaculture-producing countries in research on important socioeconomic, political and technical issues. National 'aquaculture authorities' could coordinate research to make sure that resources are used efficiently. The research findings should be publicly available and actively disseminated. The exchange of information and ideas between operators of aquaculture installations and scientists should be supported to encourage the exchange of knowledge about new technologies and practical experience with their application.
- In view of the situation of aquaculture in Germany the existing competencies should be bundled. To this end opportunities for cooperation between research groups and aquaculture study courses should be strengthened. As an EU member, Germany has an obligation to draw up a national strategy on the development of aquaculture by 2014. This will require the development of an interdepartmental and interdisciplinary research strategy for aquaculture. In the WBGU's view the strategy should in particular take precautionary and sustainability aspects into account.

8.3.3.3 Overarching issues

- There should be more support of research into the role of sustainable fisheries and sustainable aquaculture within integrated strategies aimed at future food security in the context of sustainable land use and a growing world population. The functions and distribution of the marine food contributions should also be examined in this context in order to integrate land-based and offshore food-security strategies. In particular, there is a lack of studies on how to compensate (food, income) coastal communities dependent on fisheries in developing and newly industrializing countries (but also in industrialized countries) in the event of fishing restrictions to rebuild healthy stocks. The options for ensuring food security which arise from reformed fisheries, sustainable aquaculture and sustainable land use should be examined together with the interactions that exist between them.

- A database of positive and negative case examples of fishery reform should be built up and evaluated, since this could provide valuable information on the kind of overall conditions, detailed content and timing required for reform initiatives.

8.3.4 Energy from the sea

8.3.4.1 Technology research

Further research and development efforts are required to find key technological components for future sustainable energy generation in and on the sea. The marine-energy system of the future will be made up of a range of different energy carriers, energy-generation technologies and storage forms (Section 5.3). The WBGU expressly emphasizes that these should be used in an integrated, low-carbon energy system. This will require a systemic, integrated development and dissemination of technologies. The German Federal Ministry for Education and Research, too, has stressed the importance of a systemic approach in its paper entitled Basic Energy Research 2020+ (BMBF, 2008).

The German Federal Ministry of Economics and Technology's National Master Plan for Maritime Technologies mentions the development of offshore technologies for exploiting fossil energy carriers at great water depths and ice-covered regions, the underwater extraction of oil and gas, the related infrastructure (monitoring, ships, drilling technology), as well as technologies for marine CO_2 storage and for prospecting for marine gas hydrates (BMWi, 2011a). The same applies to the Federal Ministry of Economics and Technology's research programme on Next-Generation Maritime Technologies (BMWi, 2011b).

In its vision of sustainable marine energy generation (Section 5.3) the WBGU advocates the shared use of infrastructures. This would not only open up possibilities for a more efficient development of the infrastructure, but also facilitate the necessary long-term transition from extracting fossil energy to using renewable energy. However, this requires research on the systems integration of marine renewable energies and offshore wind, as well as gas, also for use as storage capacity.

For this reason, the WBGU recommends inviting inter-ministerial tenders for research programmes on joint infrastructure development, e.g. for offshore gas as well as offshore wind or marine-energy technologies, e.g. as a joint programme of the German Federal Ministries for Education and Research (BMBF), Transport, Building, and Urban Development (BMVBS), Economics and Technology (BMWi) as well as the Environment, Nature Conservation and Nuclear Safety (BMU). At present, the contents of the Federal Government ministries' separate research programmes appear to be insufficiently integrated as a result of the responsibilities of the respective ministries.

At the same time, the WBGU has a critical attitude towards the further development of extraction technologies for fossil fuels that have been inaccessible until now, particularly in the Arctic; it recommends not using fossil energy carriers in the medium term in view of the international climate-policy target of limiting the temperature increase to 2 °C. The global transformation of the energy system towards a low-carbon, sustainable energy supply should be largely completed by 2050 (WBGU, 2011). It is therefore not necessary to further develop technologies to extract fossil energy carriers; in terms of climate policy it would send the wrong signal and would possibly extend the technology path of fossil fuels. Since natural gas will play an important role both during the transition and in a future low-carbon energy system, the extraction systems should be improved by safety research. At the same time there should be research on how biogas production can be combined with other marine-energy technologies on floating platforms and integrated into a shared transport infrastructure. Technological research on extracting fossil energy carriers in the Arctic should concentrate on the development of monitoring technologies, safety research and environmental effects. There is also a need to determine the sustainable potential of marine, low-carbon energy systems in the Arctic.

The following is a list of what the WBGU regards as the priority research needs in the field of marine-energy systems.

- *(Floating) multi-use platforms:* Multi-use platforms can contribute to a better exploitation of the available marine areas within the EEZs and reduce conflicts over use (Section 5.3). However, given the early state of development of many technologies for the use of marine energy, little experience has yet been gained on multi-use platforms to date. Further research is therefore needed on this option of combining several renewable marine energies: for example research on which marine-energy technologies can be combined, how prone they are to failure, and how safe the respective storage technologies are. In addition, safeguards and contingency plans should be developed. The negative effects of platforms on marine ecosystems and ways of avoiding them should also be examined, especially noise emissions and the influence on biodiversity and currents.
- *Development of sea-based storage applications:* The importance of storage systems will increase consid-

erably in the course of the transformation of the energy-supply system, as renewable energy's share of the energy mix increases. There are ways of storing electricity generated from renewable sources in the sea, too. For daily storage, in addition to physically storing the power in deep-sea underwater stores, osmotic drinking-water treatment plants can be converted into electricity storage installations (Section 5.2). At present, both technologies are still at the early concept phase and should be developed further. For long-term storage there is also the possibility of chemical storage by means of the electrolytic production of hydrogen with optional methanation. Because of the role that gas could play in the marine-energy system, the WBGU recommends expanding research in this field. The WBGU recommends beginning the development of marine storage applications as mentioned above under the auspices of the German National Master Plan for Maritime Technologies and the German 6th Energy Research Programme. This kind of storage should also be listed as a 'research need' in the German 'Next-Generation Maritime Technologies' Research Programme.

- *Multi-terminal high-voltage direct-current transmission for an offshore supergrid:* High-voltage direct-current (HVDC) grids offer the advantage of smaller line losses compared to alternating-current transmission systems. However, they are technically more complex. The development of multi-terminal HVDC grids is required in order to build an offshore grid connecting more than two countries (point-to-point) based on HVDC technology. This technology is still at an early application phase, and the first systems are in operation; however, further experience should be gained on a relatively small scale before building large offshore grids. Accordingly, small pilot schemes should initially be funded in the near future to test and research the technology. Offshore grids are called a 'priority theme' in the German Maritime Technologies Master Plan; the development of multi-terminal HVDC systems should be explicitly incorporated into the respective action plan.
- *High-temperature superconductivity:* Superconductors can carry very large electrical currents over long distances with practically no loss. When superconductors are enclosed in liquid methane for cooling purposes, they can act simultaneously as a gas pipeline. In the long term this can be used to transport methane parallel to the electric current, for example to connect offshore wind farms that also produce hydrogen. A considerable amount of research is required to develop this technology, including the construction of pilot and demonstration plants.
- *Determining the regional potential for combined use:* The ORECCA Project (Off-shore Renewable Energy Conversion platforms – Coordination Action) has examined the spatial potential for the combined use of marine energy and aquaculture for Europe. The WBGU recommends building on these results in order to identify suitable locations for multi-use platforms as soon as possible. Against the background of the vision of a low-carbon, marine-energy system (Section 5.3), multi-use platforms should be extended by adding macro-algae breeding, as well as the production, storage and transport of renewable methane. It is crucial to identify suitable regions in good time in the course of marine spatial-planning processes, even if the technological development is not yet advanced enough to actually construct the corresponding installations (Section 3.6.2).
- *Determining resource potential in the Arctic:* Assessments of the size and location of oil and gas deposits in the Arctic are largely based on probability statements by the U.S. Geological Survey. Further studies on the specific location and size of the deposits are required to gain greater certainty about the true size of deposits of natural resources and to expand the existing evidence base. In the WBGU's opinion, an expanded evidence base would help to objectify public debates and slow down the race for the Arctic.

8.3.4.2
Research on environmental hazards and risks

In the WBGU's view, all stages of technology development, as a general principle, should be accompanied by risk research and research on possible adverse effects on the environment. The stages are basic research, applied research, prototype development, first applications in niche markets, further dissemination, and integration into existing systems. Technology can change considerably at all stages – and not necessarily as sequentially as described here. The aim must be to take into account the continuous process of innovation by means of continuous risk research and technology assessment.

Many of the relevant technologies for a transformation of energy generation in and on the sea are still at an early stage of development, and their environmental and other sustainability effects can only be estimated with difficulty or only partially. The earlier in the development stage of a technology such possible adverse environmental effects are identified, the better the prospects of avoiding them, since the emerging technology path is then still open. The key point is that research on technology assessment is not separated from technology development, but integrated into the research and development process. Examples of suitable processes in this context include real-time technology assessments and constructive technology assessments.

Such processes could be used to detect negative effects early on, for example when prototypes or test facilities are in use. The WBGU recommends incorporating sustainable technology assessment and design into technological research programmes. One positive example of renewable energy technology development was the scientific programme accompanying the first German offshore wind farm 'Alpha Ventus'.

The WBGU's detailed recommendations are as follows:

- *Intensify research on the environmental hazards of marine methane hydrate extraction:* Several countries are planning the commercial mining of marine methane hydrates, even though the risks of extraction are largely unexplored. The WBGU recommends stepping up research efforts in the field of risk research and on the environmental hazards that can arise during the extraction of marine methane hydrates. The research findings can serve as a basis for drawing up international regulations on extraction that take the risks into account.
- *Conduct research on the comparative technology assessment of processes for extracting unconventional gas resources:* At present there are sufficient global reserves of conventional methane to meet demand within ambitious climate scenarios. Should a need for unconventional methane arise in addition, work should be done to clarify as far as possible which unconventional gas type is the least risky and should therefore be extracted. The WBGU therefore recommends carrying out projects of comparative risk research and sustainable technology assessment for the methods of mining marine methane hydrates, methane hydrates trapped in permafrost and other unconventional gas resources (shale gas, coal-bed methane, deep natural gas, tight natural gas, geopressurized zone gas). The findings could provide a sounder basis for deciding which types of unconventional gas should be extracted and on what conditions. It is important to immediately commence comparative technology and risk assessment. This must not be delayed until after commercial mining has become common practice in some countries, as is the case with the land-based extraction of unconventional gas by 'fracking'.
- *Step up research efforts on the safety of storing CO_2 under the seabed:* The technologies for storing carbon dioxide under the ocean floor are at an early stage of development, and it is still unclear whether subseabed sites can store CO_2 safely and long-term without leakage (Section 5.4.2.4). The WBGU recommends that the German Federal Government should continue researching the safety of CO_2 storage sites under the seabed. The WBGU suggests a CO_2 retention period of at least 10,000 years as a benchmark for safety and long-term sustainability (WBGU, 2006). Apart from direct research into sub-seabed CO_2 storage, experience with secondary (enhanced) oil-recovery techniques – in which, for example, CO_2 is pumped into oil fields – could also be studied from the viewpoint of long-term CO_2 storage.
- *Research the cumulative effects of offshore wind farms on marine ecosystems:* With regard to the construction of offshore wind farms there is already scientific evidence of negative environmental effects during the construction phase of offshore wind farms, and these are a matter of discussion among experts. It is necessary to close existing gaps through research into the subject. However, to date there is no scientific assessment of the cumulative environmental effects of offshore wind farms. If, for example, the EU's targets for the expansion of offshore wind energy are reached or even exceeded, large sections of the North Sea will be used by wind farms. There is little knowledge either of the effects such installations – covering large areas – have on currents and sedimentation conditions, or on the behaviour of marine fauna in the vicinity of these plants. Up to now there are no reliable estimates of the effects of a large-scale use of wind farms on marine ecosystems or biodiversity. This requires anticipatory research to estimate such effects by means of models and complex ecosystem modelling – as basic research on the understanding of marine ecosystems. Similarly, interactions between different uses are as yet unexplored, as are their effects on marine ecosystems.
- *Research the long-term effects of offshore wind farms on marine ecosystems:* Accompanying research on offshore wind farms should continue on a permanent basis in order to detect possible long-term effects of offshore wind-farm operations at an early stage. Findings from such accompanying research form the necessary basis for developing an adaptive management system for ocean use.
- *Research interactions between magnetic fields and marine ecosystems:* The environmental hazards of the electricity transport infrastructure are also important factors in offshore wind power and marine-energy technologies. The magnetic fields associated with electricity transmission, local heat release and the electrochemical influence of DC or AC fields on sea water should be analysed much more closely in future than has been the case up to now. This would help us recognize and avoid negative environmental effects at an early stage.
- *Reduce noise emissions in the marine renewable-energy sector:* Underwater noise emissions – which

arise during the construction of offshore wind farms and also (potentially) when, for example, wave-power plants and tidal turbines are being anchored – must be significantly reduced. Various technologies, such as noise-reduction measures and alternative anchoring structures, are already under development. But they cannot yet be described as commercially available technologies. The aim of further research in this field should be to develop production-ready technologies that are compatible with offshore logistics, and to optimize their noise-reducing effects. Due to the high costs of building and erecting prototypes of foundation structures, it is necessary to promote several promising approaches in parallel to avoid committing to a particular technological design too early. It is also necessary to research the physical interrelations of noise emissions, e.g. how the geology of the subsoil, water depth, materials, etc., affect noise levels and properties. The cumulative effects of large-scale installations should be examined, as should the combined effects of installation and operation noise in conjunction with other anthropogenic noise sources. There are still large gaps in our knowledge of the effects of pile-driving noise on fish. In addition to technological development, it will be necessary to lay down maximum permissible noise levels (acoustic limits). The current limits relate to a single event. It is therefore necessary to examine whether existing limits are sufficient to prevent damage from cumulative events, e.g. when there is a lot of simultaneous pile driving taking place. Similarly, tests should be carried out for specific regions to determine whether a seasonal ban on impulse pile-driving is needed to ensure that animals, especially porpoises, can reproduce and rear their young.

- *Conduct research on operations in the Arctic:* A number of knowledge gaps need to be closed to enable knowledge-based decisions to be made on future uses, particularly with regard to extracting fossil energy carriers in the Arctic. To this purpose, humanity's fundamental understanding of the Arctic ecosystems should be improved and integrated into a comprehensive understanding of the whole region. Subsequently, research should identify ecologically valuable areas to prepare for their designation as protected areas. The cumulative effects of the uses of the Arctic, particularly oil and gas extraction, should also be studied more closely to minimize negative effects on the Arctic. It is necessary to update the hydrographic maps of the North West Passage, because the melting of the ice there is opening up new shipping routes whose hazards (currents, icebergs, pack ice, etc.), have not yet been precisely mapped.

8.4 Recommendations on research policy

8.4.1 Stronger integration of interdisciplinary marine research into research programmes

Programme for sustainable marine infrastructures at the European Academies Science Advisory Council

Marine infrastructures should meet sustainability criteria and enable sustainable uses. In this report, the WBGU has called for a spatial integration of uses wherever possible and for the shared use of infrastructures for different forms of marine energy generation. Both the technologies applied for the individual sustainable uses and the necessary infrastructures are at different stages of development. Furthermore, there is a lack of coordination between the various development paths. In order to establish a suitable basis for research within the EU, the WBGU recommends the creation of a programme for an 'Integrated Infrastructure for the Sustainable Use of the Oceans' at the European Academies Science Advisory Council (EASAC).

Sustainable stewardship of the oceans in the EU's 8th Framework Research Programme

'Horizon 2020', the European Union's 8th Framework Research Programme (FRP), is currently being finalized by the EU Council and the EU Parliament. The EU Commission's proposal cites 'marine and maritime research' as a funding priority, and 60% of funds are to be channelled into research into sustainable development. The WBGU therefore advises the German Federal Government to give its backing to research-project tenders dealing with 'sustainable stewardship of the oceans' in the context of the 8th FRP. Many of the research topics referred to above could be tackled by such projects.

Integration of the oceans as a cross-cutting subject in the BMBF's 'Research for Sustainability' framework programme

'Research for Sustainability' (or to give it the German abbreviation 'FONA') is a framework programme run by the German Federal Ministry of Education and Research (BMBF). Under FONA the oceans fall under the remit of Earth-system research and are part of a variety of research projects focusing on Germany's coasts. Given the importance of the oceans for transformation towards a sustainable society, as shown in this report, the WBGU recommends that 'sustainable stewardship of the oceans' be established as a cross-cutting sub-

Box 8.4-1

Stronger institutionalization of interdisciplinary marine research

It would be particularly important to have a new research institution aimed at strengthening interdisciplinary transformation research; this does not yet exist in the marine field. Four possible ways of strengthening the institutional framework are conceivable.

The first option would be to set up interdisciplinary networks in order to cultivate working relations and develop joint research projects. The second might be to add economics, social-science and cultural-science departments to existing (major) marine-research institutions. The new departments should be staffed and resourced in a way that is on a par with the existing natural-science departments. The third option would be to set up an independent marine-research institute with a focus on social science. Its mandate would be to engage in interdisciplinary collaborative research with the established marine-research institutes. The fourth option would be to set up a new, independent and interdisciplinary marine-research institute combining natural-science, technological, cultural-science and social-science skills.

Building networks would be the least expensive option. However, networks offer little incentive to develop innovative research agendas, unless further incentives to restructure established research relations are provided at the same time, for example by inviting tenders for corresponding research projects. Moreover, publicly funded networks usually only exist for the duration of the funding period. However, if significant new funding programmes are launched in the long term, pre-funded networks can develop suitable funding applications and ensure their viability in this way.

Expanding existing research institutions by adding hitherto unrepresented disciplines would increase the chances of encouraging innovative ocean research. The new departments should be of equal standing with the existing ones; and incentives to collaborate – for example in the form of a new charter – should also be presented to existing departments.

A new marine-research institute with a focus on social science would greatly raise the profile of such approaches and create an opportunity to develop new research agendas. However, additional incentives to cooperate should also be given to existing marine-research institutions in this case. Setting up a completely new marine-research institute in which all disciplines are represented would offer the best chances of developing innovative research in line with the research needs outlined above.

ject within the FONA framework programme, in a similar way to the existing cross-cutting subject 'sustainable land management'. In the latter case, an attempt has been made to take an integrated view of the various dimensions of local and global change, including anthropogenic influences and their implications for human societies and political design options (BMBF, 2009). A similar approach should also be adopted for the oceans.

8.4.2 Stronger institutionalization of interdisciplinary marine research

Although interdisciplinary approaches to marine research already exist, there are not enough research units to tackle interdisciplinary issues with a view to the transformation towards sustainable stewardship of the oceans (Box 8.4-1). This section outlines the WBGU's recommendations on further aspects of interdisciplinary marine research.

Analysis of the Pact for Research and Innovation from the perspective of sustainability science

With the Pact for Research and Innovation, the major German scientific organizations have committed themselves to research-policy goals external to the science system that have been decided on in conjunction with government policy-makers. The overall objective – to make German research more competitive – is to be achieved by penetrating new research topics, stepping up national and international networking, collaborating more closely with business and industry and making German research organizations more attractive as places for scientists to work. Both the Federal Government and the Länder (state) governments in Germany are supporting these objectives by increasing their financial subsidies.

The WBGU believes the Pact for Research and Innovation can mark a first step towards the new contract between society and science it has already proposed (WBGU, 2011). Because of the Pact, science finds itself more starkly confronted with objectives that are of relevance to society (such as competitiveness). At the same time, cooperation with companies encourages it to integrate external knowledge.

To prepare the way for similar forms of cooperation between science and politics that might go even further, the WBGU recommends compiling an exhaustive inventory of the experience that has already been gained from the perspective of sustainability science. The key question would be: what conclusions can be drawn from the Pact for Research and Innovation regarding the deeper integration of societal problems – especially the challenge of sustainability – into research? This appraisal should be performed over and above the monitoring that has already taken place and should focus on qualitative aspects.

Discussion process on interdisciplinary research

The WBGU proposes meetings between the German Rectors' Conference, the Joint Science Conference, the German Research Foundation and the Academies of Sciences to discuss recommendations and principles for implementing and assessing both interdisciplinary transformation research and transformative research (WBGU, 2011).

Interdisciplinary Collaborative Research Centres on the transformation of marine uses

Collaborative Research Centres (CRCs) at the German Research Foundation (DFG) enable scientists to engage in interdisciplinary work on complex and innovative research issues across different institutes of higher education and for extended periods. Collaborative Research Centres strive for scientific excellence, but also cultivate an interdisciplinary approach. They can address issues of both basic research and societal research. For example, CRC1026 (Sustainable Manufacturing) develops resource-efficient production technologies and strategies, e.g. by means of cooperation between materials research, engineering sciences, information technology and the social sciences.

CRC 990 (Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems) is investigating whether and how the ecological functions of tropical rainforests can be reconciled with agricultural uses. It is also exploring the integration of agriculture and nature conservation. Biologists and economists are working hand in hand in these two Collaborative Research Centres, both of which are examples of interdisciplinary, application-oriented transformative research.

Collaborative Research Centres are suitable tools for establishing transformation-related sustainability research issues in university settings, given the long-term funding that is available, the targeted interdisciplinary approach, their good reputation, their flexibility on content and the high academic standards that must be met before approval is granted. For this reason, the WBGU recommends setting up an experimental variation on the DFG's Collaborative Research Centres programme. In this programme, interdisciplinary research into sustainable marine uses that is of relevance to societal problems and to transformation should be established as an approval criterion and given preferential funding. Extra personnel resources, logistical support and additional networking and marketing opportunities, etc., could serve as incentive mechanisms.

Integration of biological marine research and technology assessment into innovation policy

One of the goals of the National Master Plan for Maritime Technologies is to make German marine technology more competitive. This field includes technologies for tapping offshore oil and gas reserves, offshore wind parks, underwater technologies, maritime hydraulic engineering, marine aquaculture, ice and polar technology, technologies for the use of energy from the sea and technologies for extracting marine mineral resources.

A number of innovation policy measures – such as establishing networks and competence centres and carrying out demonstration projects – are mapped out within the framework of the master plan. Where technology-policy measures relating to the use of the oceans are implemented – especially in the fields of ice and polar technology, deep-sea technology and technologies for extracting marine mineral resources – the WBGU recommends the integration of research perspectives dealing with marine ecosystems and their protection, as well as technology assessment. In this way, possible negative impacts on the environment could be identified in advance, especially in the case of new technological developments.

Establishment of a research centre for marine and polar policy

Because of the growing relevance of marine and polar policy – be it for reasons of security, environmental or science policy – it would be a good idea to set up a marine and polar policy research centre. Germany has a national shortage of institutionalized and therefore appropriately focused research into marine and polar policy that both usefully complements existing scientific marine and polar research and also accumulates practical expertise which can be channelled into the political process. In terms of content, such a research centre could link up with the recommendations on governance research discussed in Section 8.2.2.

8.4.3
Strengthening of the interface between science and society in marine research

The WBGU believes that interaction between marine research and society needs to be improved. To this end, the Advisory Council proposes that the following four steps be taken:

Leveraging the integrating effect of international reports

In 2005 the General Assembly of the United Nations passed a resolution to establish a Regular Process for Global Reporting and Assessment of the State of the Marine Environment (Regular Process; Sections 3.3.1.1, 7.3.1.2) which would also serve as a scientific platform for the Oceans Compact initiated by UN Secretary General Ban Ki-moon (Section 7.3.3.1). Within this framework, the 'first integrated global marine assessment' is due to be produced by December 2014. The WBGU advises the German Federal Government to promote greater acceptance and awareness of the Regular Process among scientists and to enable a large number of respected researchers to take part in it. If the process were to achieve a high level of scientific quality and legitimacy, it could not only make an appropriate contribution to the further development of ocean governance, but also provide fresh stimulus for transformative marine research. The work of the Intergovernmental Panel on Climate Change (IPCC) is a good example of how producing international reports can have an integrating effect on research: the WBGU believes that the voluntary participation of scientists around the world in preparing the IPCC reports, which were expressly intended to be of relevance to political considerations, played a part in raising the level of interest in societal and interdisciplinary research in the climate field.

Research for a marine science/society interface in Germany

What is known as the science/society interface comprises aspects such as communicating and discussing research findings in many forms, from the media to blogs to formal political consultations. The WBGU recommends that an interdisciplinary research project be set up to develop proposals for an innovative interface between society and German marine research.

Expanding civil society's participation in designing marine-research programmes

In its flagship report entitled 'A Social Contract for Sustainability' (WBGU, 2011), the WBGU appealed for greater civil-society involvement in the research process, especially in the development of research questions and programmes. Given the importance of the oceans to sustainable development and their nature as a global public and common good, the WBGU advocates more public participation in developing the themes tackled by relevant research programmes. The first step should be to commission a scientific study on developing a concept for greater civil-society participation in the public selection of topics for marine research. The study should be produced by an independent research institution with the involvement of representatives of civil society. At the same time, a dialogue should be commenced with existing civil-society initiatives for greater participation in research policy, so that this enhanced participation can, in a second step, be tried out in practice using marine research as an example.

Launching information and educational campaigns

Since the oceans do not command the immediate attention of most people, the WBGU believes that further efforts – such as information and educational campaigns – need to be undertaken to promote an understanding of the current situation of the oceans among the public at large. In particular, citizens should be given the information they need to be able to assess the consequences which, for example, their decisions as consumers or political decisions will have on the future of the oceans. To this end, government support could also be given to existing civil-society initiatives for the protection of the marine environment. In this way, large sections of civil society could become actively involved in marine conservation; after all, the future of the oceans is too important to be left solely to discussions among groups of experts.

References

9

4C Offshore (2011): Global Offshore Wind Farms Database. Internet: http://www.4coffshore.com/offshorewind/ (viewed 10. January 2012). Suffolk: 4C Offshore Limited.

Aarkrog, A. (2003): Input of anthropogenic radionuclides into the World Ocean. Deep-Sea Research II 50, 2597–2606.

Aarset, B. and Jacobsen, S.-E. (2009): Political regulation and radical institutional change: The case of aquaculture in Norway. Marine Policy 33, 280–287.

Abulafia, D. (2011): The Great Sea: A Human History of the Mediterranean. London: Allen Lane.

ACIA – Arctic Climate Impact Assessment (2005): Arctic Climate Impact Assessment. Cambridge, New York: Cambridge University Press.

Adger, W. N. and Luttrell, C. (2000): Property rights and the utilisation of wetlands. Ecological Economics 35, 75–89.

AFMA – Australian Fisheries Management Authority (undated): About AFMA. Internet: http://www.afma.gov.au (viewed 24. January 2013). Canberra: AFMA.

AFMA – Australian Fisheries Management Authority (2010): AFMA Domestic Compliance and Enforcement Policy. Canberra: AFMA.

Agnew, D. J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J. R. and Pitcher, T. J. (2009): Estimating the worldwide extent of illegal fishing. PLoS ONE 4 (2), e4570–e4577.

Agnew, D. J., Gutiérrez, N. L., Stern-Pirlot, A., Smith, A. D. M., Zimmermann, C. and Sainsbury, K. (2013): Rebuttal to Froese and Proelß "Evaluation and legal assessment of certified seafood". Marine Policy 38, 551–553.

Ahmed, M. and Lorica, M. H. (2002): Improving developing country food security through aquaculture development – lessons from Asia. Food Policy 27, 125–141.

Akesson, S., Luschi, P., Papi, F., Broderick, A. C., Glen, F., Godley, B. J. and Hays, G. C. (2001): Oceanic long-distance navigation: Do experienced migrants use the Earth's magnetic field? Journal of Navigation 54, 419–427.

Alder, J., Campbell, B., Karpouzi, V., Kaschner, K. and Pauly, D. (2008): Forage fish: from ecosystems to markets. Annual Reviews in Environment and Resources 33, 153–166.

Alder, J. and Sumaila, U. R. (2004): Western Africa: a fish basket of Europe past and present. The Journal of Environment & Development 13 (2), 156–178.

Allison, E. H., Perry, A. L., Badjeck, M.-C., Adger, W. N., Brown, K., Conway, D., Halls, A. S., Pilling, G. M., Reynolds, J. D., Andrew, N. L. and Dulvy, N. K. (2009): Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries, 10 (2), 173–196.

Altieri, A. H. (2008): Dead zones enhance key fisheries species by providing predation refuge. Ecology 89 (10), 2808–2818.

Altmaier, P. (2012): Mit neuer Energie. 10 Punkte für eine Energie- und Umweltpolitik mit Ambition und Augenmaß. Berlin: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

Alverson, D. (1997): Global assessment of fisheries bycatch and discards: a summary overview. American Fisheries Society Symposium. Global Trends: Fisheries Management 20, 115–125.

Alverson, D. L., Freeberg, M. H., Pope, J. G. and Murawski, S. A. (1994): A Global Assessment of Fisheries Bycatch and Discards. FAO Fisheries Technical Paper No. 339. Rome: Food and Agriculture Organization (FAO).

AMAP – Arctic Monitoring and Assessment Programme (2010): Radioactivity in the Arctic. AMAP Assessment 2009. Oslo: AMAP Secretariat.

AMAP – Arctic Monitoring and Assessment Programme (2011): Snow, Water, Ice and Permafrost in the Arctic (SWIPA): Climate Change and the Cryosphere. Oslo: SWIPA.

AMAP – Arctic Monitoring and Assessment Programme (2012): Arctic Climate Issues 2011: Changes in Arctic Snow, Water, Ice and Permafrost. SWIPA 2011. Oslo: AMAP Secretariat.

Andrady, A. L. (2011): Microplastics in the marine environment. Marine Pollution Bulletin 62, 1596–1605.

Andrew, N. L. and Evans, L. (2011): Approaches and frameworks for management and research in small-scale fisheries. In: Pomeroy, R. S. and Andrew, N. L. (eds): Small-Scale Fisheries Management. Wallingford: CAB International, 16–34.

Anselmo, H. M. R., Koerting, L., Devito, S., van den Berg, J. H. J., Dubbeldam, M., Kwadijk, C. and Murk, A. J. (2011): Early life developmental effects of marine persistent organic pollutants on the sea urchin *Psammechinus miliaris*. Ecotoxicology and Environmental Safety 74, 2182–2192.

Anticamara, J. A., Watson, R., Gelchu, A. and Pauly, D. (2011): Global fishing effort (1950–2010): trends, gaps, and implications. Fisheries Research 107, 131–136.

AOSIS – Alliance of Small Island States (2013): Various documents of the AOSIS Webpage. Internet: http://aosis.org/ (viewed 24. January 2013). New York: AOSIS.

Appiah, A. K. (2007): Der Kosmopolit. Philosophie des Weltbürgertums. Bonn: Bundeszentrale für politische Bildung.

Archer, A. A. (1981): Mining seabed resources. Marine Policy 1, 89–90.

Archer, D. (2005): Destabilization of Methane Hydrates: A Risk Analysis. Expertise for the WBGU Report "The Future Oceans – Warming Up, Rising High, Turning Sour". Internet: http://www.wbgu.de/wbgu_sn2006_ex01.pdf. Berlin: WBGU.

Ardron, J., Gjerde, K., Pullen, S. and Tilot, V. (2008): Marine spatial planning in the high seas. Marine Policy 32, 832–839.

Armitage, D. R., Plummer, R., Berkes, F., Arthur, R. I., Charles, A. T., Davidson-Hunt, I. J., Diduck, A. P., Doubleday, N. C., Johnson, D. S., Marschke, M., McConney, P., Pinkerton, E. W. and Wollenberg, E. K. (2009): Adaptive co-management for social–ecological complexity. Frontiers in Ecology and the Environment 7, 95–102.

Armstrong, C. W., Foley, N. S., Tinch, R. and van den Hove, S. (2010): Services from the deep: steps towards valuation of deep sea goods and services. Ecosystem Services 2, 2–13.

Arnold, A. (2004): A Review of Public Attitudes Towards Marine Issues Within and Beyond New Zealand. DoC Science Internal Series 170. Wellington: Department of Conservation.

Arnold, G. P. and Metcalf, J. D. (1989): Fish migration: orientation and navigation or environmental transport? Journal of Navigation 42, 367–374.

Arrieta, J., M., Arnaud-Haond, S. and Duarte, C. M. (2010): What lies underneath: conserving the oceans' genetic resources. Proceedings of the National Academy of Sciences 107 (34), 18318–18324.

Arthus-Bertrand, Y. and Skerry, B. (2013): Der Mensch und die Weltmeere. Munich: Knesebeck.

Asche, F. (2008): Farming the sea. Marine Resource Economics 23, 527–547.

Asche, F. and Smith, M. D. (2010): Trade and Fisheries: Key Issues for the World Trade Organization. Staff Working Paper ERSD-2010-03. Geneva: World Trade Organization (WTO), Economic Research and Statistics Division.

Asche, F., Hansen, H. and Tveteras, R. (2010): The salmon disease crisis in Chile. Marine Resource Economics 24, 405–411.

Aubin, J., Paptryphon, E., van der Werf, H. M. G. and Chatzifotis, S. (2009): Assessment of the environmental impact of carnivorous finfish production systems using life cylce assessment. Journal of Cleaner Production 17, 354–361.

Auld, G. and Gulbrandsen, L. H. (2010): Transparency in nonstate certification: consequences for accountability and legitimacy. Global Environmental Politics 10 (3), 97–119.

Aure, A. H. (2008): Der säkularisierte und subjektivierte Naturrechtsbegriff bei Hugo Grotius. Internet: http://www.forhistiur.de/zitat/0802aure.htm (viewed 24. January 2013). Cologne, Zurich: Europäische Internetzeitschrift für Rechtsgeschichte. Forum Historiae Iuris.

Aure, J., Strand, O., Rune Erga, S. and Strohmeier, T. (2007): Primary production enhancement by artificial upwelling in a western Norwegian fjord. Marine Ecology Progress Series 352, 39–52.

Aydin, K. Y., McFarlane, G. A., King, J. R., Megrey, B. A. and Myers, K. W. (2005): Linking oceanic food webs to coastal-production and growth rates of Pacific salmon *(Oncorhynchus* spp.), using models on three scales. Deep-Sea Research II (52), 757–780.

Backer, H. (2011): Transboundary maritime spatial planning: a Baltic Sea perspective. Journal of Coastal Conservation 15 (2), 279–289.

Backer, H., Leppänen, J.-M., Brusensorff, A. C., Forsius, K., Stankiewicz, M., Mehtonen, J., Pyhälä, M., Laamanen, M., Paulomäki, H., Vlasov, N. and Haaranen, T. (2010): HELCOM Baltic Sea Action Plan – A regional programme of measures for the marine environment based on the Ecosystem Approach. Marine Pollution Bulletin 60, 642–649.

Baker, M. and German, C. (2008): Going for Gold – Who will win the race to exploit ores from the deep? Ocean Challenge 16 (1), 10–17.

Balmford, A., Gravestock, P., Hockley, N., McCLean, C. J. and Roberts, C. M. (2004): The worldwide costs of marine protected areas. Proceedings of the National Academy of Sciences 10 (1073), 9694–9697.

Balton, D. A. and Koehler, H. R. (2006): Reviewing the United Nations Fish Stocks Treaty. Sustainable Development Law & Policy 7 (1), 5–9.

Barange, M. and Perry, R. I. (2009): Physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. In: Cochrane, K., de Young, C., Soto, D. and Bahri, T. (eds): Climate Change Implications for Fisheries and Aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome: Food and Agriculture Organization (FAO), 7–107.

Barber, R. (2001): Upwelling ecosystems. Enyclopedia of Ocean Sciences, 3128–3135.

Barbier, E. B., Koch, E. W., Silliman, B. R., Hacker, S. D., Wolanski, E., Primavera, J. H., Granek, E. F., Polasky, S., Aswani, S., Cramer, L. A., Stoms, D. M., Kennedy, C. J., Bael, D., Kappel, C. V., Perillo, G. M. E. and Reed, D. J. (2008): Coastal ecosystem-based management with nonlinear ecological functions and values. Science 319, 321–324.

Bard, J. (2013): Windenergie und Meeresenergie: Sensoren im FoE-Prozess, Herstellungsprozess und Einsatzmonitoring. Presentation FVEE/AMA-Workshop "Sensorik für erneuerbare Energien und Energieeffizienz" from 12.3. to 13.3.2013 in Berlin. Kassel: IWES.

Barnes, D. K. A. (2002): Biodiversity: invasions by marine life on plastic debris. Nature 416, 808–809.

Barnes, D. K. A. (2005): Remote islands reveal rapid rise of Southern Hemisphere sea debris. Directions in Science 5, 915–921.

Barnes, D. K. A., Galgani, F., Thompson, R. C. and Barlaz, M. (2009): Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B 364, 1985–1998.

Barnes, D. K. A., Walters, A. and Gonçalves, L. (2010): Macroplastics at sea around Antarctica. Marine Environmental Research 70 (2), 250–252.

Barot, S., Heino, M., O'Brien, L. and Dieckmann, U. (2002): Reaction Norms for Age and Size at Maturation: Study of the Long-Term Trend (1970–1998) for Georges Bank and Gulf of Maine Cod Stocks. Copenhagen: International Council for the Exploration of the Sea.

Barrett, S. (2001): International cooperation for sale. European Economic Review 45, 1835–1850.

Barrett, S. (2007): Why Cooperate? The Incentive to Supply Global Public Goods. Oxford, New York: Oxford University Press.

Barton, J. R. and Fløysand, A. (2010): The political ecology of Chilean salmon aquaculture, 1982–2010: A trajectory from economic development to global sustainability. Global Environmental Change 20, 739–752.

Barton, A., Hales, B., Waldbusser, G. G., Langdon, C. and Feely, R. A. (2012): The Pacific oyster, *Crassostrea gigas*, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects. Limnology and Oceanography 57 (3), 698–710.

Bascompte, J., Melian, C. J. and Sala, E. (2005): Interaction strength combinations and the overfishing of a marine food web. Proceedings of the National Academy of Sciences 102 (15), 5443–5447.

Baslar, K. (1998): The Concept of the Common Heritage of Mankind in International Law. Developments in International Law. Volume 30. Leiden: Brill Academic Publisher.

Bathnagar, I. and Kim, S.-K. (2010): Immense excellence of exellence: marine microbial bioactive compounds. Marine Drugs 8, 2673–2701.

Baum, J. K. and Myers, R. A. (2004): Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters 7, 135–145.

Baumann, H., Talmage, S. C. and Gobler, C. J. (2012): Reduced early life growth and survival in a fish in direct response to increased carbon dioxide 2, 38–41.

Bavinck, M. and Chuengpagdee, R. (2005): Current principles for fisheries governance. In: Koiman, J., Bavinck, M., Jentoft, S. and Pullin, R. (eds): Fish for Life. Interactive Governance for Fisheries. Amsterdam: Amsterdam University Press, 245–263.

Beaudoin, Y. and Pendleton, L. (2012): Why Value the Oceans? A Discussion Paper. Arendal: UNEP-GRID.

Beaufort, L., Probert, I., de Garidel-Thoron, T., Bendif, E. M., Ruiz-Pino, D., Metzl, N., Goyet, C., Buchet, N., P., C., Grelaud, M., Rost, B., Rickaby, R. E. M. and de Vargas, C. (2011): Sensitivity of coccolithophores to carbonate chemistry and ocean acidification. Nature 476, 80–85.

Beaugrand, G., Brander, K. M., Lindley, J. A., Souissi, S. and Reid, P. C. (2003): Plankton effect on cod recruitment in the North Sea. Nature 426, 661–664.

Beck, U. (2007): Weltrisikogesellschaft. Bonn: Bundeszentrale für politische Bildung.

Bedard, R., Jacobson, P. T., Previsic, M., Musial, W. and Varley, R. (2010): An overview of ocean renewable energy technologies. Oceanography 23 (2), 22–31.

Beddington, J. R., Agnew, D. J. and Clark, C. W. (2007): Current problems in the management of marine fisheries. Science 316, 1713–1716.

Behnam, A. (2003): Ending flag state control? In: Kirchner, A. (ed): International Marine Environmental Law, Institutions, Implementation and Innovations. London: Kluwer Law International, 123–135.

Behrenfeld, M. J., O'Malley, R. T., Siegel, D. A., McClain, C. R., Sarmiento, J. L., Feldman, G. C., Milligan, A. J., Falkowski, P. G., Letelier, R. M. and Boss, E. S. (2006): Climate-driven trends in contemporary ocean productivity. Nature 444, 752–755.

Bell, J. and Waagbø, R. (2008): Safe and nutritious aquaculture produce: benefits and risks of alternative sustainable aquafeeds. In: Holmer, M. (ed): Aquaculture in the Ecosystem. Berlin, Heidelberg: Springer, 185–224.

Bellwood, D. R., Hughes, T. P., Folke, C. and Nyström, M. (2004): Confronting the coral reef crisis. Nature 429, 827–833.

Benetti, D., Brand, L., Collins, J., Orhun, R., Benetti, A., O'Hanlon, B., Danylchuk, A., Alston, D., Rivera, J. and Cabarcas, A. (2006): Can offshore aquaculture of carnivorous fish be sustainable? Case studies from the Caribbean. World Aquaculture 37 (1), 44–47.

Benjamin, T. (2009): The Atlantic World. Europeans, Africans, Indians and Their Shared History, 1400–1900. Cambridge, New York: Cambridge University Press.

Benson, S. M., Bennaceur, K., Cook, P., Davison, J., de Coninck, H., Farhat, K., Ramirez, A., Simbeck, D., Surles, T., Verma, P. and Wright, I. (2012): Chapter 13: Carbon capture and storage. In: GEA – Global Energy Assessment (ed): Global Energy Assessment – Toward a Sustainable Future. Cambridge, New York: Cambridge University Press, 993–1068.

Berg, P. E. and Davies, S. (2011): Fishery monitoring, control and surveillance. In: Cochrane, K. and Garcia, S. M. (eds): A Fishery Manager's Guidebook. New York, Chichester: Wiley-Blackwell, 373–403.

Berkes, F. (2009): Evolution of co-management: role of knowledge generation, bridging organizations and social learning. Journal of Environmental Management 90, 1692–1702.

Berkes, F., Hughes, T. P., Steneck, R. S., Wilson, J. A., Bellwood, D. R., Crona, B., Folke, C., Gunderson, L. H., Leslie, H. M., Norberg, J., Nyström, M., Olsson, P., Österblom, H., Scheffer, M. and Worm, B. (2006): Globalization, roving bandits, and marine resources. Science 311, 1557–1558.

Bernstein, S. and Hannah, E. (2012): The WTO and institutional (in)coherence. In: Narlikar, A., Daunton, M. and Stern, R. M. (eds): The Oxford Handbook on The World Trade Organization. Oxford, New York: Oxford University Press, 719–742.

Berry, K. L. E., Seemann, J., Dellwig, O., Struck, U., Wild, C. and Leinfelder, R. R. (2013): Sources and spatial distribution of heavy metals in scleractinian coral tissues and sediments from the Bocas del Toro Archipelago, Panama. Environmental Monitoring and Assessment doi: 10.1007/s10661-013-3238-8, 11.

Bertzky, B., Corrigan, C., Kemsey, J., Kenney, S., Ravilious, C., Besancon, C. and Burgess, N. D. (2012): Protected Planet Report 2012: Tracking Progress Towards Global Targets for Protected Areas. Gland, Cambridge, UK: International Union for Conservation of Nature (IUCN), United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC).

Betke, K. and Matuschek, R. (2011): Messungen von Unterwasserschall beim Betrieb der Windenergieanlagen im Offshore-Windpark alpha ventus. Oldenburg: Institut für technische und angewandte Physik GmbH (ITAP).

Beveridge, M., Phillips, M., Dugan, P. and Brummet, R. (2010): Barriers to aquaculture development as a pathway to poverty alleviation and food security. In: OECD – Organisation for Economic Co-operation and Development (ed): Advancing the Aquaculture Agenda. Workshop Proceedings. Paris: OECD, 345–359.

BfN – Federal Agency for Nature Conservation (2009): Ökosystemgerechte, nachhaltige Fischerei. Empfehlungen des BfN. Bonn: BfN.

BfN – Federal Agency for Nature Conservation (2012): Daten zur Natur 2012. Bonn: BfN.

BGR – Bundesanstalt für Geowissenschaften und Rohstoffe (2009): Energierohstoffe 2009. Reserven, Ressourcen, Verfügbarkeit. Hannover: BGR.

Bijma, J., Spero, H. J. and Lea, D. W. (1999): Reassessing foraminiferal stable isotope geochemistry: impact of the oceanic carbonate system (experimental results). In: Fischer, G. and Wefer, G. (eds): Use of Proxies in Paleoceanography. Examples from the South Atlantic. Berlin, Heidelberg: Springer, 489–512.

Bilgili, M., Yasar, A. and Simsek, E. (2011): Offshore wind power development in Europe and its comparison with onshore counterpart. Renewable and Sustainable Energy Reviews 15, 905–915.

Billé, R., Druel, E. and Rochette, J. (2011): Advancing the oceans agenda at Rio+20: where we must go. IDDRI Policy Brief 5, 8.

Binger, A. (2004): Potential and Future Prospects for Ocean Thermal Energy Conversion (OTEC) in Small Islands Developing States (SIDS). New York: UNESCO.

Birnie, P. and Boyle, A. (2002): International Law and the Environment. Second Edition. Oxford, New York: Oxford University Press.

Bischoff, A. A., Fink, P. and Waller, U. (2009): The fatty acid composition of *Nereis diversicolor* cultured in an integrated recirculated system: Possible implications for aquaculture. Aquaculture 296, 271–276.

Bjordal, Å. (2009): Regulation of fishing gears and methods. In: Cochrane, K. and Garcia, S. M. (eds): A Fishery Manager's Guidebook. New York, Chichester: Wiley, 176–195.

Bjørndal, K. A. and Brasão, A. (2006): The East Atlantic bluefin tuna fisheries: stock collapse or recovery? Marine Resource Economics 21, 193–210.

Blanco-Bazán, A. (2003): The environmental UNCLOS and the work of IMO in the field of prevention of pollution of vessels. In: Kirchner, A. (ed): International Marine Environmental Law: Institutions, Implementation and Innovation. Den Haag: Kluwer Law International, 31ff.

Blesl, M. and Kober, T. (2010): Bedeutung von CO_2-Transport- und Speicheroptionen im europäischen Energiesystem. Zeitschrift für Energiewirtschaft 34 (4), 285–301.

BMBF – Federal Ministry of Education and Research (2008): Grundlagenforschung Energie 2020+. Die Förderung der Energieforschung durch das Bundesministerium für Bildung und Forschung. Berlin: BMBF.

BMBF – Federal Ministry of Education and Research (2009): Forschung für nachhaltige Entwicklungen. Rahmenprogramm des BMBF. Berlin: BMBF.

BMU – Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2006): Integriertes Küstenzonenmanagement in Deutschland. Nationale Strategie für ein integriertes Küstenzonenmanagement. Berlin: BMU.

BMU – Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008): Nationale Strategie für die nachhaltige Nutzung und den Schutz der Meere. Berlin: BMU.

BMU – Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2012): Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Berlin: BMU.

BMVBS – Federal Ministry of Transport, Building and Urban Development (2011): Entwicklungsplan Meer – Strategie für eine integrierte deutsche Meerespolitik. Bonn, Berlin: BMVBS.

BMWi – Federal Ministry of Economics and Technology (2011a): Nationaler Masterplan Maritime Technologien (NMMT). Deutschland, Hochtechnologie-Standort für maritime Technologien zur nachhaltigen Nutzung der Meere. Berlin: BMWi.

BMWi – Federal Ministry of Economics and Technology (2011b): Maritime Technologien der nächsten Generation. Das Forschungsprogramm für Schiffbau, Schifffahrt und Meerestechnik 2011–2015. Berlin: BMWi.

BMWi – Federal Ministry of Economics and Technology and BMU – Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2010): Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung. Berlin: BMWi, BMU.

Bodansky, D. (2009): The Art and Craft of International Environmental Law. Boston: Harvard University Press.

Boehlert, G. W., McMurray, G. E. and Tortorici, C. E. (2008): Ecological Effects of Wave Energy Development in the Pacific Northwest. A Scientific Workshop. NOAA Technical Memorandum NMFS-F/SPO-92. Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service.

Boehlert, G. W. and Gill, A. B. (2010): Environmental and ecological effects of ocean renewable energy development: a current synthesis. Oceanography 23 (2), 68–81.

Boetius, A., Albrecht, S., Bakker, K., Bienhold, C., Felden, J., Fernández-Méndez, M., Hendricks, S., Katlein, C., Lalande, C., Krumpen, T., Nicolaus, M., Peeken, I., Rabe, B., Rogacheva, A., Rybakova, E., Somavilla, R., Wenzhöfer, F. and RV Polarstern ARK27-3-Shipboard Science Party (2013): Export of algal biomass from the melting Arctic sea ice. Science 339, 1430–1432.

Bömer, J., Brodersen, N., Hunke, D., Schüler, V., Günther, H., Weisse, R., Fischer, J., Schäffer, M. and Gaßner, H. (2010): Nutzung der Meeresenergie in Deutschland. Endbericht. Berlin: Ecofys Germany.

Bondad-Reantaso, M. G., Arthur, J. R. and Subasinghe, R. (2008): Understanding and Applying Risk Analysis in Aquaculture. FAO Fisheries and Aquaculture Technical Paper No. 519. Rome: Food and Agriculture Organization (FAO).

Borgerson, S. G. (2009): The National Interest and the Law of the Sea. Special Report No. 46. New York: Council on Foreign Relations Press.

Borowitzka, M. (2008): Algae and biofuels: Quo Vadis? Presentation 11th International Conference on Applied Phycology. Galway: Conference Secretariat, National University of Ireland.

Børresen, T., Boyen, C., Dobson, A., Höfle, M., Ianora, A., Jaspars, M., Kijjoa, A., Olafsen, J., Querellou, J., Rigos, G. and Wijffels, R. H. (2010): Marine Biotechnology: A New Vision and Strategy for Europe. Marine Board-ESF Position Paper 15. Ostend: ESF Marine Board.

Bostock, J., McAndrew, B., Richards, R., K., J., Telfer, T., Lorenzen, K., Little, D., Ross, L., Handisyde, N., Gatward, I. and Corner, R. (2010): Aquaculture: global status and trends. Proceedings of the Royal Society B 365, 2897–2912.

Boswell, R. (2009): Is gas hydrate energy within reach? Science 325, 957–958.

Boswell, R. and Collett, S. (2006): The gas hydrates resource pyramid. U.S. DOE-NETL Fire in the Ice Newsletter 6 (3), 5–7.

Boswell, R. and Collett, S. (2011): Current perspectives on gas hydrate resources. Energy & Environmental Science 4, 1206–1215.

Bouwman, A. F., Beusen, A. H. W. and Billen, G. (2009): Human alteration of the global nitrogen and phosphorus soil balances for the period 1970–2050. Global Biogeochemical Cycles 23 (4), 1–16.

Bowen, R. E. and Depledge, M. H. (2006): Rapid assessment of marine pollution (RAMP). Marine Pollution Bulletin 53 (10), 631–639.

Boyce, D. G., Lewis, M. R. and Worm, B. (2010): Global phytoplankton decline over the past century. Nature 466, 591–596.

Boyd, P. W. and Banzhaf, H. S. (2005): Ecosystem services and government accountability: the need for a new way of judging nature's value. Resources (Summer), 16–19.

Boyd, C. E. and McNevin, A. A. (2011): An early assessment of the effectiveness of aquaculture certification and standards. Appendix D. In: Steering Committee of the State-of-Knowledge Assessment of Standards and Certification (ed): Toward Sustainability: The Roles and Limitations of Certification. Washington, DC: Resolve Inc., A-35–A-69.

Boyd, P. W., Strzepek, R., Fu, F. and Hutchins, D. A. (2010): Environmental control of open-ocean phytoplankton groups: now and in the future. Limnology and Oceanography 55 (3), 1353–1376.

BP Europe SE (2008): Erdöl bewegt die Welt. Von der Quelle bis zum Verbraucher. Bochum: Deutsche BP.

Branch, T. A., Jensen, O. P., Ricard, D., Ye, Y. and Hilborn, R. (2011): Contrasting global trends in marine fishery status obtained from catches and from stock assessments. Conservation Biology 25 (4), 777–786.

Brander, K. M. (2005): Assessment of Possible Impacts of Climate Change on Fisheries. Expertise for the WBGU Report "The Future Oceans – Warming Up, Rising High, Turning Sour". Internet: http://www.wbgu.de/wbgu_sn2006_ex02.pdf. Berlin: WBGU.

Brander, K. M. (2007): Global fish production and climate change. Proceedings of the National Academy of Sciences 104 (50), 19709–19714.

Brander, K. M. (2010): Impacts of climate change on fisheries. Journal of Marine Systems 79, 389–402.

Brandt, E. and Gaßner, H. (2002): Seeanlagenverordnung. Kommentar. Berlin: Berliner Wissenschafts-Verlag.

Brandt, M. J., Diederichs, A., Betke, K. and Nehls, G. (2012): Effects of offshore pile driving on harbor porpoises *(Phocoena phocoena)*. In: Popper, A. N. and Hawkins, A. (eds): The Effects of Noise on Aquatic Life. Berlin, Heidelberg: Springer, 281–285.

Brashares, J. S., Arcese, P., Sam, M. K., Coppolillo, P. B., Sinclair, A. R. E. and Balmford, A. (2004): Bushmeat hunting, wildlife declines, and fish supply in West Africa. Science 306, 1180–1183.

Breitburg, D. L., Hondorp, D. W., Davias, L. A. and Diaz, R. J. (2009): Hypoxia, nitrogen, and fisheries: integrating effects across local and global landscapes. Annual Review of Marine Sciences 1, 329–349.

Breithaupt, J. L., Smoak, J. M., Smith III, T. J., Sanders, C. J. and Hoare, A. (2012): Organic carbon burial rates in mangrove sediments: strengthening the global budget. Global Biogeochemical Cycles 26, 11.

Bromley, D. W. (2009): Abdicating responsibility: the deceits of fisheries policy. Fisheries 34 (6), 280–302.

Brooke, S., Yang Lim, T. and Ardron, J. (2010): Surveillance and Enforcement of Remote Maritime Areas (SERMA). Surveillance Technical Options. Seattle, WA: Marine Conservation Biology Institute.

Brown, C. J., Fulton, E. A., Hobday, A. J., Matear, R. J., Possingham, H. P., Bulman, C., Christensen, V., Forrest, R. E., Gehrke, P. C., Gribble, N. A., Griffiths, S. P., Lozano-Montes, H., Martin, J. M., Metcalf, S., Okey, T. A., Watson, R. and Richardson, A. J. (2010): Effects of climate-driven primary production change on marine food webs: implications for fisheries and conservation. Global Change Biology 16, 1194–1212.

Brown, J. (2007): Fisheries. In: OECD – Organisation for Economic Co-operation and Development (ed): Subsidy Reform and Sustainable Development: Political Economy Aspects. Paris: OECD Publishing, 111–126.

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T. and Thompson, R. (2011): Accumulation of microplastic on shorelines worldwide: sources and sinks. Environmental Science and Technology 45, 9175–9179.

Bruckner, A. (2002): Life-Saving Products from Coral Reefs. Internet: http://www.issues.org/18.3/p_bruckner.html (viewed 24. January 2013). Richardson, TX: Issues in Science and Technology.

Bruton, T., Lyons, Y. L., Stanley, M. and Rasmussen, M. B. (2009): A Review of the Potential of Marine Algae as a Source of Biofuel in Ireland. Dublin: Sustainable Energy Ireland (SEI).

BSH – Federal Maritime and Hydrographic Agency (2011): MARPOL Umweltübereinkommen. Internet: http://www.bsh.de/de/Meeresdaten/Umweltschutz/MARPOL_Umweltuebereinkommen/index.jsp (viewed 9. May 2011). Hamburg: BSH.

Buck, B. H. and Buchholz, C. M. (2005): Response of offshore cultivated *Laminaria saccharina* to hydrodynamic forcing in the North Sea. Aquaculture International 250 (3–4), 674–691.

Buck, B. H. and Krause, G. (2012): Short Expertise on the Potential Combination of Aquaculture with Marine-Based Renewable Energy Systems. SeaKult-Sustainable Futures in the Marine Realm. Expertise for the WBGU Report "Governing the Marine Heritage". Internet: http://www.wbgu.de/wbgu_jg2012_Expertise_Buck.pdf. Berlin: WBGU.

Buck, B. H., Krause, G. and Rosenthal, H. (2004): Extensive open ocean aquaculture development within wind farms in Germany: the prospect of offshore co-management and legal constraints. Ocean & Coastal Management 47 (3–4), 95–122.

Buck, B. H., Krause, G., Michler-Cieluch, T., Brenner, M., Buchholz, C. M., Busch, J. A., Fisch, R., Geisen, M. and Zielinski, O. (2008): Meeting the quest for spatial efficiency: progress and prospects of extensive aquaculture within offshore wind farms. Helgoland Marine Research 62 (3), 269–281.

Buesseler, K., Aoyama, M. and Fukasawa, M. (2011): Impacts of the Fukushima nuclear power plants on marine radioactivity. Environmental Science & Technology 45, 9931–9935.

Burke, L., Reytar, K., Spalding, M. and Perry, A. (2011): Reefs at Risk. Revisited. Washington, DC: World Resources Institute (WRI).

Burke, L., Reytar, K., Spalding, M. and Perry, A. (2012): Reefs at Risk Revisited in the Coral Triangle. Washington, DC: World Resources Institute (WRI).

Burrows, M. T., Schoeman, D. S., Buckley, L. B., Moore, P., Poloczanska, E. S., Brander, K. M., Brown, C. J., Bruno, J. F., Duarte, C. M., Halpern, B. S., Holding, J., Kappel, C. V., Kiessling, W., O`Connor, M. I., Pandolfi, J. M., Parmesan, C., Schwing, F. B., Sydeman, W. J. and Richardson, A. J. (2011): The pace of shifting climate in marine and terrestrial ecosystems. Science 334, 652–657.

Burton, J. (1972): World Society. Cambridge, New York: Cambridge University Press.

Buschmann, A. H., Cabello, F., Young, K., Carvajal, J., Varela, D. A. and Henríquez, L. (2009): Salmon aquaculture and coastal ecosystem health in Chile: Analysis of regulations, environmental impacts and bioremediation systems. Ocean and Coastal Management 52, 243–249.

Buschmann, A. H., Riquelme, V. A., Hernández-González, M. C., Varela, D. A., Jiménez, J. E., Henríquez, L., Vergara, P. A., Guiñez, R. and Filún, L. (2006): A review of the impacts of salmonid farming on marine coastal ecosystems in the southeast Pacific. ICES Journal of Marine Science (63), 1338–1345.

Bush, S. R., van Zwieten, P. A. M., Visser, L., van Dijk, H., Bosma, R., de Boer, W. F. and Verdegem, M. (2010): Scenarios for resilient shrimp aquaculture in tropical coastal areas. Synthesis. Ecology and Society 15 (2), 17.

Bustnes, J. O., Gabrielsen, G. W. and Verreault, J. (2010): Climate variability and temporal trends of persistent organic pollutants in the Arctic: a study of Glaucous Gulls. Environmental Science and Technology 44, 3155–3161.

Byron, C. J. and Costa-Pierce, B. A. (2012): Carrying capacity tools for use in the implementation of an ecosystem approach to aquaculture. In: Ross, L. G., Telfer, T. C., Soto, D., Aguilar-Manjarrez and Falconer, L. (eds): Site Selection and Carrying Capacity for Inland and Coastal Aquaculture. FAO Institute of Aquaculture, University of Stirling Expert Workshop, 6–8 December 2010, Stirling, UK. FAO Fisheries and Aquaculture Proceedings No. 21. Rome: Food and Agriculture Organization (FAO), 101–115.

Cabello, F. C. (2006): Heavy use of prophylactic antibiotics in aquaculture: a growing problem for human and animal health and for the environment. Environmental Microbiology 8 (7), 1137–1144.

Cada, G., Ahlgrimm, J., Bahleda, M., Bigford, T., Damiani-Stavrakas, S., Hall, D., Moursund, R. and Sale, M. (2007): Potential impacts of hydrokinetic and wave energy conversion technologies on aquatic environments. Fisheries 32 (4), 174–181.

Cada, G. F., Coutant, C. C. and Whitney, R. R. (1997): Development of Biological Criteria for the Design of Advanced Hydropower Turbines. DOE/ID-10578. Prepared for the U.S. Department of Energy. Idaho: Idaho Operations Office.

CAFF – Conservation of Arctic Flora and Fauna (2013): Arctic Biodiversity Assessment. Status and Trends in Arctic Biodiversity. Conservation of Arctic Flora and Fauna. Akureyri: Aarhus University.

Caldeira, K. and Wickett, M. E. (2003): Anthropogenic carbon and ocean pH. Nature 425, 365.

Cancino, J. P., Uchida, H. and Wilen, J. E. (2007): TURFs and ITQs: collective vs. individual decision making. Marine Resource Economics 22, 391–406.

Capps, S. B. and Zender, C. S. (2010): Estimated global ocean wind power potential from QuikSCAT observations, accounting for turbine characteristics and siting. Journal of Geophysical Research 115, 32.

Cao, L. and Caldeira, K. (2008): Atmospheric CO_2 stabilization and ocean acidification. Geophysical Research Letters 35, 5.

Caras, T. and Pasternak, Z. (2009): Long-term environmental impact of coral mining at the Wakatobi marine park, Indonesia. Ocean and Coastal Management 52, 539–544.

Carbone, M. (2008): Mission impossible: the European Union and policy coherence for development. Journal of European Integration 30 (3), 323–342.

Carnegie (2013): Renewable Power from the Ocean's Waves. Internet: http://www.carnegiewave.com/ (viewed 24. January 2013). North Fremantle: Carnegie.

CBD – Convention on Biological Diversity (1995): Jakarta Mandate on Marine and Coastal Biological Diversity. The Jakarta Ministerial Statement on Implementation of the CBD. Montreal: CBD Secretariat.

CBD – Convention on Biological Diversity (2000): Ecosystem Approach. Decision V/6. Montreal: CBD Secretariat.

CBD – Convention on Biological Diversity (2004a): Marine and Coastal Biological Diversity. Decision VII/5. Montreal: CBD Secretariat.

CBD – Convention on Biological Diversity (2004b): Solutions for Sustainable Mariculture – Avoiding the Adverse Effects of Mariculture on Biological Diversity. CBD Technical Series No. 12. Montreal: CBD Secretariat.

CBD – Convention on Biological Diversity (2004c): Ecosystem approach. Decision VII/11. Montreal: CBD Secretariat.

CBD – Convention on Biological Diversity (2010a): The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets. Decision X/2. Montreal: CBD Secretariat.

CBD – Convention on Biological Diversity (2010b): Marine and Coastal Biodiversity. Decision X/29. Montreal: CBD Secretariat.

CBD – Convention on Biological Diversity (2010c): Global Biodiversity Outlook 3. Montreal: CBD Secretariat.

CBD – Convention on Biological Diversity (2012): Marine and Coastal Biodiversity: Ecologically or Biologically Significant Marine Areas. Decision XI/17. Montreal: CBD Secretariat.

CEA – California Environmental Associates (2012): Charting a Course to Sustainable Fisheries. San Francisco, CA: CEA.

Ceo, M., Fagani, S., Swan, J., Tamada, K. and Watanabe, H. (2012): Performance Reviews by Regional Fishery Bodies: Introduction, Summaries, Synthesis and Best Practices. Volume I: CCAMLR, CCSBT, ICCAT, IOTC, NAFO, NASCO, NEAFC. FAO Fisheries and Aquaculture Circular No. 1072. Rome: Food and Agriculture Organization (FAO).

Cesar, H. J. S., Burke, L. and Pet-Soede, L. (2003): The Economics of Worldwide Coral Reef Degradation. Internet: http://assets.panda.org/downloads/cesardegradationreport100203.pdf (viewed 24. January 2013). Arnhem, Zeist: Cesar Environmental Economics Consulting, WWF Netherlands.

Charles, A. (2009): Rights-based fisheries management: the role of use rights in managing access and harvesting. In: Cochrane, K. L. and Garcia, S. M. (eds): A Fishery Manager's Guidebook. Chichester: Wiley-Blackwell, 253–282.

Charles, M. (2005): Functions and Socio-Economic Importance of Coral Reefs and Lagoons and Implications for Sustainable Management. Case Study of Moorea, French Polynesia. MSc Thesis Environmental Science – Environmental Systems Analysis. Wageningen: Wageningen University.

Chassot, E., Bonhommeau, S., Dulvy, N. K., Mélin, F., Watson, R., Gascuel, D. and Le Pape, O. (2010): Global marine primary production constrains fisheries catches. Ecolcogy Letters 13, 495–505.

Chavez, F. P., Ryan, J., Lluch-Cota, S. E. and Niquen, M. C. (2003): From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299, 217–221.

Cheung, W. W. L., Lam, V. W. Y., Sarmiento, J. L., Kearney, K., Watson, K. and Pauly, D. (2009): Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries 10 (3), 235–251.

Cheung, W. W. L., Lam, V. W. Y., Sarmiento, J. L., Kearney, K., Watson, R., Zeller, D. and Pauly, D. (2010): Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology 16 (1), 1365–2486.

Chivian, E. and Bernstein, A. (eds) (2008): Sustaining Life. How Human Health Depends on Biodiversity. Oxford, New York: Oxford University Press.

Chivian, E., Bernstein, A. and Rosenthal, J. P. (2008): Biodiversity and biomedical research. In: Chivian, E. and Bernstein, A. (eds): Sustaining Life. How Human Health Depends on Biodiversity. Oxford, New York: Oxford University Press, 163–201.

Chopin, T. (2008): Integrated multi-trophic aquaculture (IMTA) will also have its place when aquaculture moves to the open ocean. Fish Farmer, 40, 41.

Chopin, T., Troell, M., Reid, G. K., Knowler, D., Robinson, S. M. C., Neori, A., Buschmann, A. H. and Pang, S. (2010a): Integrated multi-trophic aquaculture. Part I. Responsible practice provides diversified products, biomitigation. Global Aquaculture Advocate 9/10, 38–39.

Chopin, T., Troell, M., Reid, G. K., Knowler, D., Robinson, S. M. C., Neori, A., Buschmann, A. H. and Pang, S. (2010b): Integrated multi-trophic aquaculture. Part II. Increasing IMTA adoption. Global Aquaculture Advocate 11/12, 17–20.

Christian, C., Ainley, D., Bailed, M., Dayton, P., Hocevar, J., LeVine, M., Nikoloyukg, J., Nouvianh, C., Velardei, E., Wernera, R. and Jacquet, J. (2013): A review of formal objections to Marine Stewardship Council fisheries certifications. Biological Conservation 161, 10–17.

Chynoweth, D. P., Owens, J. M. and Legrand, R. (2001): Renewable methane from anaerobic digestion of biomass. Renewable Energy 22 (1–3), 1–8.

Cicin-Sain, B. and Knecht, R. (1998): Integrated Coastal and Ocean Management: Concepts and Practices. Washington, DC: Island Press.

Cinner, J. E., McClanahan, T. R., MacNeil, M. A., Graham, N. A. J., Daw, T. M., Mukminin, A., Feary, D. A., Rabearisoa, A. L., Warmukota, A., Jiddawi, N., Campbell, S. J., Baird, A. H., Januchowski-Hartley, F. A., Hamed, S., Lahari, R., Morove, T. and Kuange, J. (2012): Comanagement of coral reef social-ecological systems. Proceedings of the National Academy of Sciences 109 (14), 5219–5222.

Clark, C. W. (1996): Marine reserves and the precautionary management of fisheries. Ecological Applications 6, 369–370.

Clark, S. and Edwards, A. J. (1994): Use of artificial reef structures to rehabilitate reef flats degraded by coral mining in the Maldives. Bulletin of Marine Science 55, 724–744.

Claude, G. (1930): Power from the tropical seas. Mechanical Engineering 52 (12), 1039–1044.

Clément, A., McCullen, P., Falcão, A., Fiorentino, A., Gardner, F. and Hammarlund, K. (2002): Wave energy in Europe: current status and perspectives. Renewable and Sustainable Energy Reviews 6 (5), 405–431.

Clifton, J., Cullen, L. C., Haapkylä, J. and Unsworth, R. K. F. (2010): Ensuring appropriate and proportionate responses to environmental threats: a response to Caras and Pasternak. Ocean & Coastal Management 53, 700–702.

CMS – Convention on the Conservation of Migratory Species of Wild Animals (2010): Memorandum of Understanding on the Conservation of Migratory Sharks. Bonn: CMS.

Cochrane, K. L., De Young, C., Soto, D. and Bahri, T. (2009): Climate Change Implications for Fisheries and Aquaculture. Overview of Current Scientific Knowledge. FAO Fisheries and

Aquaculture Technical Paper No. 530. Rome: Food and Agriculture Organization (FAO).

Cochrane, K. L. and Garcia, S. M. (2009): A Fishery Manager's Guidebook. Chichester: Wiley-Blackwell.

Cole, M., Lindeque, P., Halsband, C. and Galloway, T. S. (2011): Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin 62, 2588–2597.

Cole, S., José Ortiz, M. and Schwarte, C. (2012): Protecting the Marine Environment in Areas Beyond National Jurisdiction. A Guide to the Legal Framework for Conservation and Management of Biodiversity in Marine Areas Beyond National Jurisdiction. London: Foundation for International Environmental Law and Development (FIELD).

Coll, M., Libralato, S., Pitcher, T. J., Solidoro, C. and Tudela, S. (2013): Sustainability implications of honouring the Code of Conduct for Responsible Fisheries. Global Environmental Change 23, 157–166.

Collette, B. B., Carpenter, K. E., Polidoro, B. A., Juan-Jordá, M. J., Boustany, A., Die, D. J., Elfes, C., Fox, W., Graves, J., Harrison, L. R., McManus, R., Minte-Vera, C. V., Nelson, R., Restrepo, V., Schratwieser, J., Sun, C.-L., Amorim, A., Peres, M. B., Canales, C., Cardenas, G., Chang, S.-K., Chiang, W.-C., de Oliveira Leite, N., Harwell, H., Lessa, R., Fredou, F. L., Oxenford, H. A., Serra, R., Shao, K.-T., Sumaila, R., Wang, S.-P., Watson, R. and Yáñez, E. (2011): High value and long life – double jeopardy for tunas and billfishes. Science 333, 291–292.

Colombo, D., de Gerloni, M. and Reali, M. (1999): An energy-efficient submarine desalination plant. Desalination 122, 171–176.

Comeau, S., Gorsky, G., Jeffree, R., Teyssie, J.-L. and Gattuso, J.-P. (2009): Key Arctic pelagic mollusc *(Limacina helicina)* threatened by ocean acidification. Biogeosciences 6, 2523–2537.

COML – Census of Marine Life International (2011): Scientific Results to Support the Sustainable Use and Conservation of Marine Life. A Summary for Decision Makers. Washington, DC: COML International Secretariat.

Committee on Oil in the Sea (2003): Oil in the Sea III: Inputs, Fates, and Effects. Washington, DC: National Research Council.

Community Sciences (2013): The Community Sciences Program Internet: http://www.communitysciences.org/ (viewed 24. January 2013). Edinburgh: Community Sciences.

Constable, A. J., de la Mare, W. K., Agnew, D., Everson, I. and Miller, D. (2000): Managing fisheries to conserve the Antarctic marine ecosystem: practical implementation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). ICES Journal of Marine Science 57, 778–791.

Cooley, S. R. and Doney, S. C. (2011): Anticipating ocean acidification's economic consequences for commercial fisheries. Environmental Research Letter 4, 4.

Corbin, A. (1994): Meereslust. Das Abendland und die Entdeckung der Küste. Frankfurt/M.: Fischer.

Cornett, A. M. (2008): A global wave energy resource assessment. In: ISOPE – The International Society of Offshore and Polar Engineers (ed): Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference. Cupertino, CA: ISOPE, 318–327.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M. and Hannon, B. (1997): The value of the world's ecosystem services and natural capital. Nature 387, 253–260.

Costanza, R., Andrade, F., Antunes, P., den Belt, M., Boersma, D., Boesch, D. F., Catarino, F., Hanna, S., Limburg, K. and Low, B. (1998): Principles for sustainable governance of the oceans. Science 281, 198.

Costanza, R., Andrade, F., Antunesc, P., van den Belt, M., Boesch, D., Boersma, D., Catarino, F., Hanna, S., Limburg, K., Low, B., Molitor, M., Pereira, J. G., Rayner, S., Santos, R., Wilson, J. and Young, M. (1999): Ecological economics and sustainable governance of the oceans. Ecological Economics 31, 171–187.

Costello, C., Gaines, S. D. and Lynham, J. (2008): Can catch shares prevent fisheries collapse? Science 321, 1678–1681.

Costello, C., Kinlan, B. P., Lester, S. E. and Gaines, S. D. (2012a): The Economic Value of Rebuilding Fisheries. OECD Food, Agriculture and Fisheries Working Papers No. 55. Paris: Organisation for Economic Co–Operation and Development (OECD).

Costello, C., Ovando, D., Hilborn, R., Gaines, S. D., Deschenes, O. and Lester, S. E. (2012b): Status and solutions for the world's unassessed fisheries. Science 338, 517–522.

Costello, C. J. and Kaffine, D. (2008): Natural resource use with limited-tenure property rights. Journal of Environmental Economics and Management 55, 20–36.

Council of Canadian Academies (2008): Energy from Gas Hydrates: Assessing the Opportunities & Challenges for Canada. Ottawa: Council of Canadian Academies.

Cox, M., Arnold, G. and Villamayor Tomás, S. (2010): A review of design principles for community-based natural resource management. Ecology and Society 15 (4), 38.

Craig, R. K. (2012): Place based marine governance: an overview. In: Craig, R. K. (ed): Comparative Ocean Governance. Place-Based Protections in an Era of Climate Change. Cheltenham: Edward Elgar, 91–119.

Crone, T. J. and Tolstoy, M. (2010): Magnitude of the 2010 Gulf of Mexico oil leak. Science 330, 634.

Cruisemarketwatch (2010): Cruise Market Watch Announces 2011 Cruise Line Market Share and Revenue Projections. Internet: http://www.cruisemarketwatch.com/blog1/articles/cruise-market-watch-announces-2011-cruise-line-market-share-and-revenue-projections/ (viewed 10. February 2012). Bonn, Berlin: Germanwatch.

Crutzen, P. J. and Stoermer, E. F. (2000): The "Anthropocene". Global Change Newsletter 41, 17–18.

Cullis-Suzuki, S. and Pauly, D. (2010): Failing the high seas: a global evaluation of regional fisheries management organizations. Marine Policy 34, 1036–1042.

Cury, P. M., Boyd, I. L., Bonhommeau, S., Anker-Nilssen, T., Crawford, J. M., Furness, R. W., Mills, J. A., Murphy, E. J., Österblom, H., Paleczny, M., Piatt, J. F., Roux, J.-P., Shannon, L. J. and Sydeman, W. J. (2011): Global seabird response to forage fish depletion – one-third for the birds. Science 334, 1703–1706.

Cury, P. M. and Christensen, V. (2005): Quantitative ecosystem indicators for fisheries management. ICES Journal of Marine Science 62, 307–310.

Cutler, A., Virginia Haufler, C. and Porter, T. (1999): Private authority and international affairs. In: Cutler, A., Virginia Haufler, C. and Porter, T. (eds): Private Authority and International Affairs. Albany, NY: State University of New York Press, 3–28.

Czybulka, D. and Kersandt, P. (2000): Rechtsvorschriften, rechtliche Instrumentarien und zuständige Körperschaften mit Relevanz für marine Schutzgebiete ("Marine Protected Areas"/MPAs) in der Ausschließlichen Wirtschaftszone (AWZ) und auf Hoher See des OSPAR-Konventionsgebiets, 3. BfN-Skripten 27. Bonn, Bad-Godesberg: Federal Agency for Nature Conservation (BfN).

da Silva, P. and Kitts, A. (2006): Collaborative fisheries management in the Northeast US: Emerging initiatives and future directions. Marine Policy 30 (6), 832–841.

DAFF – Australian Government Department of Agriculture Fisheries and Forestry (2005): Australian National Plan of Action To Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing. Canberra: DAFF.

Damanaki, M. (2011): Save the Fish to Save the Fishermen. Internet: http://www.cfp-reformwatch.eu/2011/07/save-the-fish-to-save-the-fishermen/. Brussels: CFP Reform Watch.

Damanaki, M. (2013): Speech at the 8th International Forum on Illegal, Unreported and Unregulated Fishing. Transcript. London: Chatham House.

Daniel, T. (2000): Ocean thermal energy conversion: an extensive, environmentally benign source of energy for the future. Sustainable Development International 3, 121–125.

Davies, A. J., Roberts, J. M. and Hall-Spencer, J. (2007): Preserving deep-sea natural heritage: Emerging issues in offshore conservation and management. Biological Conservation 138, 299–312.

Davies, R., Cripps, S. J. and Nickson, A. (2009): Defining and estimating global marine fisheries bycatch. Marine Policy 33 (4), 661–672.

Daw, T., Adger, W. N., Brown, K. and Badjeck, M.-C. (2009): Climate change and capture fisheries: potential impacts, adaptation and mitigation. In: Cochrane, K., De Young, C., Soto, D. and Bahri, T. (eds): Climate Change Implications for Fisheries and Aquaculture: Overview of Current Scientific Knowledge. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome: Food and Agriculture Organization (FAO), 107–150.

Daw, T. and Gray, T. (2005): Fisheries science and sustainability in international policy: a study of failure in the European Union's Common Fisheries Policy. Marine Policy 29, 189–197.

de Brabandere, E. (2011): NGOs and the 'Public Interest': the legality and rationale of amicus curiae interventions in international economic and investment disputes. Chicago Journal of International Law 12 (1), 85.

de Falcão, A. F. O. (2010): Wave energy utilization: a review of the technologies. Renewable and Sustainable Energy Reviews 14, 899–918.

de Schutter, O. (2012a): Fisheries and the Right to Food. UN-Document A/67/268. New York: United Nations (UN).

de Schutter, O. (2012b): 'Ocean-grabbing' as serious a threat as 'land-grabbing'. Internet: http://www.srfood.org/index.php/en/component/content/article/2543-ocean-grabbing-as-serious-a-threat-as-land-grabbing-un-food-expert (viewed 17. December 2012). New York: United Nations (UN).

de Silva, S. and Davy, F. B. (eds) (2010): Success Stories in Asian Aquaculture. Dordrecht: Springer.

de Silva, S. and Soto, D. (2009): Climate change and aquaculture: potential impacts, adaptation and mitigation. FAO Fisheries Technical Paper No. 530, 137–215.

de Silva, S. S. and Turchini, G. M. (2009): Use of wild fish and other aquatic organisms as feed in aquaculture – a review of practices and implications in the Asia-Pacific. In: Hasan, M. R. and Halwart, M. (eds): Fish as Feed Inputs for Aquaculture: Practices, Sustainability and Implications. FAO Fisheries and Aquaculture Technical Paper No. 518. Rome: Food and Agriculture Organization (FAO), 63–127.

Demirbas, A. (2010): Methane Gas Hydrate. Berlin, Heidelberg: Springer.

Dempster, T. and Sanchez-Jerez, P. (2008): Aquaculture and coastal space management in Europe: an ecological perspective. Chapter 3. In: Holmer, M., Black, K., Duarte, C. M., Marbà, N. and Karakassis, I. (eds): Aquaculture in the Ecosystem. Berlin, Heidelberg: Springer, 87–111.

Denier van der Gon, H. A. C., van het Bolscher, M., Visschedijk, A. J. H. and Zandveld, P. Y. J. (2005): Study to the Effectiveness of the UNECE Persistent Organic Pollutants Protocol and Cost of Possible Additional Measures. Phase 1. Estimation of Emission Reduction Results from the Implementation of the POP Protocol. TNO-Report B&O-A R 2005/194. Apeldoorn: TNO.

Desholm, M. and Kahlert, J. (2005): Avian collision risk at an offshore wind farm. Biology Letters 1, 296–298.

Deutsch, C., Brix, H., Ito, T., Frenzel, H. and Thompson, L. (2011): Climate-forced variability of ocean hypoxia. Science 333, 336–340.

Dewailly, E., Pereg, D., Knap, A., Rouja, P., Galvin, J. and Owen, R. (2008): Exposure and effects of seafood-borne contaminants in maritime populations. In: Walsh, P. J., Smith, S. L., Fleming, L. E., Solo-Gabriele, H. M. and Gerwick, W. H. (eds): Oceans and Human Health. Risks and Remedies From the Seas. Burlington, MA: Elsevier Academic Press, 181–199.

Dey, M. M., Bimbao, G. B., Yong, L., Regaspi, P., Kohinoor, A. H. M., Pongthana, N. and Paraguas, F. J. (2000): Current status of production and consumption of tilapia in selected Asian countries. Aquaculture Economics & Management 4 (1–2), 13–31.

Dey, M. M., Kambewa, P., Prein, M., Jamu, D., Paraguas, F. J., Pemsl, D. E. and Briones, R. M. (2006): Impact of development and dissemination of integrated aquaculture-agriculture (IAA) technologies in Malawi. NAGA, WorldFish Center Quarterly 29 (1&2), 28–35.

DG – Directorate-General for External Policies of the European Union (2010): The Geopolitics of Arctic Natural Resources, AFET, EXPO/B/AFET/FWC/2009-01/Lot 2/02. Brussels: European Commission.

Diaz, R. J. and Rosenberg, R. (2008): Spreading dead zones and consequences for marine ecosystems. Science 321, 926–929.

Diekert, F. K., Eikeset, A. M. and Stenseth, N. C. (2010): Where could catch shares prevent stock collapse? Marine Policy 34, 710–712.

Domingo, J. L., Bocio, A. and Falco, L. J. (2007): Benefits and risks of fish consumption. Part I. A quantitative analysis of the intake of omega-3 fatty acids and chemical contaminants. Toxicology and Chemistry 230, 219–226.

Donato, D. C., Kauffman, J. B., Murdiyarso, D., Kurnianto, S., Stidham, M. and Kanninen, M. (2011): Mangroves among the most carbon-rich forests in the tropics. Nature Geoscience 4, 293–297.

Doney, S. C. (2010): The growing human footprint on coastal and open-ocean biogeochemistry. Science 328, 1512–1516.

Doney, S. C., Fabry, V. J., Feely, R. A. and Kleypas, J. A. (2009): Ocean acidification: the other CO_2 problem. Annual Reviews of Marine Science 1, 169–192.

Doney, S. C., Ruckelshaus, M., Duffy, J. E., Barry, J. P., Chan, F., English, C. A., Galindo, H. M., Grebmeier, J. M., Hollowed, A. B., Knowlton, N., Polovina, J., Rabalais, N. N., Sydeman, W. J. and Talley, L. D. (2012): Climate change impacts on marine ecosystems. Annual Reviews of Marine Science 4, 11–37.

Doulman, D. J. (2007): Coping with the extended vulnerability of marine ecosystems: implementing the 1995 FAO Code of Conduct for Responsible Fisheries. Social Science Information 46 (1), 189–237.

Douvere, F. and Ehler, C. N. (2009): New perspectives on sea use management: initial findings from European experience with marine spatial planning. Journal of Environmental Management 90, 77–88.

Drew, B., Plummer, A. R. and N., S. M. (2009): A review of wave energy converter technology. Proceedings of the Institution of Mechanical Engineers 223, 887–902.

Driscoll, J. and Tyedmers, P. (2010): Fuel use and greenhouse gas emission implications of fisheries management: the case of the New England atlantic herring fishery. Marine Policy 34, 353–359.

Druel, E., Billé, R. and Treyer, S. (2011): A Legal Scenario Analysis for Marine Protected Areas in Areas Beyond National Jurisdiction. Report from the Boulogne-sur-Mer Seminar, 19–21 September 2011. Studies No. 06/11. Paris:

Institut du Développement Durable et des Relations Internationales (IDDRI), International Union for Conservation of Nature (IUCN), Agence des Aires Marines Protégées.

Druel, E., Ricard, P., Rochette, J. and Martinez, C. (2013): Governance of Marine Biodiversity in Areas Beyond National Jurisdiction at the Regional Level: Filling the Gaps and Strengthening the Framework for Action. Paris: Institute for Sustainable Development and International Relations (IDDRI).

du Jourdin, M. M. (1993): Europa und das Meer. Munich: Beck.

Duarte, C. M., Middelburg, J. J. and Caraco, N. (2005): Major role of marine vegetation on the oceanic carbon cycle. Biogeosciences 2, 1–8.

Duarte, C. M., Holmer, M., Olsen, Y., Soto, D., Marba, N., Guiu, J., Black, K. and Krakassis, I. (2009): Will the oceans help feed humanity? BioScience 59 (11), 967–976.

Dubash, N. K. and Florini, A. (2011): Mapping global energy governance. Global Policy 2 (Supplement s1), 1–5.

Easterling, W., Batima, P., Brander, K., Erda, L., Howden, M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber, J. and Tubiello, F. (2007): Food, fibre and forest products. In: IPCC – Intergovernmental Panel on Climate Change (ed): Climate Change 2007: Impacts, Adaptation and Vulnerability. Geneva: IPCC, 275–303.

ECASA – Ecosystem Approach for Sustainable Aquaculture (2013): The ECASA Toolbox. Internet: http://www.ecasa.org.uk (viewed 29. January 2013). London: ECASA.

Economist (2012): Hidden treasure. The melting north. Economist Special Report: The Arctic, 12–14.

Ecotrust Canada (2008): Fisheries Licence Banks: A Start-Up Guide to Planning, Governance, Finance & Operations. Vancouver, BC: Ecotrust Canada.

Edeson, W. R. (1996): The Code of Conduct for Responsible Fisheries: An Introduction. Current Level Developments. Food and Agriculture Organization of the UN. The International Journal of Marine and Coastal Law 11 (2), 233–238.

Edeson, W. R. (2003): Sustainable use of marine living resources. Zeitschrift für ausländisches öffentliches Recht und Völkerrecht 63, 355–376.

Edquist, C. (2000): Systems of innovations – their emergence and characteristics. In: Edquist, C. and McKelvey, M. (eds): Systems of Innovations: Growth, Competitiveness and Employment. Volume 1. Cheltenham: Edward Elgar Publishing, 3–37.

Edquist, C. (2005): Systems of innovation: perspectives and challenges. In: Fagerberg, J., Mowery, D. C. and Nelson, R. R. (eds): The Oxford Handbook of Innovation. Oxford, New York: Oxford University Press, 181–209.

Edwards, P. and Demaine, H. (1998): Rural Aquaculture: Overview and Framework for Country Reviews. Rome: Food and Agriculture Organization (FAO).

Egbert, G. D. and Ray, R. D. (2003): Semi-diurnal and diurnal tidal dissipation from TOPEX/Poseidon altimetry. Geophysical Research Letters 30 (17), 4.

Ehlers, P. (2006): Sanierung von Meeresverschmutzungen – Verantwortlichkeit und Haftung. Natur und Recht 28 (2), 86–92.

EIA – Energy Information Administration (2008): Performance Profiles of Major Energy Producers 2007. Washington, DC: EIA.

EIA – Energy Information Administration (2013): South China Sea. Internet: http://www.eia.gov/countries/regions-topics.cfm?fips=SCS (viewed 7. February 2013). Washington, DC: EIA.

Eiden, G. and Goldsmith, R. (2010): PASTA-MARE Project: Preparatory Action for Assessment of the Capacity of Spaceborne Automatic Identification System Receivers to Support EU Maritime Policy. Study Contract Issued by the European Commission and Awarded to a Consortium led by LuxSpace Sarl and ComDev Europe. Executive Summary. Brussels: European Commission Maritime Forum.

Eikeset, A. M., Richter, A. P., Diekert, F. K., Dankel, D. J. and Stenseth, N. C. (2011): Unintended consequences sneak in the back door: making wise use of regulations in fisheries management. In: Belgrano, A. and Fowler, C. W. (eds): Ecosystem-Based Management for Fisheries – An Evolving Perspective. Cambridge, NY: Cambridge University Press, 183–217.

Elias, N. (1987): Die Gesellschaft der Individuen. Frankfurt/M.: Suhrkamp.

ENB – Earth Negotiations Bulletin (2006): Summary of the UN Fish Stocks Agreements Review Conference: 22–26 May 2006. ENB Vol. 7 No. 61. New York: International Institute for Sustainable Development (IISD).

ENB – Earth Negotiations Bulletin (2010): Summary of the Resumed Review Conference of the UN Fish Stocks Agreement: 24–28 May 2010. ENB Vol. 7 No. 65. New York: International Institute for Sustainable Development (IISD).

EPA – U.S. Environmental Protection Agency (2012): Mercury. Fish Consumption Advisories. Internet: http://www.epa.gov/hg/advisories.htm (viewed 17. May 2013). Washington, DC: EPA.

Erbguth, W. and Schlacke, S. (2012): Umweltrecht. 4. Auflage. Baden-Baden: Nomos.

Erwin, P. M., López-Legentil, S. and Schuhmann, P. W. (2010): The pharmaceutical value of marine biodiversity for anti-cancer drug discovery. Ecological Economics 70, 445–451.

Essington, T. E. (2010): Ecological indicators display reduced variation in North American catch share fisheries. Proceedings of the National Academy of Sciences 107 (2), 754–759.

Essington, T. E., Beaudreau, A. H. and Wiedenmann, J. (2006): Fishing through marine food webs. Proceedings of the National Academy of Sciences 103 (9), 3171–3175.

Essington, T. E., Melnychuk, M. C., Branch, T. A., Heppell, S. S., Jensen, O. P., Link, J. S., Martell, S., Parma, A. M., Pope, J. G. and Smith, A. D. M. (2012): Catch shares, fisheries, and ecological stewardship: a comparative analysis of resource responses to a rights-based policy instrument. Conservation Letters 5, 186–195.

Estes, J. A., Terborgh, J., Brashares, J. S., Power, M. E., Berger, J., Bond, W. J., Carpenter, S. R., Essington, T. E., Holt, R. D., Jackson, J., B. C., Marquis, R. J., Oksanen, L., Oskanen, T., Paine, R. T., Pikitch, E. K., Rpple, W. J., Sandin, S. A., Scheffer, M., Schoener, T. W., Shurin, J. B., Sinclair, A. R. E., Soulé, M. E., Virtanen, R. and Wardle, D. A. (2011): Trophic downgrading of planet Earth. Science 333, 301–306.

EU – European Union (2000): Partnership Agreement Between the Members of the African, Caribbean and Pacific Group of States of the one Part, and the European Community and its Member States, of the other Part, Signed in Cotonou on 23 June 2000. Brussels: EU.

EU – European Union (2003): Directive 2003/35/EC of the European Parliament and of the Council of 26 May 2003 Providing for Public Participation in Respect of the Drawing up of Certain Plans and Programmes Relating to the Environment and Amending With Regard to Public Participation and Access to Justice. Council Directives 85/337/EEC and 96/61/EC. Brussels: EU.

EU – European Union (2004): Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on Environmental Liability with Regard to the Prevention and Remedying of Environmental Damage. Brussels: EU.

EU – European Union (2007): Council Regulation (EC) No 834/2007 of 28 June 2007 on Organic Production and Labelling of Organic Products and Repealing Regulation (EEC) No 2092/91. Brussels: EU.

EU – European Union (2008): Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 on Establishing a Framework for Community Action in the Field of Marine Environmental Policy (Marine Strategy Framework Directive). Brussels: EU.

EU – European Union (2009a): Commission Regulation (EC) No 710/2009 of 5 August 2009 Amending Regulation (EC) No 889/2008 laying down Detailed Rules for the Implementation of Council Regulation (EC) No 834/2007, as Regards laying down Detailed Rules on Organic Aquaculture Animal and Seaweed Production. Brussels: EU.

EU – European Union (2009b): Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/E. Brussels: EU.

EU – European Union (2012): Declaration of the European Ministers Responsible for the Integrated Maritime Policy and the European Commission on a Marine and Maritime Agenda for Growth and Jobs, the "Limassol Declaration". Brussels: EU.

EU Commission (1999): Towards a European Integrated Coastal Zone Management (ICZM) Strategy. General Principles and Policy Options. Brussels: European Commission.

EU Commission (2008): Roadmap for Maritime Spatial Planning: Achieving Common Principles in the EU. COM(2008) 791 final. Brussels: European Commission.

EU Commission (2009a): Communication from the Commission to the European Parliament and the Council. Building a Sustainable Future for Aquaculture. A new Impetus for the Strategy for the Sustainable Development of European Aquaculture. COM(2009) 162 final. Brussels: European Commission.

EU Commission (2009b): Towards an Integrated Maritime Policy for Better Governance in the Mediterranean. COM(2009) 466 final. Brussels: European Commission.

EU Commission (2009c): Green Paper. Reform of the Common Fisheries Policy. COM(2009) 163 final. Brussels: European Commission.

EU Commission (2011a): Proposal for a Regulation of the European Parliament and of the Council on Safety of Offshore Oil and Gas Prospection, Exploration and Production Activities. COM(2011) 688 final. Brussels: European Commission.

EU Commission (2011b): Proposal for a Regulation of the European Parliament and of the Council on Safety of Offshore Oil and Gas Prospection, Exploration and Production Activities. COM (2011) 688 final, 2011/0309 (COD). Brussels: European Commission.

EU Commission (2011c): Proposal for a Regulation of the European Parliament and of the Council on the Common Fisheries Policy. COM(2011) 425 final. Brussels: European Commission.

EU Commission (2011d): Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EC) No 1185/2003 on the Removal of Fins of Sharks on Board Vessels. COM(2011) 798 final. Brussels: European Commission.

EU Commission (2011e): Fishing Outside the EU. Internet: http://ec.europa.eu/fisheries/cfp/international/index_en.htm (viewed 31. January 2013). Brussels: European Commission.

EU Commission (2011f): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on External Dimension of the Common Fisheries Policy. COM(2011) 424 final. Brussels: European Commission.

EU Commission (2012a): Communication from the Commission to the Council Concerning a Consultation on Fishing Opportunities for 2013. COM(2012) 278 final. Brussels: European Commission.

EU Commission (2012b): New Protocol to the EU-Mauritania Fisheries Partnership Agreement Initialled in Nouakchott (Mauritania). Press Release – 27/7/2012. Internet: http://ec.europa.eu/fisheries/cfp/international/agreements/index_en.htm (viewed 31. January 2013). Brussels: European Commission.

EU Commission (2012c): Bilateral Agreements with Countries Outside the EU. Internet: http://ec.europa.eu/fisheries/cfp/international/agreements/index_de.htm (viewed 31. January 2013). Brussels: European Commission.

EU Commission (2012d): Guidance on Aquaculture and Natura 2000. Sustainable Aquaculture Activities in the Context of the Natura 2000 Network. Brussels: European Commission.

EU Commission (undated): Fisheries Partnership Agreements. Brussels: European Commission.

EU-OEA – European Ocean Energy Association (2010): Oceans of Energy. European Ocean Energy Roadmap 2010–2050. Brussels: EU-OEA.

EU-Parliament (2012): Draft report on the external dimension of the Common Fisheries Policy (2011/2318(INI)). Committee on Fisheries. Rapporteur: Isabella Lövin. Brussels: European Parliament.

EWEA – European Wind Energy Association (2009): Oceans of Opportunity. Harnessing Europe's Largest Domestic Energy Resource. Brussels: EWEA.

EWEA – European Wind Energy Association (2011): Pure Power – Wind Energy Targets for 2020 and 2030. Brussels: EWEA.

EWEA – European Wind Energy Association (2012): Seaenergy 2020: Delivering Offshore Electricity to the EU. Spatial Planning of Offshore Renewable Energies and Electricity Grid Infrastructures in an Integrated EU Maritime Policy. Brussels: EWEA.

EWEA – European Wind Energy Association (2013): Wind in Power. 2012 European Statistics. Brussels: EWEA.

Fabi, R. and Aizhu, C. (2012): Analysis: China unveils oil offensive in South China Sea squabble. Internet: http://www.reuters.com/assets/print?aid=USBRE8701LM20120801 (viewed 26. January 2013). Frankfurt/M.: Reuters Online.

Fabry, V. J., Seibel, B. A., Feely, R. A. and Orr, J. C. (2008): Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Science 65, 414–432.

Falkner, R. (2003): Private environmental governance and international relations: exploring the links. Global Environmental Politics 3 (2), 72–87.

Fang, X. (2007): Export and Industry Policy of Aquaculture Products in China. Global Trade Conference on Aquaculture. Rome: Food and Agriculture Organization (FAO).

FAO – Food and Agriculture Organization (1995): Code of Conduct for Responsible Fisheries. Rome: FAO.

FAO – Food and Agriculture Organization (1996): Precautionary Approach to Capture Fisheries and Species Introductions. FAO Technical Guidelines for Responsible Fisheries No. 2. Rome: FAO.

FAO – Food and Agriculture Organization (1997a): Fisheries Management. FAO Technical Guidelines for Responsible Fisheries No. 4. Rome: FAO.

FAO – Food and Agriculture Organization (1997b): Aquaculture Development. FAO Technical Guidelines for Responsible Fisheries 5. Rome: FAO.

FAO – Food and Agriculture Organization (2000): Small Ponds Make a Big Difference. Integrating Fish with Crop and Livestock Farming. Internet: http://www.fao.org/docrep/003/

x7156e/x7156e02.htm#P1_34 (viewed 5. February 2013). Rome: FAO.

FAO – Food and Agriculture Organization (2001): International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing. Rome: FAO.

FAO – Food and Agriculture Organization (2003): Fisheries Management: The Ecosystem Approach to Fisheries. FAO Technical Guidelines for Responsible Fisheries 4 Suppl. 2. Rome: FAO.

FAO – Food and Agriculture Organization (2004): The State of World Fisheries and Aquaculture 2004. Rome: FAO.

FAO – Food and Agriculture Organization (2005a): Straddling and Highly Migratory Fish Stocks. Rome: FAO.

FAO – Food and Agriculture Organization (2005b): Ghost Fishing. Internet: http://www.fao.org/fishery/topic/14798/en (viewed 18. February 2013). Rome: FAO.

FAO – Food and Agriculture Organization (2006): Prospective Analysis of Future Aquaculture Development. COFI:AQ/III/2006/Inf.7. Rome: FAO Fisheries Department.

FAO – Food and Agriculture Organization (2007): The World's Mangroves 1980–2005. A Thematic Study Prepared in the Framework of the Global Forest Resources Assessment 2005. FAO Forestry Paper 153. Rome: FAO.

FAO – Food and Agriculture Organization (2008): Towards Better Governance. Rome: FAO.

FAO – Food and Agriculture Organization (2009a): The State of World Fisheries and Aquaculture 2008. Rome: FAO.

FAO – Food and Agriculture Organization (2009b): International Guidelines for the Management of Deep-Sea Fisheries in the High Seas. Rome: FAO.

FAO – Food and Agriculture Organization (2009c): Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing. Rome: FAO.

FAO – Food and Agriculture Organization (2010a): Fact Sheet: The International Fish Trade and World Fisheries. Rome: FAO.

FAO – Food and Agriculture Organization (2010b): The State of World Fisheries and Aquaculture 2010. Rome: FAO.

FAO – Food and Agriculture Organization (2010c): Fishery and Aquaculture Statistics. Yearbook. Rome: FAO.

FAO – Food and Agriculture Organization (2011a): Review of the State of World Marine Fishery Resources. FAO Fisheries and Aquaculture Technical Paper No. 569. Rome: FAO.

FAO – Food and Agriculture Organization (2011b): Ecosystem Approach to Aquaculture (EAA). Internet: http://www.fao.org/fishery/topic/16035/en (viewed 30. November 2011). Rom: FAO Fisheries and Aquaculture Department.

FAO – Food and Agriculture Organization (2011c): World Aquaculture 2010. FAO Fisheries and Aquaculture Technical Paper No. 500/1. Rome: FAO.

FAO – Food and Agriculture Organization (2011d): Technical Guidelines on Aquaculture Certification. Version Approved by the 29th Session of Committee on Fisheries (COFI) held in Rome, Italy from 31 January to 04 February 2011. Internet: ftp://ftp.fao.org/Fi/DOCUMENT/aquaculture/TGAC/guidelines/Aquaculture%20Certification%20GuidelinesAfterCOFI4-03-11_E.pdf (viewed 13. November 2012). Rome: FAO.

FAO – Food and Agriculture Organization (2011e): Aquaculture Development: Use of Wild Fish as Feed in Aquaculture. FAO Technical Guidelines for Responsible Fisheries No. 5. Rome: FAO.

FAO – Food and Agriculture Organization (2011f): Private Standards and Certification in Fisheries and Aquaculture. Current Practice and Emerging Issues. Rome: FAO.

FAO – Food and Agriculture Organization (2012a): International Guidelines for Securing Small-Scale Fisheries. Rome: FAO.

FAO – Food and Agriculture Organization (2012b): The State of World Fisheries and Aquaculture 2012. Rome: FAO.

FAO – Food and Agriculture Organization (2012c): International Guidelines for Securing Sustainable Small-scale Fisheries. Zero Draft. Rome: FAO.

FAO – Food and Agriculture Organization (2012d): Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security. Rome: FAO.

FAO – Food and Agriculture Organization (2012e): Evaluation of FAO's Support to the Implementation of the Code of Conduct for Responsible Fisheries. Final Report. Rome: FAO.

FAO – Food and Agriculture Organization (2012f): Fishery and Aquaculture Country Profiles: Namibia. Internet: http://www.fao.org/fishery/countrysector/FI-CP_NA/en (viewed 24. January 2013). Rome: FAO.

FAO – Food and Agriculture Organization (2012g): FAOSTAT. Food Balance Sheets. Internet: http://faostat.fao.org (viewed 25. July 2012). Rome: FAO.

FAO – Food and Agriculture Organization (2013a): CWP Handbook of Fishery Statistical Standards. Section J: Aquaculture. Defintion of Aquaculture. Internet: http://www.fao.org/fishery/cwp/handbook/J/en (viewed 23. January 2013). Rome: FAO.

FAO – Food and Agriculture Organization (2013b): Rural Aquaculture: Overview and Framework for Country Reviews. FAO Corporate Document Repository. 1 Definitions. Internet: http://www.fao.org/docrep/003/X6941E/x6941e04.htm#TopOfPage (viewed 7. February 2013). Rome: FAO.

FAO – Food and Agriculture Organization (2013c): Governance of Aquaculture. Internet: http://www.fao.org/fishery/topic/13542/en (viewed 20. February 2013). Rome: FAO Fisheries and Aquaculture Department.

FAO – Food and Agriculture Organization (2013d): Regional Fishery Bodies Map Viewer. Internet: http://www.fao.org/figis/geoserver/factsheets/rfbs.html (viewed 20. February 2013). Rome: FAO Fisheries and Aquaculture Department.

FAO – Food and Agriculture Organization and WFC – World Fish Center (2008): Small-Scale Capture Fisheries. A Global Overview with Emphasis on Developing Countries. A Preliminary Report of the Big Numbers Project. Rome: FAO.

Fedder, B. (2013): Marine Genetic Resources, Access and Benefit Sharing. Legal and Biological Perspectives. New York: Routledge.

Feely, R., Doney, S. C. and Cooley, S. R. (2009): Ocean acidification. Present conditions and future changes in a high-CO_2 world. Oceanography 22 (4), 36–47.

Ferreira, J. G., Saurel, C. and Ferreira, J. M. (2012): Cultivation of gilthead bream in monoculture and integrated multitrophic aquaculture. Analysis of production and environmental effects by means of the FARM model. Aquaculture 358–359, 23–34.

Ferse, S. C. A., Knittweis, L., Krause, G., Maddusila, A. and Glaser, M. (2012): Livelihoods of ornamental coral fishermen in South Sulawesi/Indonesia: implications for management. Coastal Management 40, 525–555.

Field, C. B., Behrenfeld, M. J., Randerson, J. T. and Falkowski, P. G. (1998): Primary production of the biosphere: integrating terrestrial and oceanic components. Science 281, 237–241.

Field, I. C., Meekan, M. G., Buckworth, R. C. and Bradshaw, C. J. A. (2009): Susceptibility of sharks, rays and chimaeras to global extinction. Advances in Marine Biology 56, 277–328.

Finley, C. (2011): All The Fish in the Sea. Maximum Sustainable Yield and the Failure of Fisheries Management. Chicago: University of Chicago Press.

Fischer-Lescano, A. and Möller, K. (2012): Der Kampf um globale soziale Rechte. Berlin: Wagenbach.

Flechter, W. J., Shaw, J., Gaughan, D. J. and Metcalf, S. J. (2011): Ecosystem Based Fisheries Management Case Study Report – West Coast Bioregion. Fisheries Research Report No. 225. Canberra: Department of Fisheries, Western Australia.

Florentinus, A., Hamelinck, C., de Lint, S. snd van Iersel, S. (2008): Worldwide Potential of Aquatic Biomass. Report Summary. Utrecht: Ecofys.

Flothmann, S., von Kistowski, K., Dolan, E., Lee, E., Meere, F. and Album, G. (2010): Closing loopholes: getting illegal fishing under control. Science 328, 1235–1236.

Flottenkommando der Marine (2011): Jahresbericht 2011. Fakten und Zahlen zur maritimen Abhängigkeit der Bundesrepublik Deutschland. Glücksburg: Flottenkommando der Marine.

Foden, J., Roger, S. and Jones, A. (2010): Recovery of UK seabed habitats from benthic fishing and aggregate extraction – towards a cumulative impacts assessment. Marine Ecology Progress Series 411, 259–270.

Foekema, E. M., Deerenberg, C. M. and Murk, A. J. (2008): Prolonged ELS test with the marine flatfish sole *(Solea solea)* shows delayed toxic effects of previous exposure to PCB 126. Aquatic Toxicology 90 (3), 197–203.

Foster, G. and Rahmstorf, S. (2012): Global temperature evolution 1979–2010. Environmental Research Letters 7 (4), 5.

Fourqurean, J. W., Duarte, C. M., Kennedy, H., Marbà, N., Holmer, M., Mateo, M. A., Apostolaki, E. T., Kendrick, G. A., Krause-Jensen, D., McGlathery, K. J. and Serrano, O. (2012): Seagrass ecosystems as a globally significant carbon stock. Nature Geoscience 5, 505–509.

Fowler, S. and Séret, B. (2010): Shark Fins in Europe: Implications for Reforming the EU Finning Ban. Burnaby, BC: International Union for Conservation of Nature (IUCN) Shark Specialist Group.

Fox, A. D., Desholm, M., Kahlert, J., Christensen, T. K. and Petersen, I. K. (2006): Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis 148, 129–144.

Francis, R. C., Hixon, M. A., Clarke, E. M., Murawski, S. A. and Ralston, S. (2007): Ten commandments for ecosystem-based fisheries scientists. Fisheries 32 (5), 217–233.

Frank, K. T., Petrie, B., Loi, J. S. and Leggett, W. C. (2005): Trophic cascades in a formerly cod-dominated ecosystem. Science 208, 1621–1623.

Frank, K. T., Petrie, B., Fisher, J. A. D. and Leggett, W. C. (2011): Transient dynamics of an altered large marine ecosystem. Nature 477, 86–91.

Frankic, A. and Hershner, C. (2003): Sustainable aquaculture: developing the promise of aquaculture. Aquaculture International 11, 517–530.

Freeman, S., Vigoda-Gadot, E., Sterr, H., Schultz, M., Korchenkov, I., Krost, P. and Angel, D. (2012): Public attitudes towards marine aquaculture: A comparative analysis of Germany and Israel. Environmental Science & Policy 22, 60–72.

Freiwald, A. and Roberts, J. M. (eds) (2005): Cold-Water Corals and Ecosystems. Berlin, Heidelberg: Springer.

Fricke, R. (2000): Auswirkungen elektrischer und magnetischer Felder auf Meeresfische in der Nord- und Ostsee. In: Merck, T. and von Nordheim, H. (eds): Technische Eingriffe in marine Lebensräume. Workshop of the Federal Agency for Nature Conservation – INA Vilm, 27.–29. October 1999. BfN Skripten 29. Vilm: Federal Agency for Nature Conservation (BfN), 41–61.

Frid, C. L. and Paramor, O. A. L. (2012): Food for thought. Feeding the world: what role for fisheries? ICES Journal of Marine Science 69 (2), 145–150.

Friedland, J. C. (2007): Der Schutz der biologischen Vielfalt der Tiefseehydrothermalquellen: ein internationales Regime für die genetischen Tiefseeressourcen. Baden-Baden: Nomos.

Friedlander, M. (2008): Israeli R & D activities in seaweed cultivation. Israel Journal of Plant Sciences 56 (1), 15–28.

Friedrich, J. (2008): Legal challenges of nonbinding instruments: the case of the FAO Code of Conduct for Responsible Fisheries. German Law Journal 9 (11), 1539–1564.

Frieler, K., Meinshausen, M., Golly, A., Mengel, M., Lebek, K., Donner, S. D. and Hoegh-Guldberg, H. (2013): Limiting global warming to 2 °C is unlikely to save most coral reefs. Nature Climate Change 3, 165–170.

Frisch, M. (1979): Der Mensch erscheint im Holozän. Frankfurt/M.: Suhrkamp.

Froese, R. (2011): Fishery reform slips through the net. Nature 475, 7.

Froese, R. and Proelß, A. (2010): Rebuilding fish stocks no later than 2015: will Europe meet the deadline? Fish and Fisheries 11 (2), 194–202.

Froese, R. and Proelß, A. (2012): Evaluation and legal assessment of certified seafood. Marine Policy 36, 1284–1289.

Froese, R. and Proelß, A. (2013): Is a stock overfished if it is depleted by overfishing? A response to the rebuttal of Agnew et al. to Froese and Proelß ‘Evaluation and legal assessment of certified seafood’. Marine Policy 38, 548–550.

Froese, R. and Quaas, M. (2013): Rio+20 and the Reform of the Common Fisheries Policy in Europe. Marine Policy 39, 53–55.

Froese, R., Branch, T. A., Proelß, A., Quaas, M., Sainsbury, K. and Zimmermann, C. (2011): Generic harvest control rules for European fisheries. Fish and Fisheries 12 (3), 340–351.

Froese, R., Zeller, D., Kleisner, K. and Pauly, D. (2012): What catch data can tell us about the status of global fisheries. Marine Biology 159 (6), 1283.

Frommel, A. Y., Maneja, R., Lowe, D., Malzahn, A. M., Geffen, A. J., Folkvord, A., Piatkowski, U., Reusch, T. B. H. and Clemmesen, C. (2012): Severe tissue damage in Atlantic cod larvae under increasing ocean acidification. Nature Climate Change 2, 42–46.

FTD – Financial Times Deutschland (29.08.2012): Shtokman-Erdgasfeld. Gazprom gibt Arktis-Projekt auf. Frankfurt/M.: FTD.

Funge-Smith, S., Lindebo, E. and Staples, D. (2005): Asian Fisheries Today: The Production and Use of Low Value/Trash Fish from Marine Fisheries in the Asia-Pacific Region. Bangkok: FAO Regional Office for Asia and the Pacific.

Gaines, S. D., Gaylord, B. and Largier, J. (2003): Avoiding current oversights in marine reserve design. Journal of Applied Ecology 13, 32–64.

Gaines, S. D., White, C., Carr, M. H. and Palumbi, S. R. (2010): Designing marine reserve networks for both conservation and fisheries management. Proceedings of the National Academy of Sciences 107 (43), 18286–18293.

Galloway, J. N., Dentener, F., Capone, D. G., Boyer, E. W., Howarth, R. W., Seitzinger, S. P., Asner, G. P., Cleveland, C. C., Green, P. A., Holland, E. A., Karl, D. M., Michaelis, A. F., Porter, J. H., Townsend, A. R. and Vörösmarty, C. J. (2004): Nitrogen cycles: past, present, and future. Biogeochemistry 70, 153–226.

Gao, K., Xu, J., Gao, G., Li, Y., Hutchins, D. A., Huang, B., Wang, L., Zheng, Y., Jin, P., Cai, X., Häder, D.-P., Li, W., Xu, K., Liu, N. and Riebesell, U. (2012): Rising CO_2 and increased light exposure synergistically reduce marine primary productivity. Nature Climate Change 2, 519–523.

GAPI – Global Aquaculture Performance Index (2010): GAPI Global Aquaculture Performance Index. An Innovative Tool for Evaluating and Improving the Environmental Performance of Marine Aquaculture. Executive Summary. Saanich, BC: Seafood Ecology Research Group, University of Victoria.

Garcia, S. M. (2000): The FAO definition of sustainable development and the Code of Conduct for Responsible Fisheries: an analysis of the related principles, criteria and indicators. Marine Freshwater Resources 51, 535–541.

Garcia, S. M., Zerbi, A., Aliaume, C., Do Chi, T. and Lasserre, G. (2003): The Ecosystem Approach to Fisheries. Issues, Terminology, Principles, Institutional Foundations, Implementation and Outlook. FAO Fisheries Technical Paper No. 443. Rome: Food and Agriculture Organization (FAO).

Garibaldi, L. (2012): The FAO global capture production database: a six-decade effort to catch the trend. Marine Policy 36, 760–768.

Gauthier, M. (1997): Artificial upwellings and the controlled production of living resources. IOA Newsletter 8 (4), 5.

Gawel, E. (2011): Die Allmendeklemme und die Rolle der Institutionen. Oder: Wozu Märkte auch bei Tragödien taugen. Aus Politik und Zeitgeschichte 61 (28–30), 27–33.

Gazeau, F., Quiblier, C., Jansen, J. M., Gattuco, J.-P., Middelburg, J. J. and Heip, C. H. R. (2007): Impact of elevated CO_2 on shellfish calcification. Geophysical Research Letters 34, 5.

GCA – Global Conference in Aquaculture (2010a): Phuket Consensus: Farming the Waters for People and Food. A Re-Affirmation of Commitment to the Bangkok Declaration. Internet: http://www.aqua-conference2010.org/fileadmin/user_upload/gca/media/Phuket_Consensus_Final%20-%2013-12-10.pdf (viewed 13. November 2012). Phuket: GCA.

GCA – Global Conference in Aquaculture (2010b): Recommendations from the Thematic Sessions. Internet: http://www.aqua-conference2010.org/fileadmin/user_upload/gca/media/GCA%202010%20-%20Thematic%20Recommendations%20-%20Final%20-%2014-12-10.pdf (viewed 19. November 2012). Phuket: GCA.

GEA – Global Energy Assessment (2012): Global Energy Assessment – Toward a Sustainable Future. Cambridge, UK, Cambridge, New York: Cambridge University Press, Laxenburg: International Institute for Applied Systems Analysis (IIASA).

Gee, K., Kannen, A. and Heinrichs, B. (2011): Towards a Common Spatial Vision: Implication of the International and National Policy Context for Baltic Sea Space and MSP. BaltSeaPlan Report 8. Geesthacht: Helmholtz-Zentrum Geesthacht – Zentrum für Material- und Küstenforschung (GKSS).

GEF – Global Environment Facility (2012): Global Sustainable Fisheries Management and Biodiversity Conservation in the Areas Beyond National Jurisdiction (ABNJ) (FAO/UNEP/World Bank). Internet: http://www.thegef.org/gef/Ocean_Partnership_Fund (viewed 4. January 2013). Washington, DC: GEF.

GEF – Global Environment Facility (2013): Global Environmental Benefits. Internet: http://www.thegef.org/gef/GEB (viewed 24. January 2013). Washington, DC: GEF.

Gell, F. R. and Roberts, C. M. (2003): Benefits beyond boundaries: the fishery effects of marine reserves. Trends in Ecology and Evolution 18 (9), 448–455.

German Parliament (2012): Auswirkungen des Tiefseebergbaus auf die maritime Umwelt und Biodiversität. Antwort der Bundesregierung auf die Kleine Anfrage der Abgeordneten Oliver Krischer, Dr. Valerie Wilms, Krista Sager, weiterer Abgeordneter und der Fraktion Bündnis 90/Die Grünen – Drucksache 17/8753. Berlin: German Parliament.

Gianni, M. and Simpson, W. (2005): The Changing Nature of High Seas Fishing. How Flags of Convenience Provide Cover for Illegal, Unreported and Unregulated Fishing. Canberra, Australia: Australian Department of Agriculture, Fisheries and Forestry.

Gibbs, M. T. (2009): Implementation barriers to establishing a sustainable coastal aquaculture sector. Marine Policy 33, 83–89.

Gill, A. B. and Bartlett, M. (2010): Literature Review on the Potential Effects of Electromagnetic Fields and Subsea Noise from Marine Renewable Energy Developments on Atlantic Salmon, Sea Trout and European Eel. Scottish Natural Heritage Commissioned Report No. 401. Inverness: Scottish Natural Heritage.

Gill, M., Smith, P. and Wilkinson, J. M. (2010): Mitigating climate change: the role of domestic livestock. Animal 4 (3), 323–333.

Gilroy, P. (1993): Black Atlantic. Modernity and Double Consciousness. Harvard: Harvard University Press.

Gilroy, P. (2004): Between Camps. Nations, Cultures and the Allure of Race. London, New York: Routledge.

Gjerde, K. M. (2011): High seas governance: propects and challenges in the 21st century. In: Vidas, D. and Schei, P. J. (eds): The World Ocean in Globalisazion: Climate Change, Sustainable Fisheries, Biodiversity, Shipping, Regional Issues. Leiden, Boston: Martinus Nijhoff Publishers, 221–232.

Global Partnership for Oceans (2013): Partners for Action. The Global Partnership for Oceans. Internet: http://www.globalpartnershipforoceans.org/ (viewed 12. February 2013). Washington, DC: Global Partnership for Oceans.

Glover, A. G. and Smith, C. R. (2003): The deep seafloor ecosystem: current status and prospects for change by 2025. Environmental Conservation 30 (3), 1–23.

Glowka, L., Burhenne–Guilmin, F. and Synge, H., (1994): A Guide to the Convention on Biological Diversity. Gland, Cambridge: International Union for Conservation of Nature (IUCN).

Glowka, L. (2010): Evolving perspectives on the International Seabed Area's genetic resources: fifteen years after the 'deepest of ironies'. In: Vidas, D. (ed): Law, Technology and Science for Oceans in Globalisation. Leiden, Boston: Martinus Nijhoff Publishers, Brill, 397–419.

Goel, N. (2006): In situ methane hydrate dissociation with carbon dioxide sequestration: Current knowledge and issues. Journal of Petroleum Science and Engineering 51 (3–4), 169–184.

Gonzáles, E. (2008): Chile's national aquaculture policy: missing elements for the sustainable development of aquaculture. International Journal of Environment and Pollution 33 (4), 457–468.

Gordon, A. and Kassam, L. (2011): Aquaculture and Markets: A Research Agenda. Penang: The WorldFish Center.

Gordon, S. (1954): The economic theory of a common-property resource: the fishery. The Journal of Political Economy 62 (2), 124–142.

Gorina-Ysern, M., Gjerde, K. and Orbach, M. (2004): Ocean governance: a new ethos through a World Ocean Public Trust. In: Glover, L. K., Earle, S. A. and Kelleher, G. (eds): Defying the Ocean's End. An Agenda for Action. Washington, DC: Island Press, 197–212.

Graf Vitzthum, W. (2006): Handbuch des Seerechts. Munich: Beck.

Gray, L. J., Beer, J., Geller, M., Haigh, J. D., Lockwood, M., Matthes, K., Cubasch, U., Fleitmann, D., Harrison, G., Hood, L., Luterbacher, J., Meehl, G. A., Shindell, D., van Geel, B. and White, W. (2010): Solar influences on climate. Reviews of Geophysics 48 (4), 53.

Grebmeier, J. M., Moore, S. E., Overland, J. E., Frey, K. E. and Gradinger, R. (2010): Biological response to recent pacific Arctic sea ice retreats. Eos 91, 161–163.

Greenpeace (2009): Reality Check on Carbon Storage. Report 2009. Amsterdam: Greenpeace International.

Gregory, M. R. (2009): Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philosophical Transactions of the Royal Society B 364 (1526), 2013–2025.

Greve, J. and Heintz, B. (2005): Die 'Entdeckung' der Weltgesellschaft. Entstehung und Grenzen der Weltgesellschaftstheorie. Zeitschrift für Soziologie Sonderheft "Weltgesellschaft", 89–119.

Grobelaar, J. U. (2009): Factors governing algal growth in photobioreactors: the 'open' versus 'closed' debate. Journal of Applied Phycology 21 (5), 489–492.

Groth, M. (2010): Potentiale und Risiken der Nutzung von Methan aus Methanhydraten als Energieträger. Energiewirtschaft 34, 129–137.

Grozic, J. L. H. (2010): Interplay between gas hydrates and submarine slope failure. In: Mosher, D. C., Shipp, R. C., Moscardelli, L., Chaytor, J. D., Baxter, C. D. P., Lee, H. J. and Urgeles, R. (eds): Advances in Natural and Technological Hazards Research. Submarine Mass Movements and their Consequences. Volume 28. Dordrecht: Springer, 11–30.

Gruber, N. (2011): Warming up, turning sour, losing breath: ocean biogeochemistry under global change. Philosophical Transactions of the Royal Society A 369, 1980–1996.

Gruber, N., Hauri, C., Lachkar, Z., Loher, D., Frölicher, T. L. and Plattner, G.-K. (2012): Rapid progression of ocean acidification in the California current system. Science 337, 220–226.

Guinotte, J. M. and Fabry, V. J. (2008): Ocean acidification and its potential effects on marine ecosystems. Annals of the New York Academy of Sciences 1134, 320–342.

Guinotte, J. M., Orr, J. C., Cairns, S., Freiwald, A., Morgan, L. E. and George, R. (2006): Will human-induced changes in seawater chemistry alter the distribution of deep-sea sleractinian corals? Frontiers in Ecology and the Environment 4 (3), 141–146.

Gulbrandsen, L. H. (2009): The emergence and effectiveness of the Marine Stewardship Council. Marine Policy 33 (4), 654–660.

Gunaseelan, V. N. (1997): Anaerobic digestion of biomass for methane production: a review. Biomass and Bioenergy 13 (1–2), 83–114.

Gutiérrez, N. L., Hilborn, R. and Defeo, O. (2011): Leadership, social capital and incentives promote successful fisheries. Nature 470, 386–389.

Gutiérrez, N. L., Valencia, S. R., Branch, T. A., Agnew, D. J., Baum, J. K., Bianchi, P. L., Cornejo-Donoso, J., Costello, C., Defeo, O., Essington, T. E., Hilborn, R., Hoggarth, D. D., Larsen, A. E., Ninnes, C., Sainsbury, K., Selden, R. L., Sistla, S., Smith, A. D. M., Stern-Pirlot, A., Teck, S. J., Thorson, J. T. and Williams, N. E. (2012): Eco-Label conveys reliable information on fish stock health to seafood consumers. PLoS ONE 7 (8), e43765.

Guzmán, H. M., Guevara, C. A. and Castillo, A. (2003): Natural disturbances and mining of Panamanian coral reefs by indigenous people. Conservation Biology 17, 1–7.

Gwynn, J. P., Heldal, H. E., Gäfvert, T., Blinova, O., Eriksson, M., Sværen, I., Brungot, A. L., Stralberg, E., Møller, B. and Rudjord, A. L. (2012): Radiological status of the marine environment in the Barents Sea. Journal of Environmental Radioactivity 113, 155–162.

Ha, T. T. T., van Dijk, H. and Bush, S. R. (2012): Mangrove conservation or shrimp farmer's livelihood? The devolution of forest management and benefit sharing in the Mekong Delta, Vietnam. Ocean & Coastal Management 69, 185–193.

Haeckel, M. and Suess, E. (2011): Natürliche Gashydrate – künftige Energieträger oder Option zur CO_2-Speicherung? In: Zellner, R., Hoer, R. and Walter, G. (eds): Chemie über den Wolken… und darunter. Weinheim: Wiley-VCH, 65–70.

Hafner, G. (2006): Meeresumwelt, Meeresforschung und Technologietransfer. In: Graf Vitzthum, W. (ed): Handbuch des Seerechts. Munich: Beck, 347–460.

Hale, T. (2011): Marine Stewardship Council. In: Hale, T. and Held, D. (eds): The Handbook of Transnational Governance: Institutions and Innovations. London: Wiley, 307–314.

Hall, M. C. (2001): Trends in ocean and coastal tourism: the end of the last frontier. Ocean & Coastal Management 44, 601–618.

Hall, S. J., Delaporte, A., Phillips, M. J., Beveridge, M. and O'Keefe, M. (2011): Blue Frontiers: Managing the Environmental Costs of Aquaculture. Penang, Malaysia: The WorldFish Center.

Halpern, B. S., Lester, S. and McLeod, K. L. (2010): Placing marine protected areas onto the ecosystembased management seascape. Proceedings of the National Academy of Sciences 107 (43), 18312–18317.

Halpern, B. S., Longo, C., Hardy, D., McLeod, K. L., Samhouri, J. F., Katona, S. K., Kleisner, K., Lester, S. E., O'Leary, J., Ranelletti, M., Rosenberg, A. A., Scarborough, C., Selig, E. R., Best, B. D., Brumbaugh, D. R., Chapin, S. F., Crowder, L. B., Daly, K. L., Doney, S. C., Elfes, C., Fogarty, M. J., Gaines, S. D., Jacobsen, K. I., Karrer, L. B., Leslie, H. M., Neeley, E., Pauly, D., Polasky, S., Ris, B., St. Martin, K., Stone, G. S., Sumaila, R. U. and Zeller, D. (2012): An index to assess the health and benefits of the global ocean. Nature 488, 615–620.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R. and Watson, R. (2008): A global map of human impact on marine ecosystems. Science 319, 948–952.

Halwart, M. and Gupta, M. V. (eds) (2004): Culture of Fish in Rice Fields. Penang: The WorldFish Center (WFC).

Hammons, T. J. (1993): Tidal power. Proceedings of the IEE 81 (3), 419–433.

Hampton, I. (2003) Harvesting the sea. In: Molloy, F. and Reinikainen, T. (eds): Namibia's Marine Environment. Namibia: Directorate of Environmental Affairs, Ministry of Environment and Tourism, 31–69.

Hanley, N. and Barbier, E. B. (2009): Pricing Nature. Cost-Benefit Analysis and Environmental Policy. Cheltenham, Northampton, MA: Edward Elgar.

Hannington, M., Jamieson, J., Monecke, T., Petersen, S. and Beaulieu, S. (2011): The abundance of seafloor massive sulfide deposits. Geology 39 (12), 1155–1158.

Hanson, J. (2011): Netzintegration von Offshore Windparks mittels Hochspannungs-Gleichstrom-Übertragung. Munich: ABB AG.

Hardin, G. (1968): The tragedy of the commons. Science 162, 1243–1248.

Harris, P. G. (2010): World Ethics and Climate Change. From International to Global Justice. Edinburgh: Edinburgh University Press.

Harrison, H. B., Williamson, D. H., Evans, R. D., Almany, G. R., Thorrold, S. R., Russ, G. R., Feldheim, K. A., van Herwerden, L., Planes, S., Srinivasan, M., Berumen, M. L. and Jones, G. P. (2012): Larval export from marine reserves and the recruitment benefit for fish and fisheries. Current Biology 22 (11), 1023–1028.

Hasan, M. R. and Chakrabarti, R. (2009): Use of Algae and Aquatic Macrophytes as Feed in Small-Scale Aquaculture. A Review. FAO Technical Paper No. 531. Rome: Food and Agriculture Organization (FAO).

Hasan, M. R. and Halwart, M. (2009): Fish as Feed Inputs for Aquaculture. Practices, Sustainability and Implications. Rome: Food and Agriculture Organization (FAO).

Hatch Acres (2006): Potential Electromagnetic Field (EMF) Effects on Aquatic Fauna Associated with Submerged Electric Cables. Victoria, VA: Hatch Acres.

Hattingois-Forner, A.-M. (2013): L'Atlantique au XVIIIe siècle. Paris: Ellipses.

Haum, R., Petschow, U., Steinfeldt, M. and von Gleich, A. (2004): Nanotechnology and Regulation within the Framework of the Precautionary Principle. Schriftenreihe des IÖW 173/04. Berlin: Institut für Ökologische Wirtschaftsforschung (IÖW).

Hecht, T. and Jones, C. L. W. (2009): Use of wild fish and other aquatic organisms as feed in aquaculture – a review of practices and implications in Africa and the Near East. In: Hasan, M. R. and Halwart, M. (eds): Fish as Feed Inputs for Aquaculture: Practices, Sustainability and Implications. FAO Fisheries and Aquaculture Technical Paper No. 518. Rome: Food and Agriculture Organization (FAO), 129–157.

Hein, J. (2002): Cobalt-rich ferromanganese crusts: global distribution, composition, origin and reseearch activities. In: ISA – International Seabed Authority (ed): Polymetallic Massive Sulphides and Cobalt-Rich Ferromanganese Crusts: Status and Prospects. ISA Technical Study No. 2. Kingston, Jamaica: ISA, 36–89.

Hein, J. (2012): Prospects for Rare Earth Elements from Marine Minerals. International Seabed Authority Briefing Paper 02/12. Internet: http://www.isa.org.jm/files/documents/EN/Pubs/BP2.pdf (viewed 13. September 2012). Kingston, Jamaica: International Seabed Authority (ISA).

Heintz, P. (1974): Der heutige Strukturwandel der Weltgesellschaft in der Sicht der Soziologie. Universitas 29, 449–556.

Heiskanen, A.-S., van de Bund, W. and Cardoso, A. C. (2011): Marine Strategy Framework Directive: Experiences from the Water Framework Directive Implementation. Plouzané: IFREMER.

HELCOM – Helsinki Commission (2004): Measures Aimed at the Reduction of Discharges from Freshwater and Marine Fish Farming. HELCOM Recommendation 25/4. Internet: http://www.helcom.fi/Recommendations/en_GB/rec25_4/?u4.highlight=aquaculture (viewed 19. Febuary 2013). Helsinki: HELCOM.

HELCOM – Helsinki Commission (2007): Baltic Sea Action Plan. Internet: http://www.helcom.fi/stc/files/BSAP/BSAP_Final.pdf (viewed 19. February 2013). Helsinki: HELCOM.

HELCOM – Helsinki Commission (2008): Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992 (Helsinki Convention). Internet: http://www.helcom.fi/stc/files/Convention/Conv1108.pdf (viewed 19. February 2013). Helsinki: HELCOM.

Hendriks, C., Graus, W. and van Bergen, F. (2004): Global Carbon Dioxide Storage Potential and Costs. Utrecht: Rijksinstituut voor Volksgezondheid en Milieu.

Henriksen, T. (2009): Revisiting the freedom of fishing and legal obligations on states not party to regional fisheries management organizations. Ocean Development & International Law 40, 80–96.

Hernando, M. D., Vettori, S. D., Martínez Bueno, M. J. and Fernández-Alba, A. R. (2007): Toxicity evaluation with *Vibrio fischeri* test of organic chemicals used in aquaculture. Chemosphere 68 (4), 724–730.

Heymans, J. J., Mackinson, S., Sumaila, R., Dyck, A. and Little, A. (2011): The impact of subsidies on the ecological sustainability and future profits from North Sea fisheries. PLoS ONE 6 (5), 13.

Hilborn, R. (2007): Moving to sustainability by learning from successful fisheries. Ambio 36 (4), 296–303.

Hilborn, R. and Branch, T. A. (2013): Does catch reflect abundance? Counterpoint: no, it is misleading. Nature 494, 303–306.

Hilborn, R. and Hilborn, U. (2012): Overfishing. What Everyone Needs to Know. Oxford, New York: Oxford University Press.

Hilborn, R., Stokes, K., Maguire, J.-J., Smith, T., Botsford, L. W., Mangel, M., Orensanz, J., Parma, A. M., Rice, J. C., Bell, J. D., Cochrane, K. L., Garcia, S. M., Hall, S. J., Kirkwood, G. P., Sainsbury, K. J., Stefansson, G. and Walters, C. (2004): When can marine reserves improve fisheries management? Ocean & Coastal Management 47, 197–205.

Hishamunda, N., Cai, J. and Leung, P. (2009): Commercial Aquaculture and Economic Growth, Poverty Alleviation and Food Security. Assessment Framework. FAO Fisheries and Aquaculture Technical Paper No. 512. Rome: Food and Agriculture Organization (FAO).

Hishamunda, N., Ridler, N., Bueno, P., Satia, B., Kuemlangan, B., Percy, D., Gooley, G., Brugere, C. and Sen, S. (2012): Improving aquaculture governance: what is the status and options? In: FAO – Food and Agriculture Organization and NACA – Network of Aquaculture Centres in Asia-Pacific (eds): Farming the Waters for People and Food. Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand, 22–25 September 2010. Rome, Bangkok: FAO, NACA, 233–264.

Hoagland, P., Beaulieu, S., Tivey, M. A., Eggert, R. G., German, C., Glowka, L. and Lin, J. (2010): Deep-sea mining of seafloor massive sulfides. Marine Policy 34, 728–732.

Hoegh-Guldberg, H. (2011): Coral reef ecosystems and anthropogenic climate change. Regional Environmental Change 11 (1), 215–227.

Hoegh–Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., Harvell, C. D., Sale, P. F., Edwards, J., Caldeira, K., Knowlton, N., Eakin, C. M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R. H., Dubi, A. and Hatziolos, M. E. (2007): Coral reefs under rapid climate change and ocean acidification. Science 318, 1737–1742.

Höfer, T. and Mez, L. (2005): Effektivität der internationalen Umweltschutzabkommen zum Mineralöltransport auf See und daraus abgeleitete Vorschläge zur Politikrevision. Berlin: Environmental Policy Research Centre. Free University Berlin.

Hofmann, M. and Schellnhuber, H. J. (2009): Oceanic acidification affects marine carbon pump and triggers extended marine oxygen holes. Proceedings of the National Academy of Sciences 106 (9), 3017–3022.

Holland, P. R. and Kwok, R. (2012): Wind-driven trends in Antarctic sea-ice drift. Nature Geoscience 5, 872–875.

Holm, P., Marboe, A. H., Poulsen, B. and MacKenzie, B. R. (2010): Marine animal populations: a new look back in time. In: McIntyre, A. (ed): Life in the World's Oceans. Diversity, Distribution, and Abundance. Chichester, London: Wiley-Blackwell, 3–23.

Holmer, M. (2010): Environmental issues of fish farming in offshore waters: perspectives, concerns and research needs. Review. Aquaculture Environmental Interactions 1, 57–70.

Homer-Dixon, T. (2006): Catastrophe, Creativity, and the Renewal of Civilisation. Washington, DC: Souvenir Press.

Hönisch, B., Ridgwell, A., Schmidt, D. N., Thomas, E., Gibbs, S. J., Sluijs, A., Zeebe, R., Kump, L., Martindale, R. C., Greene, S. E., Kiessling, W., Ries, J., Zachos, J. C., Royer, D. L., Barker, S., Marchitto jr., T. M., Moyer, R., Pelejero, C., Ziveri, P., Foster, G. L. and Williams, B. (2012): The geological record of ocean acidification. Science 335, 1058–1063.

Hoogwijk, M. and Graus, W. (2008): Global Potential of Renewable Energy Sources: A Literature Assessment. Background Report. Berlin: Ecofys Germany.

Hosch, G., Ferraro, G. and Failler, P. (2011): The 1995 FAO Code of Conduct for Responsible Fisheries: adopting, implementing or scoring results? Marine Policy 35, 189–200.

Hossain, A. B. M. S. and Salleh, A. (2008): Biodiesel fuel production from algae as renewable energy. American Journal of Biochemistry and Biotechnology 4 (3), 250–254.

Howart, W. (2006): Global challenges in the regulation of aquaculture. In: van der Zwaag, D. and Chao, G. (eds): Aquaculture, Law and Policy. Towards Principled Access and Operations. London: Routledge, 13–36.

HSTF – High Seas Task Force (2005): Better High Seas Monitoring, Control, and Surveillance – An Improved Network. Paper Prepared for the Meeting of the High Seas Task Force, Paris, 9 March 2005. Paris: HSTF.

HSTF – High Seas Task Force (2006): Closing the Net. Stopping Illegal Fishing on the High Seas. Final Report of the Ministerially-Led Task Force on IUU Fishing on the High Seas. Governments of Australia, Canada, Chile, Namibia, New Zealand, and the United Kingdom, WWF, IUCN, and the Earth Institute at Columbia University. Paris: HSTF.

Huggings, L. E. (2011): Fencing Fisheries in Namibia and Beyond: Lessons from the Developing World. PERC Policy Series No. 49. Bozeman, MO: PERC.

Hughes, T. P., Rodrigues, M. J., Bellwood, D. R., Ceccarelli, D., Hoegh-Guldberg, H., McCook, L., Moltschaniwskyj, N., Pratchett, M. S., Steneck, R. S. and Willis, B. (2007): Phase shifts, herbivory, and the resilience of coral reefs to climate change. Current Biology 17, 360–365.

Humrich, C. (2011): Ressourcenkonflikte, Recht und Regieren in der Arktis : Das Seerechtsübereinkommen. Aus Politik und Zeitgeschichte 5–6, 6–13.

Hunt, B. and Vincent, A. C. J. (2006): Scale and sustainability of marine bioprospecting for pharmaceuticals. Ambio 35 (2), 57–64.

Hunt, B. P. V., Pakhomov, E. A., Hosie, G. W., Siegel, V. and Bernard, K. (2008): Pteropods in Southern Ocean ecosystems. Progress in Oceanography 78, 193–221.

Huntington, T. and Hasan, M. R. (2009): Fish as feed inputs for aquaculture – practices, sustainability and implications: a global synthesis. In: Hasan, M. R. and Halwart, M. (eds): Fish as Feed Inputs for Aquaculture: Practices, Sustainability and Implications. FAO Fisheries and Aquaculture Technical Paper No. 518. Rome: Food and Agriculture Organization (FAO), 1–61.

Huppert, H. E. and Turner, J. S. (1981): Double-diffuse convection. The Journal of Fluid Mechanics 106, 299–329.

Hüppop, O., Dierschke, J., Exo, K.-M., Fredrich, E. and Hill, R. (2006): Bird migration studies and potential collision risk with offshore wind turbines. Ibis 148, 90–109.

IBRU – International Boundaries Research Unit (2013): Maritime Jurisdiction and Boundaries in the Arctic Region. Internet: https://www.dur.ac.uk/ibru/resources/arctic/ (viewed 17. February 2013). Durham: IBRU, Durham University.

ICES – International Council for the Exploration of the Sea (2000): Report of the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem. Gdansk, Poland, 11–14 April 2000. CM 2000/E:07. Ref.: ACME. Copenhagen: ICES Marine Habitat Committee.

ICES – International Council for the Exploration of the Sea (2004): ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2004. Internet: http://www.ices.dk/reports/general/2004/ICESCOP2004.pdf (viewed 19. November 2012). Copenhagen: ICES.

ICES – International Council for the Exploration of the Sea (2012a): Report of the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT). 16–20 April 2012, Rouen, France. Copenhagen: ICES.

ICES – International Council for the Exploration of the Sea (2012b): Report of the Study Group on Socio-Economic Dimensions of Aquaculture (SGSA), 24–26 April 2012, Stockholm, Sweden. Stockholm: ICES.

ICES WGMASC – International Council for the Exploration of the Sea – Working Group on Marine Shellfish Culture (2011): Report of the Working Group on Marine Sellfish Culture. Paris: ICES.

ICSU – International Council for Science (2010): Earth System Science for Global Sustainability: The Grand Challenges. Paris: ICSU.

IEA – International Energy Agency (2005): Resources to Reserves – Oil and Gas Technologies for the Energy Markets of the Future. Press Release. Internet: http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=159 (viewed 10. November 2011). Paris: IEA.

IEA – International Energy Agency (2008): World Energy Outlook 2008. Paris: IEA.

IEA – International Energy Agency (2009a): Annual Report 2009: Ocean Energy Systems Implementing Agreement (OES-IA) on Ocean Energy Systems. Paris: IEA.

IEA – International Energy Agency (2009b): Technology Roadmap: Wind Energy. Paris: IEA.

IEA – International Energy Agency (2010): Annual Report 2010: Ocean Energy Systems Implementing Agreement (OES-IA) on Ocean Energy Systems. Paris: IEA.

IEA – International Energy Agency (2011a): World Energy Outlook 2011. Special Report: Are we Entering a Golden Age of Gas? Paris: IEA.

IEA – International Energy Agency (2011b): World Energy Outlook 2011. Paris: IEA.

IEA – International Energy Agency (2012): World Energy Outlook 2012. Paris: IEA.

IEA ETSAP – International Energy Agency – Energy Technology Systems Analysis Programme (2010): Marine Energy. Technology Brief E13. Paris: IEA ETSAP.

IEA RETD – International Energy Agency – Renewable Energy Technology Development (2011): Accelerating the Deployment of Offshore Renewable Energy Technologies. Final Report. Paris: IEA-RETD.

IFAW – International Fund for Animal Welfare (2008): Ocean Noise: Turn it Down. A Report on Ocean Noise Pollution. Internet: http://www.ifaw.org/sites/default/files/Ocean%20Noise%20Pollution%20Report.pdf (viewed 12. February 2012). Yarmouth Port, MA: IFAW.

IMF – International Monetary Fund (2012): Data on World Gross Domestic Product 1991–2011. World Economic Outlook Database. Washington, DC: IWF.

Imhoff, J. F., Labes, A. and Wiese, J. (2011): Bio-mining the microbial treasures of the ocean: new natural products. Biotechnology Advances 29, 468–482.

IMO – International Maritime Organisation (2005): IMO Resolution A.982(24) of 1. December 2005. London: IMO.

IMO – International Maritime Organisation (2011): Member States, IGOs and NGOs. Internet: http://www.imo.org/About/Membership/Pages/Default.aspx (viewed 30. March 2012). London: IMO.

IMO – International Maritime Organization (2013a): What exactly is IMO? Internet: http://www.imo.org/About/Pages/FAQs.aspx (viewed 22. February 2013). London: IMO.

IMO – International Maritime Organization (2013b): Prevention of Pollution by Garbage from Ships. Overview of Annex V. Internet: http://www.imo.org/OurWork/Environment/PollutionPrevention/Garbage/Pages/Default.aspx (viewed 23. February 2013). London: IMO.

IMO – International Maritime Organization (2013c): Particularly Sensitive Sea Areas. Internet: http://www.imo.org/OurWork/Environment/pollutionprevention/pssas/Pages/Default.aspx (viewed 12. February 2013). London: IMO.

IMO – International Maritime Organization (2013d): Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. Internet: http://www.imo.org/About/Conventions/ListOfConventions/Pages/Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter.aspx (viewed 24. January 2013). London: IMO.

Inger, R., Attrill, M. J., Bearhop, S., Broderick, A. C., Grecian, W. J., Hodgson, D. J., Mills, C., Sheehan, E., Votier, S. C., Witt, M. J. and Godley, B. J. (2009): Marine renewable energy: potential benefits to biodiversity? An urgent call for research. Journal of Applied Ecology 46 (6), 1145–1153.

Ingimundarson, V. (2011): Die Kartierung der Arktis: Bodenschätze, Großmachtpolitik und multilaterale Governance. Aus Politik und Zeitgeschichte 5–6, 14–23.

International Sustainability Unit (2012): Towards Global Sustainable Fisheries. The Opportunity for Transition. London: The Prince's Charities' International Sustainability Unit.

Interpol (2013): Project Scale. An Interpol Initiative to Detect, Suppress and Combat Fisheries Crime. Lyon: Interpol General Secretariat.

IOC – Intergovernmental Oceanographic Commission (2009): Marine Spatial Planning. A Step-by-Step Approach Toward Ecosystem-Based Management. Paris: IOC.

IOC – Intergovernmental Oceanographic Commission, UNESCO – United Nations Educational Scientific and Cultural Organization, IMO – International Maritime Organization, FAO – Food and Agriculture Organization and UNDP – United Nations Development Programme (2011): A Blueprint for Ocean and Coastal Sustainability. Paris: IOC, UNESCO.

IPCC – Intergovernmental Panel on Climate Change (2000): Emissions Scenarios. A Special Report of Working Group III of IPCC. Cambridge, New York: Cambridge University Press.

IPCC – Intergovernmental Panel on Climate Change (2005): Carbon Dioxide Capture and Storage. IPCC Special Report prepared by Working Group III. Cambridge, New York: Cambridge University Press.

IPCC – Intergovernmental Panel on Climate Change (2011): Special Report on Renewable Energy Sources and Climate Change Mitigation. Working Group III of the Intergovernmental Panel on Climate Change. Cambridge, New York: Cambridge University Press.

IPCC – Intergovernmental Panel on Climate Change (2013): 2013 Supplement to 2006 IPCC Guidelines for National Gas Inventories: Wetlands. Internet: http://www.ipcc-nggip.iges.or.jp/home/docs/1105_WetlandsToC.pdf (viewed 24. January 2013). Geneva: IPCC.

Isaacs, J. D. and Seymour, R. J. (1973): The ocean as a power resource. International Journal of Environmental Studies 43 (3), 201–205.

ISE – Fraunhofer Institute for Solar Energy Systems (2012): Studie Stromgestehungskosten erneuerbare Energien. Freiburg: ISE.

Islam, M. S. and Tanaka, M. (2004): Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. Marine Pollution Bulletin 48, 624–649.

Issar, A. S. and Neori, A. (2010): Progressive development of new marine environments – IMTA (Integrated Multi-Trophic Aquaculture) production. In: Israel, A., Einav, R. and Seckbach, J. (eds): Seeweeds and their Role in Globally Changing Environments. Berlin, Heidelberg: Springer, 305–318.

ISSC – International Social Science Council (2012): Transformative Cornerstones of Social Science Research for Global Change. Paris: ISSC.

ITLOS – International Tribunal for the Law of the Sea (2011): Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area – Advisory Opinion. New York: ITLOS.

ITLOS – International Tribunal for the Law of the Sea (2013): List of Cases. Internet: http://www.itlos.org/index.php?id=35 (viewed 24. February 2013). New York: ITLOS.

IUCN – International Union for Conservation of Nature (2007): Guide for the Sustainable Development of Mediterranean Aquaculture. Interactions between Aquaculture and the Environment. Gland: IUCN.

IWES – Fraunhofer Institute for Wind Energy and Energy System Technology (2012): Windenergie Report Deutschland 2011. Kassel: IWES.

IZT – Institute for Future Studies and ISI – Fraunhofer Institute for Systems and Innovation Research (2009): Rohstoffe für Zukunftstechnologien. Einfluss des branchenspezifischen Rohstoffbedarfs in rohstoffintensiven Zukunftstechnologien auf die zukünftige Rohstoffnachfrage. Karlsruhe, Berlin: IZT, ISI.

Jackson, J. (2008): Ecological extinction and evolution in the brave new ocean. Proceedings of the National Academy of Sciences 105 (Supplement 1), 114458–111465.

Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Erlandson, J., Estes, J. A., Hughes, T. P., Kidwell, S., Lange, C. B., Lenihan, H. S., Pandolfi, J. M., Peterson, C. H., Steneck, R. S., Tegner, M. J. and Warner, R. R. (2001): Historical overfishing and the recent collapse of coastal ecosystems. Science 293, 629–638.

Jacobson, M. Z. (2008): Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science 2, 148–173.

Jacquet, J. and Pauly, D. (2008): Funding priorities: big barriers to small-scale fisheries. Conservation Biology 22 (4), 832–835.

Jacquet, J., Pauly, D., Ainley, D., Holt, S., Dayton, P. and Jackson, J. (2010): Seafood stewardship in crisis. Nature 467, 28–29.

Jahan, K. M., Ahmed, M. and Belton, B. (2010): The impacts of aquaculture development on food security: lessons from Bangladesh. Aquaculture Research 41 (4), 481–495.

Jahnke, R. A. (1996): The global ocean flux of particulate organic carbon: areal distribution and magnitude. Global Biogeochemical Cycles 10, 71–88.

Jeffrey, C. F. G., Leeworthy, V. R., Monaco, M. E., Piniak, G. and Fonseca, M. (2012): An Integrated Biogeographic Assessment of Reef Fish Populations and Fisheries in Dry Tortugas:Effects of No-take Reserves. NOAA Technical Memorandum NOS NCCOS 111. Silver Spring, MD: NOAA NCCOS Center for Coastal Monitoring and Assessment.

Jenisch, U. (2008): Seerecht und Klimawandel. Natur und Recht 30 (4), 227–237.

Jenisch, U. (2010): Renaissance des Meeresbodens – mineralische Rohstoffe und Seerecht. Zeitschrift für Öffentliches Recht in Norddeutschland Part I and Part II, 373–382 and 429–433.

Jennings, S. and Kaiser, M. J. (1998): The effects of fishing on marine ecosystems. Advances in Marine Biology 34, 201–212.

Jensen, O. P., Branch, T. A. and Hilborn, R. (2012): Marine fisheries as ecological experiments. Theoretical Ecology 5, 3–22.

Jessen, H. (2012): Staatenverantwortlichkeit und seevölkerrechtliche Haftungsgrundsätze für Umweltschäden durch Tiefseebergbau. Zeitschrift für Umweltrecht 2, 71–81.

Johansen, L. H., Jensen, I., Mikkelsen, H., Bjorn, P. A., Jansen, P. A. and Bergh, O. (2011): Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway. Aquaculture 315 (3–4), 167–186.

Johnston, P. F. (2010): Arctic energy resources and global energy security. Journal of Military and Strategic Studies 12 (2), 22.

Jünemann, A. (2012): Vorerst gescheitert: Perspektiven einer glaubwürdigen EU-Mittelmeerpolitik nach dem Arabischen

Frühling. Proteste und Potentaten – Die arabische Welt im Wandel. Der Bürger im Staat 62, 64–72.

Jungclaus, J. H., Lorenz, S. J., Timmreck, C., Reick, C. H., Brovkin, V., Six, K., Segschneider, J., Girogetta, M. A., Crowley, T. J., Pongratz, J., Krivova, N. A., Vieira, L. E., Solanki, S. K., Klocke, D., Botzet, M., Esch, M., Gayler, V., Haak, H., Raddatz, T. J., Roeckner, E., Schnur, R., Widmann, H., Claussen, M., Stevens, B. and Marotzke, J. (2010): Climate and carbon cycle variability over the last millennium. Climate of the Past 6, 723–737.

K+S (2013): Die weltweiten Salzvorkommen. Internet: http://www.k-plus-s.com/de/wissen/rohstoffe/salzvorkommen.html (viewed 24. January 2013). Kassel: K+S.

Kabel, K., Moros, M., Porsche, C., Neumann, T., Adolphi, F., Joest Andersen, T., Siegel, H., Gerth, M., Leipe, T., Jansen, E. and Damsté, J. S. S. (2012): Impact of climate change on the Baltic Sea ecosystem over the past 1,000 years. Nature Climate Change 2, 871–874.

Kaczynski, V. and Fluharty, D. L. (2002): European policies in West Africa: who benefits from fisheries agreements? Marine Policy 26, 75–93.

Kahn, A. U., Sumaila, R., Watson, R., Teydemers, P. and Pauly, D. (2006): The nature and magnitude of global non-fuel fisheries subsidies. In: Sumaila, R. and Pauly, D. (eds): Catching more Bait: A Bottom-up Re-estimation of Global Fisheries Subsidies. Fisheries Centre Research Report Vancouver: University of British Columbia, 5–37.

Kaiser, M. J. and Edwards-Jones, G. (2006): The role of ecolabeling in fisheries management and conservation. Conservation Biology 20 (2), 392–398.

Kalaidijian, W. (2010): Fishing for solutions: the European Union's fisheries partnership agreements with West African coastal states and the call for effective regional oversight in an exploited ocean. Emory International Law Review 24, 389–431.

Kalfagianni, A. and Pattberg, P. (2013): Fishing in muddy waters: Exploring the conditions for effective governance of fisheries and aquaculture. Marine Policy 38, 124–132.

Kampachi Farms (2011): Further and Deeper – Developing Technology for Next-Generation Mariculture. Internet: http://www.kampachifarm.com/offshore.html (viewed 25. February 2013). Kailua-Kona, HI: Kampachi Farms.

Karl, D. M. and Letelier, R. M. (2008): Nitrogen fixation-enhanced carbon sequestration in low nitrate, low chlorophyll seascapes. Marine Ecology Progress Series 364, 257–268.

Katsanevakis, S. (2008): Marine Debris, a Growing Problem: Sources, Distribution, Composition, and Impacts. In: Hofer, T. N. (ed): Marine Pollution New Research. New York: Nova Science Publishers, 53–100.

Kaul, I., Grunberg, I. and Stern, M. A. (eds) (1999): Global Public Goods. International Cooperation in the 21st Century. Oxford, New York: Oxford University Press.

Kawarazuka, N. and Béné, C. (2010): Linking Small-scale fisheries and aquaculture to household nutritional security: an overview. Food Security 2, 343–357.

Keeling, R. F., Körtzinger, A. and Gruber, N. (2010): Ocean deoxygenation in a warming world. Annual Review of Marine Science 2, 199–229.

Kelleher, K. (2005): Discards in the World's Marine Fisheries. An Update. FAO Fisheries Technical Paper No. 470. Rome: Food and Agriculture Organization (FAO).

Kemp, A. C., Horton, B. P., Donnelly, J. P., Mann, M. E., Vermeer, M. and Rahmstorf, S. (2011): Climate related sea-level variations over the past two millennia. Proceedings of the National Academy of Sciences 108 (27), 11017–11022.

Kennedy, H., Beggins, J., Duarte, C. M., Fourqurean, J. W., Holmer, M., Marbã, N. and Middelburg, J. J. (2010): Seagrass sediments as a global carbon sink: isotopic constraints. Global Biogeochemical Cycles 24, 8.

Kent, G. (2003): Fish trade, food security and the human right to adequate food. In: FAO – Food and Agriculture Organization (ed): Report of the FAO Expert Consultation on International Fish Trade and Food Security. Casablanca, Morocco, 27–30 January 2003. FAO Fisheries Report No. 708. Rome: Food and Agriculture Organization (FAO), 49–70.

Kenyon, K. E. (2007): Upwelling by a wave pump. Journal of Oceanography 63, 327–331.

Kerr, D. (2007): Marine energy. Philosophical Transactions of the Royal Society A 365 (1853), 971–992.

Kerr, R. A. (2012): Technology is turning U.S. oil around but not the world's. Science 335, 522–523.

Khan, J. and Bhuyan, G. (2009): Ocean Energy: Global Technology Development Status Report. Paris: IEA.

Khatiwala, S., Tanhua, T., Fletcher, S. M., Gerber, M., Doney, S. C., Graven, H. D., Gruber, N., McKinley, G. A., Murata, A., Rios, A. F., Sabine, C. L. and Sarmiento, J. L. (2012): Global ocean storage of anthropogenic carbon. Biogeosciences 9, 8931–8988.

Kim, R. E. (2012): Is a new multilateral environmental agreement on ocean acidification necessary? RECIEL 21 (3), 243–258.

Kim, T. G. and Grigalunas, T. (2009): Simulating direct and indirect damages to commercial fisheries from marine sand mining: a case study in Korea. Environmental Management 44 (3), 566–578.

Kimbal, L. (2001): International Ocean Governance, Using International Law and Organisations to Manage Marine Resources Sustainably. Gland: International Union for Conservation of Nature (IUCN).

King, S. C. and Pushchak, R. (2008): Incorporating cumulative effects into environmental assessments of mariculture: Limitations and failures of current siting methods. Environmental Impact Assessment Review 28, 572–586.

Kirby, R. and Retière, C. (2009): Comparing environmental effects of Rance and Severn barrages. Proceedings of the ICE – Water and Maritime Engineering 162, 11–26.

Kirke, B. (2003): Enhancing fish stocks with wave-powered artificial upwelling. Ocean & Coastal Management 46, 901–915.

Klaer, N. L. (2004): Abundance indices for main commercial fish species caught by trawl from the south-eastern Australian continental shelf from 1918–1957. Marine and Freshwater Research 55 (6), 561–571.

Klein, R. A. (2009): Getting a Grip on Cruise Ship Pollution. Report Prepared for Friends of the Earth. Washington, DC: Friends of the Earth.

Kloepfer, M. (2004): Umweltrecht. Munich: Beck.

Knowlton, N. (2008): Coral reefs. Current Biology 18 (1), R18–R21.

Koivurova, T. and Hossain, K. (2008): Offshore Hydrocarbon: Currrent Policy Context in the Marine Arctic. Rovaniemi: Arctic Centre.

Kongkeo, H. and Davy, F. B. (2010): Backyard hatcheries and small scale shrimp and prawn farming in Thailand. In: de Silva, S. S. and Davy, F. B. (eds): Success Stories in Asian Aquaculture. Berlin, Heidelberg: Springer, 67–85.

König, D. (1990): Durchsetzung internationaler Bestands- und Umweltschutzvorschriften auf hoher See im Interesse der Staatengemeinschaft. Berlin: Dunker & Humblot.

König, D. (2002): The enforcement of the International Law of the Sea by coastal and port states. Zeitschrift für ausländisches öffentliches Recht und Völkerrecht 62, 1–15.

Kortsch, S., Primicerio, R., Beuchel, F., Renaud, P. E., Rodrigues, J., Lonne, O. J. and Gulliksen, B. (2012): Climate-driven regime shifts in Arctic marine benthos. Proceedings of the National Academy of Sciences (early edition), 6.

Koschinski, S. and Lüdemann, K. (2011): Stand der Entwicklung schallmindernder Maßnahmen beim Bau von Offshore-Windenergieanlagen. Vilm: Federal Agency for Nature Conservation (BfN).

KPMG (2010): Offshore-Windparks in Europa. Marktstudie 2010. Berlin: KPMG AG Wirtschaftsprüfungsgesellschaft.

Kraan, S. (2010): Mass Production of Macroalgae, Opportunities for Value Added Ingredients from Protein to Phosphate. Algal Biomass Summit. Phoenix, AZ: Doty Energy.

Krause, G. (2010): The geography of the Braganca coastal region. In: Schneider, H. and Saint-Paul, U. (eds): Mangrove Dynamics and Management in North Brazil. Ecological Studies Volume 211. Berlin, Heidelberg: Springer, 19–34.

Krewitt, W. (2009): Role and Potential of Renewable Energy and Energy Efficiency for Global Energy Supply (UBA-FB, 001323/E). Dessau: Federal Environment Agency (UBA).

Krey, V., Canadell, J. G., Nakicenovic, N., Abe, Y., Andruleit, H., Archer, D., Grubler, A., Hamilton, N. T., Johnson, A., Kostov, V., Lamarque, J.-F., Langhome, N., Nisbet, E. G., O'Neill, B., Riahi, K., Riedel, M., Wang, W. and Yakushev, V. (2009): Gas hydrates: entrance to a methane age or climate threat? Environmental Research Letters 4, 7.

Kuhn, T., Rühlemann, C., Wiedicke-Hombach, M., Barckhausen, U., Schwarz-Schampera, U., Rutkowski, J. and Lehmann, S. (2010): New Insights of Mn Nodule Exploration from the German License Area in the Pacific Manganese Nodule Belt. Proceedings of the Underwater Mining Institute. Honolulu, HI Underwater Mining Institute (UMI).

Kuhn, T., Rühlemann, C., Wiedicke-Hombach, M., Rutkowski, J. and Lehmann, S. (2011): Tiefseeförderung von Manganknollen. Schiff & Hafen 5, 78–83.

Kullnick, U. and Marhold, S. (2004): Direkte oder indirekte biologische Wirkungen durch magnetische und/oder elektrische Felder im marinen (aquatischen) Lebensraum: Überblick über den derzeitigen Erkenntnisstand. Part I. In: Merck, T. and von Nordheim, H. (eds): Technische Eingriffe in marine Lebensräume. Tagungsband. Vilm: Federal Agency for Nature Conservation (BfN), 4–18.

Kumara, P. B. T. P., Cumaranathunga, P. R. T. and Lindén, O. (2005): Bandaramulla reef of Southern Sri-Lanka: present status and impacts of coral mining. In: Souter, D. and Lindén, O. (eds): Coral Reef Degradation in the Indian Ocean. Status Report 2005. Gland: International Union for Conservation of Nature (IUCN), 233–242.

Kupperman, K. O. (2012): The Atlantic in World History. Oxford, New York: Oxford University Press.

Kurien, J. (1998): Small-scale fisheries in the context of globalisation. Thiruvananthapuram: Centre for Development Studies.

Kvamme, B., Kuznetsova, T., Hebach, A., Oberhof, A. and Lunde, E. (2007): Measurements and modeling of interfacial tension for water and carbon dioxide systems at elevated pressures. Computational Materials Science 38, 506–513.

Kvenvolden, K. A. (1993): Gas hydrates as a potential energy resource – a review of their methane content. In: Howell, D. G. (ed): The Future of Energy Gases. U.S. Geological Survey Professional Paper 1570. Washington, DC: United States Government Printing Office, 555–561.

Lack, M. and Sant, G. (2006): Confronting Shark Conservation Head On! A Traffic Report. Cambridge, UK: Traffic International.

Laffoley, D. and Grimsditch, G. D. (2009): The Management of Natural Coastal Carbon Sinks. Gland: International Union for Conservation of Nature (IUCN).

Lagoni, R. (2007): Seerecht und Meeresnutzung im Wandel. Zeitschrift für Transportrecht 1, 1–5.

Lampitt, R. S., Achterberg, E. P., Anderson, T. R., Hughes, J. A., Iglesias-Rodriguez, M. D., Kelly-Gerreyn, B. A., Lucas, M., Popova, E. E., Sanders, R., Shepherd, J. G., Smythe-Wright, D. and Yool, A. (2008): Ocean fertilisation: a potential means of geo-engineering? Philosophical Transactions of the Royal Society 366 (1882), 3919–3945.

Landeck Miller, R. E. and Wands, J. R. (2009): Applying the System Wide Eutrophication Model (SWEM) for a Preliminary Quantitative Evaluation of Biomass Harvesting as a Nutrient Control Strategy for Long Island Sound. New Jersey: HydroQual.

Larkin, P. A. (1977): An Epitaph for the concept of maximum sustainable yield. Transactions of the American Fisheries Society 106 (1), 11.

Law, K. L., Morét-Ferguson, S., Maximenko, N. A., Proskurowski, G., Peacock, E. E., Hafner, J. and Reddy, C. M. (2010): Plastic accumulation in the North Atlantic subtropical gyre. Science 329, 1185–1188.

Laxon, S. W., Giles, K. A., Ridout, A. L., Wingham, D. J., Willatt, R., Cullen, R., Kwok, R., Schweiger, A., Zhang, J., Haas, C., Hendricks, S., Krishfield, R., Kurtz, N., Farrell, S. and Davidson, M. (2013): CryoSat-2 estimates of Arctic sea ice thickness and volume. Geophysical Research Letters 40, 732–737.

LCICG – Low Carbon Innovation Coordination Group (2012): Technology Innovation Needs Assessment (TINA). Offshore Wind Power Summary Report. London: LCICG.

Le Manach, F., Gough, C., Harris, A., Humber, F., Harper, S. and Zeller, D. (2012): Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36, 218–225.

Le Quére, C., Raupach, M. R., Canadell, J. G. and Marland, G. (2009): Trends in the sources and sinks of carbon dioxide. Nature Geoscience 2, 831–836.

Leaman, K. D., Molinari, R. L. and Vertes, P. S. (1987): Structure and variability of the Florida Current at 27°N. Journal of Physical Oceanography 17, 565–583.

Leary, D. (2012): Moving the marine genetic resources debate forward: some reflections. The International Journal of Marine and Coastal Law 27, 435–448.

Leary, D., Vierros, M., Hamon, G., Arico, S. and Monagle, C. (2009): Marine genetic resources: a review of scientific and commercial interest. Marine Policy 33, 183–194.

Leggewie, C. (2001): Das Erasmus-Programm. Gibt es eine transnationale Bürgergesellschaft? In: Leggewie, C. and Münch, R. (eds): Politik im 21. Jahrhundert. Frankfurt/M.: Suhrkamp, 458–479.

Leggewie, C. (2003): Die Globalisierung und ihre Gegner. Munich: Beck.

Leggewie, C. (2012): Zukunft im Süden. Wie die Mittelmeerunion Europa wiederbeleben kann. Hamburg: Körber Stiftung.

Leinfelder, R. (2013): Verantwortung für das Anthropozän übernehmen. Ein Auftrag für neuartige Bildungskonzepte. In: Vogt, M., Ostheimer, J. and Uekötter, F. (eds): Wo steht die Umweltethik? Argumentationsmuster im Wandel. Beiträge zur sozialwissenschaftlichen Nachhaltigkeitsforschung. Volume 5. Marburg: Metropolis.

Leinfelder, R. R., Seemann, J., Heiss, G. A. and Struck, U. (2012): Could 'Ecosystem Atavisms' Help Reefs to Adapt to the Anthropocene? Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia, 9–13 July 2012. 2B Coral Reefs: Is the Past the Key to the Future? Internet: http://www.icrs2012.com/proceedings/manuscripts/ICRS2012_2B_2.pdf (viewed 24. January 2013). Brisbane: ICRS2012 Secretariat.

Lester, S. E., Halpern, B. S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B. I., Gaines, S. D., Airamé, S. and Warner, R. R. (2009): Biological effects within no-take marine reserves: a global synthesis. Marine Ecology Progress Series 384, 33–46.

Leutz, R., Akisawa, A. and Kashiwagi, T. (2001): World-Wide Offshore Wind Energy Potentials Derived from Satellite Wind Speed Measurements and Ocean Bathymetry. In: Proceedings of Second International Workshop on Transmission Networks for Offshore Wind Farms, March 2001, Stockholm, Sweden. Stockholm: Royal Institute of Technology.

Lewis, A., Estefen, S., Huckerby, J., Musial, W., Pontes, T. and Torres-Martinez, J. (2011): Ocean energy. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge, New York: Cambridge University Press, 497–534.

Lewis, K. A., Tzilivakis, J. and Warner, D. (2010): Final Report for Defra Projekt FO0419: Effective Approaches to Environmental Labelleing of Food Products. Hertfordshire: University of Hertfordshire Agriculture and Environment Research Unit, Science and Technology Research Institute.

Liang, N.-K. and Peng, H.-K. (2005): A study of air-lift artificial upwelling. Ocean Engineering 32, 731–745.

Liu, C. C. K., Dai, J. J., Lin, H. and Guo, F. (1999): Hydrodynamic performance of wave-driven artificial upwelling device. Journal of Engineering Mechanics July, 728–732.

Liu, C. P. (1999): Research on artificial upwelling and mixing at the University of Hawaii at Manoa. IOA Newsletter 10 (4), 1–8.

Livingston, H. D. and Povinec, P. P. (2000): Anthropogenic marine radioactivity. Ocean & Coastal Management 43, 689–712.

Lloyd's (2012): Arctic Opening: Opportunity and Risk in the High North. London: Chatham House.

Lodge, M., Anderson, D., Lobach, T., Munro, G., Sainsbury, K. and Willock, A. (2007): Recommended Best Practice for Regional Fisheries Management Organizations. Report of an Independent Panel to Develop a Model for Improved Governance by Regional Fisheries Management Organizations. London: Chatham House.

Lohbeck, K. T., Riebesell, U. and Reusch, T. B. H. (2012): Adaptive evolution of a key phytoplankton species to ocean acidification. Nature Geoscience 5, 346–351.

Lohmann, D. (2012): Salz – vom Luxusgut zum Massenprodukt. Im Fokus: Bodenschätze. Berlin, Heidelberg: Springer.

Lohmann, R., Breivik, K., Dachs, J. and Muir, D. (2007): Global fate of POPs: current and future research directions. Environmental Pollution 150, 150–165.

Long, D., Lovell, M. A., Rees, J. G. and Rochelle, C. A. (2009): Sediment-hosted gas hydrates: new insights on natural and synthetic systems. Geological Society, London, Special Publications 319, 1–9.

Long Island Sound (2013): Long Island Sound Study Action Agenda: 2011–2013. Stamford, CT: EPA Long Island Sound Office.

Lorenz, E. N. (1967): The Nature and the Theory of the General Circulation of the Atmosphere. Geneva: World Meteorological Organization (WMO).

Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., Kidwell, S., Kirby, M. X., Peterson, C. H. and Jackson, J. B. C. (2006): Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312, 1806–1809.

Lovelock, J. E. and Rapley, C. G. (2007): Ocean pipes could help the Earth to cure itself. Nature 449, 1.

Lu, X., McElroy, M. and Kiviluoma, J. (2009): Global potential for wind-generated electricity. Proceedings of the National Academy of Sciences 106 (27), 10933–10938.

Lübbert, D. (2005): Das Meer als Energiequelle – Wellenkraftwerke, Osmose-Kraftwerke und weitere Perspektiven der Energiegewinnung aus dem Meer. Wissenschaftliche Dienste des Deutschen Bundestags. INFO-BRIEF WF VIII–116. Berlin: German Bundestag.

Lucke, K., Lepper, P. A., Blanchet, M.-A. and Siebert, U. (2009): Temporary shift in masked hearing thresholds in a harbor porpoise *(Phocoena phocoena)* after exposure to seismic airgun stimuli. Journal of the Acoustical Society of America 125 (6), 4060–4070.

Luhmann, N. (1975): Die Weltgesellschaft. Soziologische Aufklärung 2, 51–71.

Luk, S. and Ryrie, R. (2010): Legal Background Paper: Environmental Regulation of Oil Rigs in EU Waters and Potential Accidents. London: Client Earth.

Lundquist, T. J., Woertz, I. C., Quinn, N. W. and Benemann, J. R. (2010): A Realistic Technology and Engineering Assessment of Algae Biofuel Production. Berkeley: Energy Biosciences Institute EBI.

MA – Millennium Ecosystem Assessment (2005a): Volume I: Ecosystems and Human Well–Being. Current State and Trends. Washington, DC: Island Press.

MA – Millennium Ecosystem Assessment (2005b): Volume III: Ecosystems and Human Well-Being. Policy Responses. Washington, DC: Island Press.

Ma, J., Hung, H., Tian, C. and Kallenborn, R. (2011): Revolatilization of persistent organic pollutants in the Arctic induced by climate change. Nature Climate Change 1, 256–260.

MacArtain, P., Gill, C. I. R., Brooks, M., Campbell, R. and Rowland, I. R. (2007): Nutritional value of edible seaweeds. Nutrition Reviews 65 (12), 535–543.

MacKenzie, B. R., Mosegaard, H. and Rosenberg, A. A. (2008): Impending collapse of bluefin tuna in the northeast Atlantic and Mediterranean. Conservation Letters 2, 25–34.

Mackenzie, F. T., Ver, L. M. and Lerman, A. (2002): Century-scale nitrogen and phosphorus controls of the carbon cycle. Chemical Geology 190, 13–32.

Mackinson, S. (2001): Representing trophic interactions in the North Sea in the 1880s, using the Ecopath mass-balance approach. In: S., G., Christensen, V. and Pauly, D. (eds): Fisheries Impacts on North Atlantic Ecosystems: Models and Analyses. Fisheries Centre Research Reports 9. Vancouver, BC: UBC Fisheries Centre, 35–98.

Madigan, D. J., Baumann, Z. and Fisher, N. S. (2012): Pacific bluefin tuna transport Fukushima-derived radionuclides from Japan to California. Proceedings of the National Academy of Sciences 109 (24), 9483–9486.

Madsen, P. T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack, P. (2006): Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Marine Ecology Progress Series 309, 279–295.

Maersk Group (2013): CO_2 Transportation and Storage. Kopenhagen: Maersk Group.

Mann Borgese, E. (1975): Das Drama der Meere. Frankfurt/M.: Fischer.

Mann Borgese, E. (1998): The Oceanic Circle: Governing the Seas as a Global Resource. Tokyo: UNU Press.

Mann Borgese, E. (1999): Mit den Meeren leben. Hamburg: Dreiviertel Verlag.

Manta Consulting (2011): Financing Fisheries Change: Learning From Case Studies. Dovedale, CT, Marriottsville, MD: Manta Consulting.

Marí, F. (2010): Unfair abgefischt – Armut aufgetischt. Die Plünderung der Fischgründe vor Westafrika – 30 Jahre EU Fischereipolitik. Rundbrief Umwelt & Entwicklung: SOS für die Meere 3, 8–10.

Marí, F. J. (2012): Fremde Gewässer. Entwicklung + Zuammenarbeit 53, 423–427.

Maribus (ed) (2010): World Ocean Review 1 – Mit den Meeren leben. Hamburg: Maribus.

Maribus (ed) (2013): World Ocean Review 2 – Die Zukunft der Fische, die Fischerei der Zukunft. Hamburg: Maribus.

Marine Harvest (2008): Sustainability Report 2008. Internet: http://www.marineharvest.com/en/CorporateResponsibility/Sustainability-Reports (viewed 27. July 2012). Bergen: Marine Harvest.

Marine Harvest (2011): Annual Report 2011. Internet: http://www.marineharvest.com/en/CorporateResponsibility/Sustainability-Reports (viewed 27. July 2012). Bergen: Marine Harvest.

Marko, P. B., Nance, H. A. and Guynn, K. D. (2011): Genetic detection of mislabeled fish from a certified sustainable fishery. Current Biology 21 (16), R621–R622.

Markus, T. (2010): Die Regulierung anthropogener Lärmeinträge in die Meeresumwelt. Natur und Recht 32 (4), 236–247.

Markus, T. (2012): Die EU-Fischereihandelspolitik: Analyse und Handlungsbedarf. Expertise for the WBGU Report "Governing the Marine Heritage". Internet: http://www.wbgu.de/wbgu_jg2012_Expertise_Markus.pdf. Berlin: WBGU.

Markus, T. and Maurer, A. (2012): Windenergie und Gewerbesteuer. Zur Lückenhaftigkeit des Rechts der Offshore-Windenergie-Besteuerung. Neue Zeitschrift für Verwaltungsrecht – Extra 10, 10.

Martell, S. and Froese, R. (2012): A simple method for estimating MSY from catch and resilience. Fish and Fisheries submitted, DOI: 10.1111/j.1467-2979.2012.00485.x.

Maruyama, S., Tsubaki, K., Taira, K. and Sakai, S. (2004): Artificial upwelling of deep seawater using the perpetual salt fountain for cultivation of ocean desert. Journal of Oceanography 60, 563–568.

Matsuda, F., Tsurutani, T., Szyper, J. P. and Takahashi, P. (1998): The ultimate ocean ranch. OCEANS 98. Conference Proceedings 2, 971–976.

Matsuda, F., Szyper, J., Takahashi, P. and Vadus, J. R. (1999): The ultimate ocean ranch. Sea Technology 40 (8), 17–26.

Matz-Lück, N. and Fuchs, J. (2012): Die Ausweisung mariner Schutzgebiete in hoheitsfreien Räumen am Beispiel des OSPAR-Abkommens. Zeitschrift für Umweltrecht 10, 532–542.

McClimans, T. A., Handa, A., Fredheim, A., Lien, E. and Reitan, K. I. (2010): Controlled artificial upwelling in a fjord to stimulate non-toxic algae. Aquacultural Engineering 42, 140–147.

McCook, L., Ayling, T., Cappo, M., Choat, J. H., Evans, R. D., De Freitas, D. M., Heupel, M., Hughes, T. P., Jones, G. P., Mapstone, B., Marsh, H., Mills, M., Molloy, F. J., Pitcher, C. R., Pressey, R. L., Russ, G. R., Sutton, S., Sweatman, H., Tobin, R., Wachenfeld, D. R. and Williamson, D. H. (2010): Adaptive management of the Great Barrier Reef: a globally significant demonstration of the benefits of networks of marine reserves. Proceedings of the National Academy of Sciences 107 (43), 18278–18285.

McDorman, T. L. (2005): Impementing existing tools: turning words into actions – decision-making processes of Regional Fisheries Management Organisations (RFMOs). The International Journal of Marine and Coastal Law 20 (3–4), 423–457.

McDorman, T. L. (2006): Law and politics in ocean governance: The UN Fish Stocks Agreement and regional fisheries management. Ocean Development & International Law 37 (3–4), 390–391.

McIntyre, A. D. (2010): Life in the World's Oceans. Diversity, Distribution, and Abundance. London: Wiley-Blackwell.

McKinley, K. R. and Takahashi, P. K. (1991): Deep ocean water, artifical upwelling, and open ocean mariculture: a promise for the future. OCEANS 91. Ocean Technologies and Opportunities in the Pacific for the 90's. Proceedings 1, 195–199.

McKinsey (2008): Carbon Capture and Storage: Assessing the Economics. New York: McKinsey Climate Change Initiative.

McKinsey (2011): The Emerging Equity Gap: Growth and Stability in the New Investor Landscape. New York: McKinsey Global Institute.

MCS Network (2012): What is the Role of the MCS Network? Internet: http://imcsnet.org/about-us/ (viewed 6. September 2012). Maryland: MCS Network.

Mee, L. (2006): Reviving dead zones. How can we restore coastal seas ravaged by runaway plant and algae growth caused by human activities? Scientific American (11), 80–88.

Mee, L. D., Jefferson, R. L., Laffoley, D. and Elliot, M. (2008): How good is good? Human values and Europe's proposed Marine Strategy Directive. Marine Pollution Bulletin 56, 187–204.

Melnychuk, M. C., Essington, T., Branch, T. A., Heppell, S. S., Jensen, O. P., Link, J. S., Martell, S., Parma, A. M., Pope, J. and Smith, A. D. M. (2012): Can catch share fisheries better track management targets? Fish and Fisheries 13, 267–290.

Menasveta, P. (1997): Mangrove destruction and shrimp culture systems. World Aquaculture 28, 36–42.

Mendel, B. and Garthe, S. (2010): Kumulative Auswirkungen von Offshore-Windkraftnutzung und Schiffsverkehr am Beispiel der Seetaucher in der Deutschen Bucht. Coastline Reports 15, 31–44.

Merino, G., Barange, M., Blanchard, J. L., Harle, J., Holmes, R., Allen, I., Allison, E. H., Badjeck, M. C., Dulvy, N. K., Holt, J., Jennings, S., Mullon, C. and Rodwell, L. D. (2012): Can marine fisheries and aquaculture meet fish demand from a growing human population in a changing climate? Global Environmental Change 22, 795–806.

Merkel, A. (2011): Rede von Bundeskanzlerin Angela Merkel anlässlich des Kongresses der CDU/CSU-Fraktion "Rio+20: Gehen die Meere unter? – Neue Impulse für den internationalen Meeresschutz". Internet: http://www.bundesregierung.de/Content/DE/Rede/2011/10/2011-10-24-bkin-kongres-meeresschutz.html (viewed 25. January 2013). Berlin: German Government.

Mero, J. L. (1965): The Mineralological Resources of the Sea. New York: Elsevier.

Messner, D. (2000): Strukturen und Trends der Weltgesellschaft. In: SEF – Development and Peace Foundation (ed): Globale Trends 2000. Fakten. Analysen. Prognosen. Frankfurt/M.: Fischer, 44–75.

Messner, D. (2010): Globale Strukturanpassung: Weltwirtschaft und Weltpolitik in den Grenzen des Erdsystems. In: Welzer, H. (ed): Klimakulturen. Frankfurt/M.: Campus, 65–80.

Met Office (2012): Met Office Hadley Centre Observations Datasets. Internet: http://www.metoffice.gov.uk/hadobs/hadsst3/data/download.html (viewed 26. February 2013). London: Met Office Hadley Centre.

Meyer, J. (1980): The world polity and the authority of the nation-state. In: Bergensen, A. (ed): Studies of the Modern World System. New York: Academic Press, 109–137.

Michelet, J. (2006 [1861]): Das Meer. Frankfurt/M.: Campus.

Midtlyng, P. J., Grave, K. and Horsberg, T. E. (2011): What has been done to minimize the use of antibacterial and antiparasitic drugs in Norwegian aquaculture? Aquaculture Research 42 (Supplement 1), 28–34.

Miljutin, D. M., Miljutina, M. A., Arbizu, P. M. and Galéron, J. (2011): Deep-sea nematode assemblage has not recovered 26 years after experimental mining of polymetallic nodules

(Clarion-Clipperton Fracture Zone, Tropical Eastern Pacific). Deep Sea Research Part O: Oceanographic 58 (8), 885–897.

Milkov, A. V. (2004): Global estimates of hydrate-bound gas in marine sediments: How much is really out there? Earth Science Review 66, 183–197.

Miller, M. (1993): The rise of coastal and marine tourism. Ocean and Coastal Management 20, 181–199.

MIT – Massachusetts Institute of Technology (2011): The Future of Natural Gas. An Interdisciplinary MIT Study. Cambridge, MA: Cambridge University Press.

Mitchell, C., Sawin, J., Pokharel, G. R., Kammen, D. and Wang, Z. (2011): Policy, financing and implementation. In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., Zwickel, T., Eickemeier, P., Hansen, G., Schlömer, S. and von Stechow, C. (eds): IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge, New York: Cambridge University Press, 5–97.

Mitchell, R. B. (1994): Regime design matters: international oil pollution and treaty compliance. International Organisation 48 (3), 425–458.

Moberg, F. and Folke, C. (1999): Ecological goods and services of coral reef ecosystems. Ecological Economics 29 (2), 215–233.

Mohammed, E. Y. (2012): Payments for coastal and marine ecosystem services: prospects and principles. IIED Briefing May, 4.

Molenaar, E. J. (2007): Current legal and institutional issues relating to the conservation and management of high-seas deep-sea fisheries. FAO Fisheries Reports 838, 113–127.

Molenaar, E. J. (2011): Non-participation in the fish stocks agreement: status and reasons. The International Journal of Marine and Coastal Law 26, 195–234.

Molenaar, E. J. and Corell, R. W. (2009): Background Paper Fisheries. Pittsburg, PA: Arctic Transform, The Heinz Center.

Mollat du Jourdin, M. (1993): Europa und das Meer. Munich: Beck.

Mooney-Seus, M. and Rosenberg, A. A. (2007): Regional Fisheries Management Organizations (RFMOs): Progress in Adopting Precautionary Approach and Ecosystem-Based Management. Greenville, SC: Fort Hill Associates LLC.

Mora, C., Myers, R. A., Coll, M., Libralato, S., Pitcher, T. J., Sumaila, R. U., Zeller, D., Watson, R., Gaston, K. J. and Worm, B. (2009): Management effectiveness of the world's marine fisheries. PLoS Biology 7 (6), e1000131.

Moridis, G., Collet, T., Boswell, R., Kurihara, M., Reagan, M., Koh, C. and Sloan, E. D. (2009): Toward production from gas hydrates: current status, assessment of resources, and simulation-based evaluation of technology and potential. SPE Reservoir Evaluation & Engineering 12 (5), 745–771.

Mørk, G., Barstow, S., Kabuth, A. and Pontes, M. T. (2010): Assessing the Global Wave Energy Potential. Proceedings of the 29th International Conference on Ocean, Offshore Mechanics and Arctic Engineering (OMAE). Shanghai: OMAE Secretariat.

Moy, A. D., Howard, W. R., Bray, S. G. and Trull, T. W. (2009): Reduced calcification in modern Southern Ocean planktonic foraminifera. Nature Geoscience 2, 276–280.

MRAG – Marine Resources Assessment Group (2005): Review of Impacts of Illegal, Unreported and Unregulated Fishing on Developing Countries. Synthesis Report. London: MRAG.

MSC – Marine Stewardship Council (2012a): Marine Stewardship Council Annual Report 2011/12. London: MSC.

MSC – Marine Stewardship Council (2012b): MSC-Umweltstandard für nachhaltige Fischerei. Internet: http://www.msc.org/ueber-uns/standards-de/msc-standard-und-methodik (viewed 24. February 2012). London: MSC.

MSC – Marine Stewardship Council (2013): List of All Certified Fisheries. Internet: http://www.msc.org/track-a-fishery/fisheries-in-the-program/certified/all-certified-fisheries (viewed 24. February 2013). London: MSC.

Muhling, B. A., Lee, S.-K., Lamkin, J. T. and Liu, Y. (2011): Predicting the effects of climate change on bluefin tuna *(Thunnus thynnus)* spawning habitat in the Gulf of Mexico. ICES Journal of Marine Science 68, 1051–1062.

Müller, M. and Wallace, R. (2008): Enabling science and technology for marine renewable energy. Energy Policy 36, 4376–4382.

Munday, P. L., Dixson, D. L., Donelson, J. M., Jones, G. P., Pratchett, M. S., Devitsina, G. V. and Doving, K. B. (2011): Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. Proceedings of the National Academy of Sciences 106 (6), 1848–1852.

Munday, P. L., Dixson, D. L., McCormick, M. I., Meekan, M., Ferrari, M. C. O. and Chivers, D. P. (2010): Replenishment of fish populations is threatened by ocean acidification. Proceedings of the National Academy of Sciences 107 (29), 12930–12934.

Munro, G., van Houtte, A. and Willmann, R. (2004): The Conservation and Management of Shared Fish Stocks: Legal and Economic Aspects. FAO Fisheries Technical Paper No. 465. Rome: Food and Agriculture Organization (FAO).

Munro, G. R. (2010): From Drain to Gain in Capture Fisheries Rent. A Synthesis Study. FAO Fisheries and Agricultural Technical Paper No. 538. Rome: Food and Agriculture Organization (FAO).

Murray, B. C., Pendleton, L., Jenkins, A. W. and Sifleet, S. (2011): Green Payments for Blue Carbon. Economic Incentives for Protecting Threatened Coastal Habitats. Durham, NC: Nicholas Institute for Environmental Policy Solutions.

Myers, R. A., Baum, J. K., Shepherd, T. D., Powers, S. P. and Peterson, C. H. (2007): Cascading effects of the loss of apex predatory sharks from a coastal ocean. Science 315, 1846–1850.

Myers, R. A. and Worm, B. (2003): Rapid worldwide depletion of predatory fish communities. Nature 423, 280–283.

Naber, H., Lange, G.-M. and Hatziolos, M. (2008): Valuation of Marine Ecosystem Services: A Gap Analysis. Washington, DC: World Bank, The Earth Institute.

NACA – Network of Aquaculture Centres in Asia-Pacific and FAO – Food and Agriculture Organization (2000): Aquaculture Development Beyond 2000: The Bangkok Declaration and Strategy. Conference on Aquaculture in the Third Millennium, 20–25 February 2000, Bangkok, Thailand. Internet: ftp://ftp.fao.org/docrep/fao/006/ad351e/AD351e00.pdf (viewed 13. November 2012). Rome, Bangkok: FAO, NACA.

Nakayama, K., Oshima, Y., Nagafuchi, K., Hano, T., Shimasaki, Y. and Honjo, T. (2005): Early-life-stage toxicity in offspring from exposed parent medaka, *Oryzias latipes*, to mixtures of tributyltin and polychlorinated biphenyl. Environmental Toxicology and Chemistry 24 (3), 591–596.

Nanz, P. and Fritsche, M. (2012): Handbuch Bürgerbeteiligung. Bonn: Bundeszentrale für politische Bildung.

NASA – National Aeronautics and Space Administration (2006): TOPEX/Poseidon: Revealing Hidden Tidal Energy. Greenbelt: NASA Goddard Space Flight Center Scientific Visualization Studio.

NASA – National Aeronautics and Space Administration (2013): Sea Ice Concentrations (Percent) September 2012. Internet: http://earthobservatory.nasa.gov/Features/WorldOfChange/sea_ice.php (viewed 24. January 2013). Greenbelt: NASA.

Naylor, R. and Burke, M. (2005): Aquaculture and ocean resources: raising tigers of the sea. Annual Review of Environment and Resources 30, 185–218.

Naylor, R. L., Goldburg, R., Primavera, J. H., Kautsky, N., Beveridge, M. C. M., Clay, J., Fole, C., Lubchenco, J., Mooney, H. and Troell, M. (2000): Effect of aquaculture on world fish supplies. Nature 405, 1017–1024.

Naylor, R. L., Hardy, R. W., Bureau, D. P., Chiu, A., Elliott, M., Farrell, A. P., Forster, I., Gatlin, D. M., Goldburg, R. J., Hua, K. and Nichols, P. D. (2009): Feeding aquaculture in an era of finite resources. Proceedings of the National Academy of Sciences 106 (36), 15103–15110.

NBR – National Bureau of Asian Research (2011): Maritime Energy Resources in Asia. Energy and Geopolitics. NBR Special Report No. 35. Washington, DC: NBR.

NCR – NOAA Coral Reef Conservation Program (2011): Medicine: About Corals. Values. Internet: http://coralreef.noaa.gov/aboutcorals/values/medicine/ (viewed 24. January 2013). Silver Spring, MD: NCR.

Nel, W. (2003): Feasibility of Energy Plant in Agulhas Ocean Current. Eskom Report No RES/SC/03/22509. Johannesburg: Eskom Holdings Ltd.

Nellemann, C., Corcoran, E., Duarte, C. M., Valdés, L., De Young, C., Fonseca, L. and Grimsditch, G. (2009): Blue Carbon. A Rapid Response Assessment. Nairobi, New York: United Nations Environment Programme (UNEP), GRID-Arendal.

Nerem, R. S., Chambers, D., Choe, C. and Mitchum, G. T. (2010): Estimating mean sea level change from the TOPEX and Jason altimeter missions. Marine Geodesy 33 (1, supp 1), 435.

Nerem, R. S., Chambers, D., Choe, C. and Mitchum, G. T. (2013): 2013_rel2: Global Mean Sea Level Time Series (seasonal signals removed). Edited: 2013-02-27. Internet: http://sealevel.colorado.edu/ (viewed 4. March 2013). Boulder, CO: University of Colorado.

Neuhoff, K. (2005): Large-scale deployment of renewables for electricity generation. Review of Economic Policy 21 (1), 88–110.

Newman, D. J., Kilama, J., Bernstein, A. and Chivian, E. (2008): Medicines from nature. In: Chivian, E. and Bernstein, A. (eds): Sustaining Life. How Human Health Depends on Biodiversity. Oxford, New York: Oxford University Press, 117–161.

Ngembo, J. M. (2008): Rapport d´enquete sûr l´impact des importations des poissons sûr la pêche artisanale au bas-fleuve. Bonn: Evangelischer Entwicklungsdienst (EED).

Nicolas, D., Chaalali, A., Drouineau, H., Lobry, J., Uriarte, A., Borja, A. and Boet, P. (2011): Impact of global warming on European tidal estuaries: some evidence of northward migration of estuarine fish species. Regional Environmental Change 11, 639–649.

Niesten, E. and Gjertsen, H. (2010): Economic Incentives for Marine Conservation. Arlington, VA: Conservation International.

Nihous, G. C. (2007): A preliminary assessment of ocean thermal energy conversion resources. Journal of Energy Resources Technology 129, 10–17.

Nihous, G. C. (2010): Mapping available Ocean Thermal Energy Conversion resources around the main Hawaiian Islands with state-of-the-art tools. Journal of Renewable Sustainable Energy 2 (4), 043104.

NODC – National Oceanographic Data Center (2005): World Ocean Atlas (WOA). Internet: http://odv.awi.de/en/data/ocean/world_ocean_atlas_2005/ (viewed 19. October 2011). Silver Spring: NODC.

Noone, K., Sumaila, R. and Diaz, R. J. (2012): Valuing the Ocean. Stockholm: Stockholm Environment Institute (SEI).

Norse, E. A., Brooke, S., Cheung, W. W. L., Clark, M. R., Ekeland, I., Froese, R., Gjerde, K. M., Haedrich, R. L., Heppell, S. S., Morato, T., Morgan, L. E., Pauly, D., Sumaila, R. and Watson, R. (2012): Sustainability of deep-sea fisheries. Marine Policy 36, 307–320.

North, D. C. (1992): Institutionen, institutioneller Wandel und Wirtschaftsleistung. Tübingen: Mohr Siebeck.

NRC – National Research Council (2002): Effects of Trawling and Dredging on Seafloor Habitat. Washington, DC: National Academy Press.

NRC – National Research Council (2006): Dynamic Changes in Marine Ecosystems: Fishing, Food Webs, and Future Options. Washington, DC: National Academy Press.

NSIDC – National Snow & Ice Data Center (2012a): Arctic Sea Ice Extent Settles at Record Seasonal Minimum. Internet: http://nsidc.org/arcticseaicenews/2012/09/arctic-sea-ice-extent-settles-at-record-seasonal-minimum/ (viewed 16. February 2013). Boulder, CO: NSIDC.

NSIDC – National Snow & Ice Data Center (2012b): Poles Apart: A Record-Braking Summer and Winter. Internet: http://nsidc.org/arcticseaicenews/2012/10/poles-apart-a-record-breaking-summer-and-winter/ (viewed 16. February 2013). Boulder, CO: NSIDC.

O'Leary, B. C., Brown, R. L., Johnson, D. E., von Nordheim, H., Ardron, J., Packeiser, T. and Roberts, C. M. (2011): The first network of marine protected areas (MPAs) in the high seas: the process, challenges and where next. Marine Policy 36, 598–605.

O'Rourke, F., Boyle, F. and Reynolds, A. (2010): Tidal energy update 2009. Applied Energy 87 (2), 398–409.

Oda, S. (1983): Fisheries under the United Nations Convention on the Law of the Sea. The American Journal of International Law 77, 739–755.

Oebius, H. U., Becker, H. J., Rolinski, S. and Jankowski, J. A. (2001): Parametrization and evaluation of marine environmental impacts produced by deep-sea manganese nodule mining. Deep-Sea Research II (48), 3453–3467.

OECD – Organisation for Economic Co-operation and Development (2004): Review of Fisheries in OECD Countries. Country Statistics 2000–2002. Paris: OECD Publishing.

OECD – Organisation for Economic Co-operation and Development (2008): Fishing for Coherence in West Africa: Policy Coherence in the Fisheries Sector in Seven West Africa Countries. Executive Summary. Paris: OECD Publishing.

OECD – Organisation for Economic Co-operation and Development (2009): Strengthening Regional Fisheries Management Organizations. Paris: OECD Publishing.

OECD – Organisation for Economic Co-operation and Development (2010): Globalisation in Fisheries and Aquaculture, Opportunities and Challenges. Paris: OECD Publishing.

OECD – Organisation for Economic Co-operation and Development (2012a): OECD Environmental Outlook to 2050: The Consequences of Inaction. Paris: OECD Publishing.

OECD – Organisation for Economic Co-operation and Development (2012b): Rebuilding Fisheries. The Way Forward. Paris: OECD Publishing.

OECD – Organisation for Economic Co-operation and Development (2012c): OECD Review of Fisheries: Country Statistics 2012. Paris: OECD Publishing.

OES – Ocean Energy Systems (2011a): An International Vision for Ocean Energy. Internet: http://www.iea-oceans.org (viewed 11. July 2012). Lissabon: OES.

OES – Ocean Energy Systems (2011b): Annual Report 2011: Implementing Agreement on Ocean Energy Systems. Lissabon: OES.

Offshore-Windenergie.net (2013): Genehmigte Offshore-Windparks. Internet: http://www.offshore-windenergie.net/windparks/genehmigt (viewed 24. January 2013). Munich: International Economic Platform for Renewable Energies (IWR).

Ökologische Briefe Redaktion (1995): Kiel verfolgt einen vorsorgenden Ansatz. Ökologische Briefe 39, 2.

Oligae (2010): Oligae Guide to Fuels from Macroalgae. Tamilnadu: Oligae.

Olivier, J. G., Janssens-Maenhout, G. and Peters, J. A. H. W. (2012): Trends in Global CO_2 Emissions. 2012 Report. The Hague, Bilthoven: PBL Netherlands Environment Assessment Agency.

Olsen, E. M., Heino, M., Lilly, G. R., Morgan, J. M., Brattey, J., Ernande, B. and Dieckmann, U. (2004): Maturation trends indicative of rapid evolution preceded the collapse of northern cod. Nature 428, 932–935.

Olsen, Y., Otterstad, O. and Duarte, C. (2008): Status and future perspectives of marine aquaculture. In: Holmer, M., Black, K., Duarte, C. M., Marbà, N. and Karakassis, I. (eds): Aquaculture in the Ecosystem. Berlin, Heidelberg: Springer, 293–319.

Oosterveer, P. (2008): Governing global fish provisioning: ownership and management of marine resources. Ocean and Coastal Management 51, 797–805.

Orr, J. C. (2011): Recent and future changes in ocean carbonate chemistry. In: Gattuso, J.-P. and Hansson, L. (eds): Ocean Acidification. Oxford, NY: Oxford University Press, 41–66.

Orr, J. C., Fabry, V. J., Aumont, O., Bopp, L., Doney, S. C., Feely, R. A., Gnanadesikan, A., Gruber, N., Ishida, A., Joos, F., Key, R. M., Lindsay, K., Maier–Reimer, E., Matear, R., Monfray, P., Mouchet, A., Najjar, R. G., Plattner, G. K., Rodgers, K. B., Sabine, C. L., Sarmiento, J. L., Schlitzer, R., Slater, R. D., Totterdell, I. J., Weirig, M. F., Yamanaka, Y. and Yool, A. (2005): Anthropogenic ocean acidification over the twenty–first century and its impact on calcifying organisms. Nature 437, 681–686.

Oschlies, A., Pahlow, M., Yool, A. and Matear, R. J. (2010): Climate engineering by artificial ocean upwelling: chanelling the sorcerer's apprentice. Geophysical Research Letters 37, L04701.

OSPAR (2008): Background Document on Potential Problems Associated with Power Cables Other than Those for Oil and Gas Activities. London: OSPAR Commission.

OSPAR (2009): Overview of the Impacts of Anthropogenic Underwater Sound in the Marine Environment. London: OSPAR Commission.

OSPAR (2010a): The North-East Atlantic Environment Strategy. Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010–2020. OSPAR Agreement 2010-3. Internet: http://www.ospar.org/html_documents/ospar/html/10-03e_nea_environment_strategy.pdf#BDC (viewed 19. February 2013). London: OSPAR Commission.

OSPAR (2010b): Hazardous substances. Chapter 5. In: OSPAR Commission (ed): Quality Status Report 2010. London: OSPAR Commission, 37–52.

OSPAR (2010c): Quality Status Report 2010. London: OSPAR Commission.

Ostrom, E. (1990): Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge, New York: Cambridge University Press.

Ostrom, E. (2009a): A general framework for analyzing sustainability of social-ecological systems. Science 325, 419–423.

Ostrom, E. (2009b): Beyond markets and states: polycentric governance of complex economic systems. American Economic Review 100 (3), 641–672.

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B. and Policansky, D. (1999): Revisiting the commons: local lessons, global challenges. Science 284, 278.

Ouchi, K. and Nakahara, H. (1999): The deep ocean water upwelling machine using density current creation of fishing ground and absorption of CO_2. Oceans '99 MTS/IEEE 2, 1019–1024.

Padiyar, A. (2005): Aquaclubs: the way forward for shrimp health and quality management at village level. Aquaculture X (2), 33–35.

Pagiola, S., Bishop, J. and Landell–Mills, N. (eds) (2002): Selling Forest Environmental Services. Market–based Mechanisms for Conservation and Development. London: Earthscan.

Pattberg, P. H. (2004a): Private-private Partnerships als innovative Modelle zur Regel(durch)setzung. Das Beispiel des Forest Stewardship Councils. In: Brühl, T. (ed): Unternehmen in der Weltpolitik. Politiknetzwerke, Unternehmensregeln und die Zukunft des Multilateralismus. Bonn: Dietz, 143–162.

Pattberg, P. H. (2004b): The Institutionalisation of Private Governance. Conceptualising an Emerging Trend in Global Environmental Politics. Global Governance Working Paper No. 9. Amsterdam: University Amsterdam.

Pattberg, P. H. (2007): Private Institutions and Global Governance. The New Politics of Environmental Sustainability. Cheltenham, Northampton: Edward Elgar Publishing.

Paul, N. A., Tseng, C. K. and Borowitzka, M. (2012): Seaweed and microalgae. Chapter 13. In: Lucas, J. S. and Southgate, P. C. (eds): Aquaculture. Farming Aquatic Animals and Plants. London: Wiley-Blackwell, 268–294.

Pauly, D. (1995): Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology & Evolution 10, 430.

Pauly, D. (2013): Does catch reflect abundance? Point: yes, it is a crucial signal. Nature 494, 303–306.

Pauly, D. and Froese, R. (2012): Comments on FAO's State of Fisheries and Aquaculture, or 'SOFIA 2010'. Marine Policy 36, 746–752.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. and Torres jr., F. (1998): Fishing down marine food webs. Science 279, 860–863.

Pauly, D., Christensen, V., Guenette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., Watson, R. and Zeller, D. (2002): Towards sustainability in world fisheries. Nature 418, 689–695.

Pauly, D., Alder, J., Bennett, G., Christensen, V., Tyedmers, P. and Watson, R. T. (2003): The future for fisheries. Science 302, 1359–1361.

Pavitt, K. (2005): Innovation process. In: Fagerberg, J., Mowery, D. C. and Nelson, R. R. (eds): The Oxford Handbook of Innovation. Oxford, New York: Oxford University Press, 86–115.

Pêchecops – Fédération Nationale des Pêches de Mauritanie (2012): The Proposed Protocol to the EU-Mauritania Fisheries Agreement: Towards Sustainable Fisheries? Report and Recommendations. Mauritanian Civil Society Round Table Discussion 14–15 October 2012, Nouakchott. Nouakchott: Pêchecops.

PEG – Pew Environment Group (2010): Oil Spill. Prevention and Response in the U.S. Arctic Ocean: Unexamined Risks, Unacceptable Consequences. Philadelphia, PA: Pew Environment Group.

PEG – Pew Environment Group (2012): COFI Policy Statement. Recommendations to the 30th Session of the Committee on Fisheries of the Food and Agriculture Organization of the United Nations. Philadelphia, PA: PEG.

Peixoto, J. P. and Oort, A. H. (1992): Physics of Climate. New York: American Institute of Physics.

Pelamis Wave Power (2011): Technology and Projects. Internet: http://www.pelamiswave.com/our-projects/ (viewed 19. October 2011). Edinburgh: Pelamis Wave Power Ltd.

Pelc, R. A. and Fujita, R. M. (2002): Renewable energy from the ocean. Marine Policy 26, 471–479.

Pelc, R. A., Warner, R. R., Gaines, S. D. and Paris, C. B. (2010): Detecting larval export from marine reserves. Proceedings of the National Academy of Sciences 107 (43), 18266–18271.

Pelletier, N., Tyedmers, P., Sonesson, U., Scholz, A., Ziegler, F., Flysjo, A., Kruse, S., Cancino, B. and Silverman, H. (2009): Not all salmons are created equal: life cycle assessment (LCA) of global salmon farming systems. Environmental Science & Technology 43 (23), 8730–8736.

Pendleton, L., Donato, D. C., Murray, B. C., Crooks, S., Jenkins, A. W., Sifleet, S., Craft, C., Fourqurean, J. W., Kauffman, J. B., Marbà, N., Megonigal, P., Pidgeon, E., Herr, D., Gordon, D. and Baldera, A. (2012): Estimating global "Blue Carbon" emissions from conversion and degradation of vegetated coastal ecosystems. PLoS ONE 7 (9), e43542.

Perrette, M., Landerer, F., Riva, R., Frieler, K. and Meinshausen, M. (2013): A scaling approach to project regional sea level rise and its uncertainties. Earth System Dynamics 4, 11–29.

Perry, A. L., Low, P. J., Ellis, J. R. and Reynolds, J. D. (2005): Climate change and distribution shifts in marine fishes. Science 308, 1912–1915.

Peters, G. P., Marland, G., Le Quére, C., Boden, T., Canadell, J. G. and Raupach, M. R. (2012): Rapid growth in CO_2 emissions after the 2008–2009 global financial crisis. Nature Climate Change 2, 2–4.

Pikitch, E. K., Santora, C., Babcock, E. A., Bakun, A., Bonfil, R., Conover, D. O., Dayton, P. K., Doukakis, P., Fluharty, D. L., Heneman, B., Houde, E. D., Link, J., Livingston, P., Mangel, M., McAllister, D. E., Pope, J. and Sainsbury, K. J. (2004): Ecosystem–based fishery management. Science 305, 346–347.

Pikitch, E. K., Rountos, K. J., Essington, T., Santora, C., Pauly, D., Watson, R., Sumaila, U. R., Boersma, D., Boyd, I. L., Conover, D. O., Cury, P. M., Heppell, S. S., Houde, E. D., Mangel, M., Plagányi, E., Sainsbury, K. J., Steneck, R. S., Geers, T. M., Gownaris, N. and Munch, S. B. (2012a): The global contribution of forage fish to marine fisheries and ecosystems. Fish and Fisheries doi: 10.1111/faf.12004.

Pikitch, E. K., Boersma, P. D., Boyd, I. L., Conover, D. O., Cury, P., Essington, T., Heppell, S. S., Houde, E. D., Mangel, M., Pauly, D., Plagányi, E., Sainsbury, K. J. and Steneck, R. S. (2012b): Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Washington, DC: Lenfest Ocean Program.

Pils, H. and Kühn, K. (eds) (2012): Elisabeth Mann Borgese und das Drama der Meere. Hamburg: mare Verlag.

Pimm, S. L., Alves, M. A. S., Chivian, E. and Bermstein, A. (2008): What is biodiversity? In: Chivian, E. and Bernstein, A. (eds): Sustaining Life. How Human Health Depends on Biodiversity. Oxford, New York: Oxford University Press, 3–26.

Pinnegar, J. K. and Engelhard, G. H. (2008): The 'shifting baseline' phenomenon: a global perspective. Reviews in Fish Biology and Fisheries 18, 1–6.

Piria, R. and Zavolas, L. (2012): Priorities in the North Sea Grid Debate. SEFEP Working Paper. Berlin: Smart Energy for Europe Platform (SEFEP).

Pitcher, T. J., Kalikoski, D., Pramod, G. and Short, K. (2009): Not honouring the code. Countries are not complying with the UN Code of Conduct for Responsible Fisheries. Nature 457, 658–659.

Pitcher, T. J., Kalikoski, D., Short, K., Varkey, D. and Pramod, G. (2008): An evaluation of progress in implementing ecosystem-based management of fisheries in 33 countries. Marine Policy 33, 223–232.

PlasticsEurope (2012): Plastics – the Facts 2012. An Analysis of European Plastics Production, Demand and Waste Data for 2011. Brussels: PlasticsEurope.

Platt McGinn, A. (2000): Why Poison Ourselves? A Precautrionary Approach to Synthetic Chemicals. Worldwatch Paper 153. Washington, DC: Worldwatch Institute.

Ploskey, G. R. and Carlson, T. J. (2004): Comparison of Blade-Strike Modeling Results with Empirical Data. PNNL-14603. Richland, WA: Pacific Northwest National Laboratory.

POGO – Partnership for Observation of the Global Oceans (2010): Speed installation of system to monitor vital signs of global ocean, scientists urge. Internet: http://www.eurekalert.org/pub_releases/2010-10/pfoo-sio102510.php (viewed 27. September 2012). Plymouth: POGO.

POGO – Partnership for Observation of the Global Oceans (2011): An Ocean under Change. Plymouth: POGO.

Polacheck, T. (2012): Politics and independent scientific advice in RFMO processes: a case study of crossing boundaries. Marine Policy 36, 132–141.

Pörtner, H. O. (2005): Auswirkungen von CO_2–Eintrag und Temperaturerhöhung auf die marine Biosphäre. Expertise for the WBGU Report "The Future Oceans – Warming Up, Rising High, Turning Sour". Internet: http://www.wbgu.de/wbgu_sn2006_ex04.pdf. Berlin: WBGU.

Pörtner, H. O. (2010): Oxygen- and capacity-limitation of thermal tolerance: a matrix for integrating climate-related stressor effects in marine ecosystems. The Journal of Experimental Biology 213, 881–893.

Pörtner, H. O. and Knust, R. (2007): Climate change affects marine fishes through the oxygen limitation of thermal tolerance. Science 315, 95–97.

Posner, E. A. and Sykes, A. O. (2010): Economic foundations of the Law of the Sea. The American Journal of International Law 104, 569–596.

Post, J. W., Veerman, J., Hamelers, H. V. M., Euverink, G. J. W., Metz, S. J., Nymeijer, K. and Buisman, C. J. N. (2007): Salinity-gradient power: Evaluation of pressure-retarded osmosis and reverse electrodialysis. Journal of Membrane Science 288, 218–230.

Post, E., Forchhammer, M. C., Bret-Harte, S. M., Callaghan, T. V., Christensen, T. R., Elberling, B., Fox, A. D., Gilg, O., Hik, D. S., Høye, T. T., Ims, R. A., Jeppesen, E., Klein, D. R., Madsen, J., McGuire, A. D., Rysgaard, S., Schindler, D. E., Stirling, I., Tamstorf, M. P., Tyler, N. J. C., van der Wal, R., Welker, J., Wookey, P. A., Schmidt, N. M. and Aastrup, P. (2009): Ecological dynamics across the Arctic associated with recent climate change. Science 325, 1355–1358.

Potts, T. and Haward, M. (2006): International trade, eco-labelling, and sustainable fisheries – recent issues, concepts and practices. Environment, Development and Sustainability 9, 91–106.

Priest, T. (2007): Extraction not creation: the history of offshore petroleum in the Gulf of Mexico. Enterprise & Society June, 227–267.

Primavera, J. H. (2000): Development and conservation of Philippine mangroves: institutional issues. Ecological Economics 35, 91–106.

Primavera, J. H. (2006): Overcoming the impacts of aquaculture on the coastal zone. Ocean & Coastal Management 49, 531–545.

Primavera, J. H. and Esteban, J. A. (2008): A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. Wetlands Ecological Management 16, 345–358.

Proelß, A. (2004): Meeresschutz im Völker- und Europarecht. Das Beispiel des Nordostatlantiks. Berlin: Dunker & Humblot.

Proelß, A. (2009): Der Beitrag des Völkerrechts zu einem maritimen Infrastrukturrecht. In: Ehlers, P. and Erbguth, W. (eds): Infrastrukturrecht zur See: Neue Wege der Meeresordnung. Baden-Baden: Nomos, 13–26.

Proelß, A. (2010): Allgemeine Rechtslage. In: Exzellenzcluster Ozean der Zukunft (ed): Die Ölkatastrophe im Golf von Mexiko – was bleibt? Kiel: Universität Kiel, 34–35.

Proelß, A. and Müller, T. (2008): The legal regime of the Arctic ocean. Zeitschrift für ausländisches öffentliches Recht und Völkerrecht 68, 651–687.

Proelß, A. and Hong, C. (2012): Ocean upwelling and international law. Ocean Development & International Law 43 (4), 371–385.

Przeworski, A., Stokes, S. C. and Manin, B. (2009): Democracy, Accountability, and Representation. Cambridge, New York: Cambridge University Press.

Puig, P., Canals, M., Company, J. B., Martin, J., Amblas, D., Lastras, G., Palanques, A. and Calafat, A. M. (2012): Ploughing the deep sea floor. Nature 489, 286–290.

Pullin, R. S. V. and Sumaila, U. R. (2005): Aquaculture. Diversity, complexity, and dynamics in aquaculture. In: Kooiman, J., Bavinck, M., Jentoft, S. and Pullin, R. (eds): Fish for Life. Interactive Governance for Fisheries. MARE Publication Series No. 3. Centre for Maritime Research. Amsterdam: Amsterdam University Press, 93–107.

Punt, A. E., Siddeek, M. S. M., Garber-Yonts, B., Dalton, M., Rugolo, L., Stram, D., Turnock, B. J. and Zheng, J. (2012): Evaluating the impact of buffers to account for scientific uncertainty when setting TACs: application to red king crab in Bristol Bay, Alaska. ICES Journal of Marine Science 69 (4), 624–634.

Rabalais, N. N., Diaz, R. J., Levin, L. A., Turner, R. E., Gilbert, D. and Zhang, J. (2010): Dynamics and distribution of natural and human-caused hypoxia. Biogeosciences 7, 585–619.

Rabalais, N. N., Turner, E. R. and Wiseman jr., W. J. (2002): Gulf of Mexico hypoxia, A.K.A. "The Dead Zone". Annual Review of Ecology, Evolution, and Systematics 33, 235–263.

Ramirez-Llodra, E., Tyler, P. A., Baker, M. C., Bergstad, O. A., Clark, M. R., Escobar, E., Levin, L. A., Menot, L., Rowden, A. A., Smith, C. R. and van Dover, C. L. (2011): Man and the last great wilderness: human impact on the deep sea. PLoS ONE 6 (7), 25.

Ranger, S., Duncan, C., Richardson, P., Solandt, J.-L. and Wood, C. (undated): The public voice for the sea: taking account of traditionally excluded stakeholders in the MPA debate. Herefordshire: Marine Conservation Society (MCS).

Rave, T., Triebswetter, U. and Wackerbauer, J. (2013): Koordination von Innovations-, Energie- und Umweltpolitik. Studien zum deutschen Innovationssystem No. 10. Berlin: Commission of Experts for Research and Innovation (EFI).

Rawski, T. G. and Xiao, W. (2001): Roundtable on Chinese economic statistics: introduction. Chinese Economy Review 12, 298–302.

Raye, R. E. (2001): Characterization Study of the Florida Current at 26.11° North Latitude, 79.50° West Longitude for Ocean Current Power Generation. M.S. Thesis. Boca Raton, FL: College of Engineering, Florida Atlantic University.

Reist, J. D., Wrona, F. J., Prowse, T. D., Power, M., Dempson, J. B., Beamish, R. J., King, J. R., Carmichael, G. R. and Sawatzky, C. D. (2006): General effects of climate change on Arctic fishes and fish populations. Ambio 35 (7), 370–379.

Reith, J. H., Deurwaarder, E. P., Hemmes, K., Curvers, A. P., Kamermans, P., Brandenburg, W. and Zeeman, G. (2005): Bio-Offshore. Grootschalige Teelt van Zeewieren in Combinatie met Offshore Windparken in de Noordzee. Petten: Energy Research Centre of the Netherlands (ECN).

Reith, J. H., van Hal, J. W., Lenstra, W. J. and López Contreras, A. M. (2012): Perspectives of Open Ocean Seaweed Cultivation and Seaweed Biorefinerey for Large-Scale Production of Biobased Fuels and Chemicals. World Biofuels Markets, 13–15 March 2012, Rotterdam. Internet: http://www.ecn.nl/docs/library/report/2012/l12055.pdf (viewed 12. July 2012). Petten: ECN.

Rejeski, D. (2012): The Next Industrial Revolution. How We Will Make Things in the 21st Century and Why it Matters. Washington, DC: Wilson Center.

Ressurreição, A., Zarzycki, T., Kaiser, M., Edwards-Jones, G., Ponce Dentinho, T., Santos, R. S. and Gibbons, J. (2012): Towards an ecosystem approach for understanding public values concerning marine biodiversity loss. Marine Ecology Progress Series 467, 15–18.

Riahi, K., F., Dentener, D., Gielen, A., Grubler, J., Jewell, Z., Klimont, V., Krey, D., McCollum, S., Pachauri, S., Rao, B., van Ruijven, D. P., van Vuuren, E. and Wilson, C. (2012): Chapter 17: energy pathways for sustainable development. In: GEA – Global Energy Assessment (ed): Global Energy Assessment – Toward a Sustainable Future. Cambridge, New York: Cambridge University Press, 1203–1306.

Richardson, A. J., Bakun, A., Hays, G. C. and Gibbons, M. J. (2012): The jellyfish joyride: causes, consequences and management responses to a more gelatinous future. Trends in Ecology and Evolution 24 (6), 312–322.

Richter, S. (2012a): China demonstriert seine Macht mit einem Fischerdorf. Internet: http://www.zeit.de/politik/ausland/2012-07/china-paracel-spratly (viewed 26. January 2013). Hamburg: Zeit Online.

Richter, S. (2012b): Maritimer Machtkampf in Ostasien. Internet: http://www.zeit.de/politik/ausland/2012-04/manoever-suedostasien-china (viewed 26. January 2013). Hamburg: Zeit Online.

Ridgwell, A. and Schmidt, D. N. (2010): Past constraints on the vulnerability of marine calcifiers to massive carbon dioxide release. Nature Geoscience 3, 196–200.

Riebesell, U., Zondervan, I., Rost, B., Tortell, P. D., Zeebe, R. E. and Morel, F. M. M. (2000): Reduced calcification of marine plankton in response to increased atmospheric CO_2. Nature 407, 364–367.

Rignot, E., Mouginot, J. and Scheuchl, B. (2011): Ice flow of the Antarctic ice sheet. Science 333, 1427–1430.

Risse, T. and Börzel, T. (2005): Public-private partnerships. Effective and legitimate tools of international governance? In: Grande, E. and Pauly, L. W. (eds): Complex Sovereignty. Reconstituting Political Authority in the Twenty-First Century. Toronto: University of Toronto Press, 195–216.

Roberts, C. W. (2007): The Unnatural History of the Sea. The Past and Future of Humanity and Fishing. Washington, DC: Island Press.

Roberts, C. W. (2012): Ocean of Life. How Our Seas are Changing. London: Penguin.

Roberts, C. W. (2013): Der Mensch und das Meer. Warum der größte Lebensraum der Erde in Gefahr ist. Munich: DVA.

Robinson, A., Calov, R. and Ganopolski, A. (2012): Multistability and critical thresholds of the Greenland icesheet. Nature Climate Change 2, 429–432.

Rochette, J. and Billé, R. (2012): ICZM protocols to regional seas conventions: What? Why? How? Marine Policy 36, 977–984.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Witt, C. A., Hughes, T. M. C., van der Leeuw, S., Rodhe, H., Sörlim, S., Snyder, P. K., Constanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B., Livermann, D., Richardson, K., Crutzen, P. J. and Foley, J. A. (2009): Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14 (2), 32–58.

Roderburg, J. (2011): Marine aquaculture: impacts and international regulation. Australian and New Zealand Maritime Law Journal 25 (1), 161–179.

Roels, O. A., Laurence, S. and van Hemelryck, L. (1979): The utilization of cold, nutrient-rich deep ocean water for energy and mariculture. Ocean Management 5, 199–210.

Roesijadi, G., Rezvankhah, S., Perez-Matus, A., Mitelberg, A., Torruellas, K. and van Veld, P. A. (2008): Dietary cadmium and benzo(a)pyrene increased intestinal metallothionein expression in the fish *Fundulus heteroclitus*. Marine Environmental Research 67 (1), 25–30.

Roesijadi, G., Jones, S. B., Snowden-Swan, L. J. and Zhu, Y. (2010): Macroalgae as a Biomass Feedstock: A Preliminary Analysis. Richland: Pacific Northwest National Laboratory, U.S. Department of Energy.

Rogers, A. D. and Laffoley, D. (2011): International Earth System Expert Workshop on Ocean Stresses and Impacts. Summary Report. Oxford: International Programme on the State of the Ocean (IPSO).

Rogner, H.-H., Barthel, F., Cabrera, M., Faaij, A., Giroux, M., Hall, D., Kagramanian, V., Kononov, S., Lefevre, T., Moreira, R., Nötstaller, R., Odell, P. and Taylor, M. (2000): Energy resources. In: Goldemberg, J. (ed): World Energy Assessment. Energy and the Challenge of Sustainability. New York: United Nations Development Programme (UNDP), 135–173.

Rogner, H.-H., Aguilera, R. F., Bertani, R., Bhattacharya, S. C., Dusseault, M. B., Gagnon, L., Haberl, H., Hoogwijk, M., Johnson, A., Rogner, M. L., Wagner, H. and Yakushev, V. (2012): Chapter 7: energy resources and potentials. In: GEA – Global Energy Assessment (ed): Global Energy Assessment – Toward a Sustainable Future. Cambridge, UK: Cambridge University Press, 423–512.

Rolinski, S., Segschneider, J. and Sundermann, J. (2001): Long-term propagation of tailings from deep-sea mining under variable conditions by means of numerical simulations. Deep-Sea Research II (48), 3469–3485.

Rona, P. A. (2008): The changing vision of marine minerals. Ore Geology Reviews 33, 618–666.

Ronnback, P., Bryceson, I. and Kautsky, N. (2002): Coastal aquaculture development in Eastern Africa and the Western Indian Ocean: Prospects and problems for food security and local economies. Ambio 31, 537–542.

Roos, N., Wahab, A., Chamnan, C. and Thilsted, S. H. (2007): The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. The Journal of Nutrition 137, 1106–1109.

Rose, G. A. (2005): On distributional responses of North Atlantic fish to climate change. ICES Journal of Marine Science 62, 1360–1374.

Rosenbaum, B. (2006): Errichtung und Betrieb von Windenergieanlagen im Offshore-Bereich – Vorgaben des internationalen und nationalen Rechts. Kiel: University Kiel, Lorenz-von-Stein-Institute.

Rosenberg, R. (1985): Eutrophication – the future marine coastal nuisance? Marine Pollution Bulletin 16 (6), 227–231.

Roth, E., Rosenthal, H. and Burbridge, R. (2000): A discussion of the use of the sustainability index: ‘ecological footprint’ for aquaculture production. Aquatic Living Resources 13 (6), 461–469.

Rothermund, D. (2002): Geschichte Indiens. Vom Mittelalter bis zur Gegenwart. Munich: Beck.

Royal Society (2005): Ocean Acidification due to Increasing Atmospheric Carbon Dioxide. London: The Royal Society.

Ruppel, C. (2011): MITEI Natural Gas Report. Methane Hydrates and the Future of Natural Gas. Supplementary Paper 4. Woods Hole, MA: U.S. Geological Survey.

Russ, G. R., Cheal, A. J., Dolman, A. M., Emslie, M. J., Evans, R. D., Miller, I., Sweatman, H. and Williamson, D. H. (2008): Rapid increase in fish numbers follows creation of world’s largest marine reserve network. Current Biology 18 (12), R514–R515.

Ryan, J. (2005): Offshore Aquaculture – Do we Need it, and Why is it Taking so Long? International Salmon Farmers Association Expert Workshop on “Sustainable Aquaculture”. Sevilla: Institute for Prospective Technological Studies.

Salomon, M., Markus, T. and Dross, M. (2013): Die Gemeinsame Fischereipolitik im Reformprozess: Innovations- und Konfliktlösungspotentiale. Zeitschrift Natur und Recht 35, 89–98.

Salzwedel, J. (1987): Risiko im Umweltrecht – Zuständigkeit, Verfahren und Maßstäbe der Bewertung. Neue Zeitschrift für Verwaltungsrecht 87, 276–278.

Sánchez Durand, N. and Seminario, G. (2009): Status of and trends in the use of small pelagic fish species for reduction fisheries and for human consumption in Peru. In: Hasan, M. R. and Halwart, M. (eds): Fish as Feed Inputs for Aquaculture: Practices, Sustainability and Implications. FAO Fisheries and Aquaculture Technical Paper No. 518. Rome: Food and Agriculture Organization (FAO), 325–369.

Sandler, T. (1998): Global and regional public goods: a prognosis for collective action. Fiscal Studies 19 (3), 221–247.

Scheffer, M., Carpenter, S., Foley, J. A. and Walker, B. (2001): Catastrophic shifts in ecosystems. Nature 413, 591–596.

Schlacke, S. and Kenzler, J. (2009): Klimaschutz durch Meeresdüngung? Zum (Spannungs-)Verhältnis zwischen Seevölkerrecht und Biodiversitätskonvention. Natur und Recht 31, 753–759.

Schmehl, A. and Wack, S. (2009): Umweltfragen des Wachstums der Fischproduktion: Das Recht der Aquakultur in Küsten- und Meeresgewässern. Zeitschrift für Umweltrecht 10, 473–479.

Scholte, J. A. (2011): Towards greater legitimacy on global governance. Review of International Political Economy 18 (1), 110–120.

Scholz, S. (2011): Rohstoffversorgung durch Meeresbergbau. Schiff & Hafen 5, 72–76.

Schrag, D. P. (2009): Storage of carbon dioxide in offshore sediments. Science 325, 1658–1660.

Schrank, W. E. (2003): Introducing Fisheries Subsidies. Rome: Food and Agriculture Organization (FAO).

Schrope, M. (2007): Digging deep. Nature 447, 246–247.

Schultz-Zehden, A. and Gee, K. (2013): Findings. Experiences and Lessons from BaltSeaPlan. Brussels: BaltSeaPlan.

Schultz-Zehden, A., Gee, K. and Scibior, K. (2008): Handbook on Integrated Maritime Spatial Planning. Experience, Tools & Instruments, Case Studies. Berlin: sustainable projects.

Schulze-Fielitz, H. (2011): Technik und Umweltrecht. In: Schulte, M. and Schröder, R. (eds): Handbuch des Technikrechts. Berlin, Heidelberg: Springer, 455–504.

Schweizer, P. E., Cada, G. F. and Bevelhimer, M. S. (2011): Estimation of the Risks of Collision or Strike to Freshwater Aquatic Organisms Resulting from Operation of Instream Hydrokinetic Turbines. FY 2010 Annual Progress Report. Oak Ridge, TN: Oak Ridge National Laboratory, US Department of Energy.

Scråmestø, O. S., Skilhagen, S.-E. and Nielsen, W. K. (2009): Power Production Based on Osmotic Pressure. Waterpower XVI. Spokane, WA: Hydroworld.

Seemann, J., Carballo-Bolaños, R., Berry, K. L., González, C. T., Richter, C. and Leinfelder, R. R. (2012): Importance of Heterotrophic Adaptations of Corals to Maintain Energy Reserves. Proceedings of the 12th International Coral Reef Symposium, Cairns, Australia, 9–13 July 2012. 19A Human Impacts on Coral Reef. Internet: http://www.icrs2012.com/proceedings/manuscripts/ICRS2012_19A_4.pdf (viewed 24. January 2013). Brisbane: ICRS2012 Secretariat.

Seidler, C. (2011): Die traditionellen Arktis-Bewohner und der Klimawandel. Aus Politik und Zeitgeschichte 5–6, 30–34.

Serri, L., Sempreviva, A. M., Pontes, T., Murphy, J., Lynch, K., Airoldi, D., Hussey, J., Rudolph, C. and Karagali, I. (2012): Resource Data and GIS Tool for Offshore Renewable Energy Projects in Europe. Brussels: Off-shore Renewable Energy Conversion Platforms – Coordination Action (Orecca).

Service, R. F. (2012): Rising acidity brings an ocean of trouble. Science 337, 146–148.

Sesabo, J. K., Lang, H. and Tol, R. S. J. (2006): Perceived Attitude and Marine Protected Areas (MPAs) Establishment: Why Households' Characteristics Matters in Coastal Resources Conservation Initiatives in Tanzania. Working Paper FNU-99. Hamburg: International Max-Planck Research School for Maritime Affairs.

Seto, K. C. and Fragkias, M. (2007): Mangrove conversion and aquaculture development in Vietnam: a remote sensing-based approach for evaluating the Ramsar Convention on Wetlands. Global Environmental Change 17 (3–4), 486–500.

Shackelford, S. J. (2010): Was Selden right? The expansion of closed seas and its consequences. Stanford Journal of International Law 47, 59.

Sherman, K. and Hempel, G. (2008): The UNEP Large Marine Ecosystem Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas. UNEP Regional Seas Reports and Studies No. 182. Nairobi: UNEP.

Sherman, K. and McGovern, G. (eds) (2012): Frontline Observations on Climate Change and Sustainability of Large Marine Ecosystems. New York: UNDP.

Sherman, K., Belkin, I. M., Friedland, K. D., O'Reilly, J. and Hyde, K. (2009): Accelerated warming and emergent trends in fisheries biomass yields of the world's large marine ecosystems. Ambio 38 (4), 215–224.

Shields, M. A., Woolf, D. K., Grist, E. P. M., Kerr, S. A., Jackson, A. C., Harris, R. E., Bell, M. C., Beharie, R., Want, A., Osalusi, E., Gibb, S. W. and Side, J. (2011): Marine renewable energy: The ecological implications of altering the hydrodynamics of the marine environment. Ocean & Coastal Management 54, 2–9.

Siikamäki, J., Sanchirico, J. N. and Jardine, S. L. (2012): Global economic potential for reducing carbon dioxide emissions from mangrove loss. Proceedings of the National Academy of Sciences 109 (36) 14369–14374.

Sims, N. A. and Key, G. (2011): Fish Without Footprints. Oceans 2011. Internet: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6107321&url=http%3A%2F%2Fieeexplore.ieee.org%2Fstamp%2Fstamp.jsp%3Ftp%3D%26arnumber%3D6107321 (viewed 17. February 2013). Waikoloa, Hawaii: Conference Secretariat.

Sims, R. E. H., Schock, R. N., Adegbululgbe, A., Fenhann, J., Konstantinaviciute, I., Moomaw, W., Nimir, H. B., Schlamadinger, B., Torres-Martínez, J., Turner, C., Uchiyama, Y., Vuori, S. J. V., Wamukonya, N. and Zhang, X. (2007): Energy supply. In: IPCC – Intergovernmental Panel on Climate Change (ed): Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, New York: Cambridge University Press, 253–317.

Sipkema, D., Franssen, M. C. R., Osinga, R., Tramper, J. and Wijffels, R. H. (2005): Marine sponges as pharmacy. Marine Biotechnology 7 (3), 142–162.

Skilhagen, S. E. (2010): Osmotic power – A new, renewable energy source. Desalination Water Treatment 15 (1–3), 271–278.

Slobodian, L., Kinna, R., Kambu, A. and Ognibene, L. (2012): Bioprospecting in the Global Commons: Legal Issues Brief. Nairobi: UNEP.

Small, C. (2005): Regional Fisheries Management Organisations: Their Duties and Performance in Reducing Bycatch of Albatrosses and Other Species. Cambridge, UK: BirdLife International.

Smetacek, V., Klaas, C., Strass, V. H., Assmy, P., Montresor, M., Cisewski, B., Savoye, N., Webb, A., d'Ovidio, F., Arrieta, J., M., Bathmann, U., Bellerby, R., Berg, G. M., Groot, P., Gonzalez, S., Henjes, J., Herndl, G. J., Hoffmann, L. J., Leach, H., Losch, M., Mills, M. M., Neill, C., Peeken, I., Röttgers, R., Sachs, O., Sauter, E., Schmidt, M. M., Schwarz, J., Terbrüggen, A. and Wolf-Gladrow, D. (2012): Deep carbon export from a Southern Ocean iron-fertilized diatom bloom. Nature 487, 313–319.

Smith, C. R., Levin, L. A., Koslow, A., Tyler, P. A. and Glover, A. G. (2008): The near future of the deep seafloor ecosystems. Cambridge University Press:

Smith, M. D., Lynham, J., Sanchirico, J. N. and Wilson, J. A. (2010a): Political economy of marine reserves: Understanding the role of opportunity costs. Proceedings of the National Academy of Sciences 107 (43), 18300–18305.

Smith, M. D., Roheim, C. A., Crowder, L. B., Halpern, B. S., Turnipseed, M., Anderson, J. L., Asche, F., Bourillón, L., Guttormsen, A. G., Khan, A., Liguori, L. A., McNevin, A., O'Connor, M. I., Squires, D., Tyedmers, P., Brownstein, C., Carden, K., Klinger, D. H., Sagarin, R. and Selkoe, K. A. (2010b): Sustainability and global seafood. Science 327, 784–786.

Smith, S. J., van Aardenne, J., Klimont, Z., Andres, R. J., Volke, A. and Delgado Arias, S. (2011): Anthropogenic sulfur dioxide emissions: 1850–2005. Atmospheric Chemistry and Physics 11, 1101–1116.

Smits, R. and Kuhlmann, S. (2004): The rise of systemic instruments in innovation policy. International Journal of Foresight and Innovation Policy 1 (1/2), 32.

Sogin, M. L., Morrison, H. G., Huber, J. A., Welch, D. M., Huse, S. M., Neal, P. R., Arrieta, J. M. and Herndl, G. J. (1996): Microbial diversity in the deep sea and the underexplored 'rare biosphere'. Proceedings of the National Academy of Sciences 103 (32), 12115–12120.

Sørensen, H. C. and Weinstein, A. (2008): Ocean Energy. Position Paper for IPCC. Copenhagen, Brussels: European Ocean Energy Association.

Sorensen, J. (2002): Baseline 2002 Background Report: The Status of Integrated Coastal Management as an International Practice. Dessau: Integriertes Küstenzonenmanagement (IKZM).

Soto, D., Aguilar-Manjarrez Soto, D., Aguilar-Manjarrez, J., Brugère, C., Angel, D., Bailey, C., Black, K., Edwards, P., Costa-Pierce, B., Chopin, T., Deudero, S., Freeman, S., Hambrey, J., Hishamunda, N., Knowler, D., Silvert, W., Marba, N., Mathe, S., Norambuena, R., Simard, F., Tett, P., Troell, M. and Wainberg, A. (2008): Applying an ecosystem-based approach to aquaculture: principles, scales and some management measures. In: Soto, D., Aguilar-Manjarrez, J. and Hishamunda, N. (eds): Building an Ecosystem Approach to Aquaculture. FAO/Universitat de les Illes Balears Expert Workshop 7–11 May 2007, Palma de Mallorca. Rome: Food and Agriculture Organization (FAO) Fisheries and Aquaculture Proceedings, 15–35.

Spalding, M. D., Meliane, I., Milam, A., Fitzgerald, C. and Hale, L. Z. (2013): Protecting marine spaces: global targets and changing approaches. In: Chircop, A., Coffen-Smout, S. and McConnell, M. (eds): Ocean Yearbook 27. Leiden, Boston: Koninklijke Brill, 213–248.

Spruill, Vikki N. (1997): U.S. public attitudes toward marine environmental issues. Oceanography 10 (3), 149–152.

Srinivasan, T. U., Cheung, W. W. L., Watson, R. and Sumaila, R. U. (2010): Food security implications of global marine catch losses due to overfishing. Journal of Bioeconomy 12, 183–200.

Srinivasan, T. U., Watson, R. and Sumaila, R. U. (2012): Global fisheries losses at the exclusive economic zone level, 1950 to present. Marine Policy 36, 544–549.

SRU – German Advisory Council on the Environment (2004): Marine Environment Protection for the North and Baltic Seas. Special Report. Berlin: SRU.

SRU – German Advisory Council on the Environment (2011a): Pathways Towards a 100% Renewable Electricity System. Special Report. Berlin: SRU.

SRU – German Advisory Council on the Environment (2011b): Sustainable Management of Fish Stocks. Reforming the Common Fisheries Policy. Statement No. 16. Berlin: SRU.

SRU – German Advisory Council on the Environment (2012a): Environmental Report 2012. Berlin: SRU.

SRU – German Advisory Council on the Environment (2012b): Towards Effective Marine Nature Conservation. Fisheries Management in the Natura 2000 Sites of Germany's Exclusive Economic Zone. Statement No. 17. Berlin: SRU.

STAP – Scientific and Technical Advisory Panel (2011): Marine Debris as a Global Environmental Problem: Introducing a Solutions Based Framework Focused on Plastic. A STAP Information Document. Washington, DC: Global Environment Facility (GEF).

Staples, D. and Funge-Smith, S. (2009): Ecosystem Approach to Fisheries and Aquaculture: Implementing the FAO Code of Conduct for Responsible Fisheries. Bangkok: FAO Regional Office for Asia and the Pacific.

Starkey, D. J., Holm, P. and Barnard, M. (2008): Oceans Past. Management Insights from the History of Marine Animal Populations. London: Earthscan.

Stein, J. (2009): The legal status of eco-labels and product and process methods in the World Trade Organization. American Journal of Economics and Business Administration 1 (4), 285–295.

Steinacher, M., Joos, F., Frölicher, T. L., Bopp, L., Cadule, P., Cocco, V., Doney, S. C., Gehlen, M., Lindsay, K., Moore, J. K., Schneider, B. and Segschneider, J. (2010): Projected 21st century decrease in marine productivity: a multi-model analysis. Biogeosciences 7, 979–1005.

Steinacher, M., Joos, F., Frölicher, T. L., Plattner, G. K. and Doney, S. C. (2009): Imminent ocean acidification in the Arctic projected with the NCAR global coupled carbon cycle-climate model. Biogeosciences 6, 515–533.

Stelzenmüller, V., South, A. B., Breen, P. A., van Dalfsen, J., Jones, P., Degraer, S., Rabaut, M., Vincx, M., Rogers, S. I. and ter Hofstede, R. (2010): Monitoring and Evaluation of Spatially Managed Areas: A Generic Framework and its Application. Copenhagen: International Council for the Exploration of the Sea (ICES).

Stenevik, E. K. and Sundby, S. (2007): Impacts of climate change on commercial fish stocks in Norwegian waters. Marine Policy 31, 19–31.

Stern, N. (2006): Stern Review: The Economics of Climate Change. London: HM Treasury.

Stevenson, J. R. and Irz, X. (2009): Is aquaculture development an effective tool for poverty alleviation. A review of theory and evidence. Cahiers d'Agriculture 18, 292–299.

Stewart, H. B. (1974): Proceedings of the MacArthur Workshop on the Feasibility of Extracting Useable Energy from the Florida Current. Palm Beach, FL: MacArthur Workshop.

Stickney, R. R. and McVey, J. P. (eds) (2002): Responsible Marine Aquaculture. New York: CABI Publishing.

Stockholm Convention (2013a): Stockholm Convention. Status of Ratifications. Internet: http://chm.pops.int/Countries/StatusofRatifications/tabid/252/Default.aspx (viewed 15. January 2013). Stockholm: Stockholm Convention.

Stockholm Convention (2013b): Stockholm Convention. Listing of POPs in the Stockholm Convention. Internet: http://chm.pops.int/Convention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx (viewed 15. January 2013). Stockholm: Stockholm Convention.

Stockholm Convention (2013c): Stockholm Convention. The New POPs under the Stockholm Convention. Internet: http://chm.pops.int/Convention/ThePOPs/TheNewPOPs/tabid/2511/Default.aspx (viewed 15. January 2013). Stockholm: Stockholm Convention.

Stokstad, E. (2010): Down on the shrimp farm. Can shrimp become the new chicken of the sea without damaging the ocean? Science 328, 1504–1505.

Stommel, H., Arons, A. B. and Blanchard, D. (1956): An Oceanographical Curiosity: The Perpetual Salt Fountain. Woods Hole, MA: Woods Hole Oceanographic Institution.

Stramma, L., Prince, E. D., Schmidtko, S., Luo, J., Hoolihan, J. P., Visbeck, M., Wallace, D. W. R., Brandt, P. and Körtzinger, A. (2011): Expansion of oxygen minimum zones may reduce available habitat for tropical pelagic fishes. Nature Climate Change 2, 33–37.

Stramma, L., Schmidtko, S., Levin, L. A. and Johnson, G. C. (2010): Ocean oxygen minima expansions and their biological impacts. Deep Sea Research Part I: Oceanographic Research Papers 57 (4), 587–595.

Stumpf, C. A. (2006): The Grotian Theology of International Law. Hugo Grotius and the Moral Foundations of International Relations. Berlin, New York: de Gruyter.

Subasinghe, R., Soto, D. and Jia, J. (2009): Global aquaculture and its role in sustainable development. Reviews in Aquaculture 1, 2–9.

Sumaila, R. (2012): Is an all or nothing WTO Fisheries Subsidies Agreement achievable? In: Meléndez-Ortiz, R., Bellmann, C. and Rodriguez Mendoza, M. (eds): The Future and the WTO: Confronting the Challenges. A Collection of Short Essays. Geneva: International Centre for Trade and Sustainable Development (ICTSD), 173–177.

Sumaila, R., Alder, J. and Keith, H. (2006): Global scope and economics of illegal fishing. Marine Policy 30, 696–703.

Sumaila, R., Cheung, W. W. L., Dyck, A., Gueye, K., Huang, L., Lam, V. W. Y., Pauly, D., Srinivasan, T. U., Swartz, W., Watson, R. and Zeller, D. (2012): Benefits of rebuilding global marine fisheries outweigh costs. PLoS ONE 7 (7), 12.

Sumaila, R. U., Khan, A. S., Dyck, A. J., Watson, R., Munro, G., Tydemers, P. and Pauly, D. (2010): A bottom-up re-estimation of global fisheries subsidies. Journal of Bioeconomy 12, 201–225.

Sumaila, U. R., Cheung, W. W. L., Lam, V. W. Y., Pauly, D. and Herrick, S. (2011): Climate change impacts on the biophysics and economics of world fisheries. Nature Climate Change 1, 449–456.

Sumaila, U. R., Teh, L., Watson, R., Tyedmers, P. and Pauly, D. (2008): Fuel price increase, subsidies, overcapacity, and resource sustainability. ICES Journal of Marine Science 65, 832–840.

Sutton, G. and Boyd, S. (eds) (2009): Effects of Extraction of Marine Sediments on the Marine Environment 1998–2004. Paris: ICES.

Suuronen, P., Chopin, F., Glass, C., Lokkeborg, S., Matsushita, Y., Queirolo, D. and Rihan, D. (2012): Low impact and fuel efficient fishing – Looking beyond the horizon. Fisheries Research 119–120, 135–146.

Swartz, W., Sala, E., Tracey, S., Watson, R. and Pauly, D. (2010): The spatial expansion and ecological footprint of fisheries (1950 to present). PLoS ONE 5 (12), e15143.

Tacon, A. G. J., Hasan, M. R. and Metian, M. (2011): Demand and Supply of Feed Ingredients for Farmed Fish and Crustaceans. Trends and Prospects. Technical Paper No. 564. Rome: Food and Agriculture Organization (FAO).

Tacon, A. G. J. and Metian, M. (2008): Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects. Aquaculture 285, 146–158.

Tacon, A. G. J. and Metian, M. (2009a): Fishing for feed or fishing for food: increasing global competition for small pelagic forage fish. Ambio 38 (6), 294–302.

Tacon, A. G. J. and Metian, M. (2009b): Fishing for aquaculture: non-food use of small pelagic forage fish – a global perspective. Reviews in Fisheries Science 17 (3), 305–317.

Tacon, A. G. J., Metian, M., Turchinic, G. M. and de Silvad, S. S. (2010): Responsible Aquaculture and Trophic Level Implications to Global Fish Supply. Reviews in Fisheries Science 18 (1), 94–105.

Takahashi, M. M. (2000): Sea-water rears fish. In: Takahashi, M. M. (ed): Dow – Deep Ocean Water as Our Next Natural Resource. Tokyo: Terra Scientific Publishing Company, 45–81.

Tanaka, Y. (2011): The changing approaches to conservation of marine living resources in international law. Zeitschrift für ausländisches öffentliches Recht und Völkerrecht 291, 291–330.

Tarasofsky, R. (2007): Enhancing the Effectiveness of Regional Fisheries Management Organizations Through Trade and Market Measures. London: Chatham House.

Taylor, P. (2012): Wem gehört die Welt jenseits aller Grenzen? Das Gemeinsame Erbe der Menschheit. Internet: http://www.sueddeutsche.de/wissen/gastbeitrag-das-gemeinsame-erbe-der-menschheit-wem-gehoert-die-welt-jenseits-der-grenzen-1.1350432 (viewed 25. October 2012). Munich: Süddeutsche Zeitung.

TEEB – The Economics of Ecosystems and Biodiversity Initiative (2009): The Economics of Ecosystems and Biodiversity. TEEB for Policy Makers. Nairobi: United Nations Environment Programme (UNEP).

Telfor, T. and Robinson, K. (2003): Environmental Quality and Carrying Capacity for Aquaculture in Mulroy Bay, Co. Donegal. Stirling: Environmental Services. Institute of Aquaculture University of Sterling.

TEN – Training for Excellence Network (2012): Occupational Mapping Namibian Fishing and Maritime Industry. Phase One Commercial Fishing Industry & Ports and Harbours. Windhoek: TEN.

ten Brink, P., Lutchman, I., Bassi, S., Speck, S., Sheavly, S., Register, K. and Woolaway, C. (2009): Guidelines on the Use of Market-based Instruments to Address the Problem of Marine Litter. Brussels, Virginia Beach, VA: Institute for European Environmental Policy (IEEP), Sheavly Consultants.

ten Kate, K. and Laird, S. A. (2000): The commercial use of biodiversity. Access to genetic resources and benefit-sharing. London: Earthscan.

Tett, P. (2008): Fish farm wastes in the ecosystem. In: Holmer, M., Black, K., Duarte, C. M., Marbà, N. and Karakassis, I. (eds): Aquaculture in the Ecosystem. Berlin, Heidelberg: Springer, 1–46.

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., BjÃrn, A., Rowland, S. J., Thompson, R. C., Galloway, T. S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P. H., Tana, T. S., Prudente, M., Boonyatumanond, R., Zakaria, M. P., Akkhavong, K., Ogata, Y., Hirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M. and Takada, H. (2009): Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical Transactions of the Royal Society B: Biological Sciences 364, 2027–2045.

The Future Ocean (2010): Die Ölkatastrophe im Golf von Mexiko – was bleibt? Hintergrundinformationen und offene Fragen zu den Folgen der Explosion der "Deepwater Horizon" für die Meere und ihre Küsten – von Wissenschaftlern aus dem Kieler Exzellenzcluster "Ozean der Zukunft". Kiel: Cluster of Excellence "The Future Ocean", University Kiel.

The Nature Conservancy (2011): Permit Banks: A Strategy for Viable and Sustainable Fisheries. Overview and Recommendations. Arlington, VA:

Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W. (2006): Effects of Offshore Wind Farm Noise on Marine Mammals and Fish. A Cowrie Report. Hamburg: Biologisch-landschaftsökologische Arbeitsgemeinschaft (biola).

Thornton, J. K. (2012): A Cultural History of the Atlantic World, 1250–1820. Cambridge, New York: Cambridge University Press.

Thorpe, T. W. (1999): A Brief Review of Wave Energy. Report No. ETSU-120. Oxfordshire: The UK Department of Trade and Industry.

Thrane, M. (2004): Environmental Impacts from Danish Fish Products. Hotspots and Environmental Policies. PhD Dissertation. Aalborg: Aalborg University.

Tiller, R., Brekken, T. and Bailey, J. (2012): Norwegian aquaculture expansion and Integrated Coastal Zone Management (ICZM): simmering conflicts and competing claims. Marine Policy 36, 1086–1095.

Tindall, C. (2010): Baseline Study on the CFP External Dimension and Global Fisheries Governance. Report Commissioned for the DEFRA. London: UK Department for Food and Rural Affairs.

Toropova, C., Meliane, I., Laffoley, D., Matthews, E. and Spalding, M. (eds) (2010): Global Ocean Protection: Present Status and Future Possibilities. Gland: International Union for Conservation of Nature (IUCN).

Tougaard, J., Carstensen, J. and Teilmann, J. (2009): Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises *(Phocoena phocoena)*. Journal of the Acoustical Society of America 126, 11–14.

Toyota, T. and Nakashima, T. (1987): Using Deep Seawater for Biological Production. Woods Hole, MA: Woods Hole Oceanographic Institution.

Trêhu, A. M., Torres, M. E., Bohrmann, G. and Colwell, F. S. (2006): Leg 204 Synthesis: Gas hydrate distribution and dynamics in the central Cascadia accretionary complex. Proceedings of the Ocean Drilling Programme 204, 1–40.

Troell, M., Joyce, A., Chopin, T., Neori, A., Buschmann, A. H. and Fang, J.-G. (2009): Ecological engineering in aquaculture – Potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems. Aquaculture 297, 1–9.

Tsamenyi, M., Djalal, H. and Palma, M. A. (2003): International Frameworks for Ecosystem-based Management in the Asia-Pacific Region. Ecosystem Based Management Workshop: Beyond Biodiversity – Sustainable Management and Conservation of the Oceans using the EBM. Cairns, Australia: National Ocean's Office.

Turley, C., Eby, M., Ridgwell, A. J., Schmidt, D. N., Findlay, H. S., Brownlee, C., Riebesell, U., Fabry, V. J., Feely, R. A. and Gattuso, J.-P. (2010): The societal challenge of ocean acidification. Marine Pollution Bulletin 60, 787–792.

Turley, C. and Gattuso, J.-P. (2012): Future biological and ecosystem impacts of ocean acidification and their socio-economic-policy implications. Current Opinion in Environmental Sustainability 4, 278–286.

Turley, C. M., Roberts, J. M. and Guinotte, J. (2007): Corals in deep-water: will the unseen hand of ocean acidification destroy cold-water ecosystems? Coral Reefs 26, 445–448.

Tveterås, S. (2003): Norwegian salmon aquaculture and sustainability: the relationship between environmental quality and industry growth. In: Tveterås, S. (ed): Value Chains for Primary Goods: From Wild to Farmed Fish. Oslo: Norges Handelshoyskole. Norwegian School of Economics and Business Administration, 153–173.

Tyedmers, P. and Pelletier, N. (2007): Biophysical accounting in aquaculture: insights from current practice and the need for methodological development. FAO Fisheries Proceedings 10, 229–241.

Tyedmers, P., Watson, R. and Pauly, D. (2005): Fueling global fishing fleets. Ambio 34 (8), 635–638.

UBA – Federal Environment Agency (2007): Verursacher müssen Umweltschäden künftig auf eigene Kosten beseitigen. Press Information No. 72. Dessau: UBA.

UBA – Federal Environment Agency (2010): Schutz der Meere. London-Übereinkommen. Internet: http://www.umweltbundesamt.de/wasser/themen/meere/london-uebereinkommen.htm (viewed 24. January 2013). Dessau: UBA.

UBA – Federal Environment Agency (2012): Politikrelevante Nachhaltigkeitsforschung. Anforderungsprofil für Forschungsförderer, Forschende und Praxispartner aus der Politik zur Verbesserung und Sicherung von Forschungsqualität – Ein Wegweiser. Dessau: UBA.

UN – United Nations (1958): Convention on Fishing and Conservation of the Living Resources of the High Seas. New York: UN.

UN – United Nations (1995): Agreement for the Implementation of the Provisisons of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. A/CONF.164/37. New York: UN.

UN – United Nations (2001): Recommendations for the Guidance of the Contractors for the Assessment of the Possible Environmental Impacts Arising from Exploration for Polymetallic Nodules in the Area. UN Doc. ISBA/7/LTC/Rev. 1, 10.7.2001. New York: UN.

UN – United Nations (2002): Report on the World Summit on Sustainable Development, A/CONF.199/20 & CONF.199/20/Corr.1. New York: UN.

UN – United Nations (2011): The United Nations Convention on the Law of the Sea (A Historical Perspective). Internet: http://www.un.org/Depts/los/convention_agreements/convention_historical_perspective.htm (viewed 10. November 2011). New York: UN Division for Ocean Affairs and the Law of the Sea, Office of Legal Affairs.

UN – United Nations (2012a): The UN Oceans Compact – Healthy Oceans for Prosperity. An Initiative of the United Nations Secretary-General. Internet: https://www.un.org/Depts/los/ocean_compact/SGs%20OCEAN%20COMPACT%202012-EN-low%20res.pdf (viewed 13. September 2012). New York: UN.

UN – United Nations (2012b): The Right to Food. Note by the Secretary-General. Interim Report of the Special Rapporteur on the Right to Food (A67/268). New York: UN.

UN –United Nations (2012c): Oceans and the Law of the Sea. Resolution 66/231. New York: UN.

UN – United Nations (2013a): Status of the United Nations Convention on the Law of the Sea, of the Agreement Relating to the Implementation of Part XI of the Convention and of the Agreement for the Implementation of the Provisions of the Convention Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. Table Recapitulating the Status of the Convention and of the Related Agreements, as at 30 January 2013. Internet: http://www.un.org/Depts/los/reference_files/status2010.pdf (viewed 24. January 2013). New York: UN.

UN – United Nations (2013b): Sustainable Fisheries, Including Through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and Related Instruments. Resolution 67/79. New York: UN.

UN-Oceans (2013): About UN-Oceans. Internet: http://www.unoceans.org/Index.htm (viewed 24. January 2013). New York: UN-Oceans.

UNCED – United Nations Conference on Environment and Development (1992a): The Rio Declaration on Environment and Development. New York: UNCED.

UNCED – United Nations Conference on Environment and Development (1992b): Agenda 21. New York: UNCED.

UNCHE – United Nations Conference on the Human Environment (1972): Recommendations for Action at the International Level. Stockholm: UNCHE.

UNCSD – United Nations Conference on Sustainable Development (2012): The Future we Want. Outcome Document. New York: UNCSD.

UNCTAD – United Nations Conference on Trade and Development (2011): Review of Maritime Transport 2011. New York, Geneva: UNCTAD.

UNCTAD – United Nations Conference on Trade and Development (2012): Review of Maritime Transport 2012. New York, Geneva: UNCTAD.

UNDP – United Nations Development Programme and GEF – Global Environment Facility (2012a): Catalysing Ocean Finance. Volume I: Transforming Markets to Restore and Protect the Global Ocean. New York: UNDP.

UNDP – United Nations Development Programme and GEF – Global Environment Facility (2012b): Catalysing Ocean Finance. Volume II: Methodologies and Case Studies. New York: UNDP.

UNDP – United Nations Development Programme and GEF – Global Environment Facility (2012c): International Waters – Delivering Results. New York: UNDP, GEF.

UNEP – United Nations Environment Programme (1982): Achievements and Planned Development of UNEP's Regional Seas Programme and Comparable Programmes Sponsored by Other Bodies. UNEP Regional Seas Reports and Studies No. 1. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2000): World Energy Assessment 2010: Energy and the Challenge of Sustainability. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2002): Global Mercury Assessment. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2005): The Trade and Environmental Effects of Ecolabels: Assessment and Response. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2007): Global Strategic Directions for the Regional Seas Programmes 2008–2012: Enhancing the Role of the Regional Seas Conventions and Action Plans. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2008): Fisheries Subsidies: A Critical Issue for Trade and Sustainable Development at the WTO. An Introductory Guide. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2010a): UNEP Yearbook 2010. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2010b): Environmental Consequences of Ocean Acidification: A Threat to Food Security. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2011a): Towards a Green Economy. Pathways to Sustainable Development and Poverty Eradication. Arendal: UNEP/GRID.

UNEP – United Nations Environment Programme (2011b): Fisheries: Investing in Natural Capital. In: UNEP (ed): Towards a Green Economy. Pathways to Sustainable Development and Poverty Eradication. Nairobi: UNEP, 79–111.

UNEP – United Nations Environment Programme (2011c): Plastic Debris in the Ocean. UNEP Yearbook 2011. Internet:

www.unep.org/yearbook/2011/pdfs/plastic_debris_in_the_ocean.pdf (viewed 3. May 2011). Nairobi: UNEP.

UNEP – United Nations Environment Programme (2012a): Green Economy in a Blue World. Synthesis Report. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2012b): Global Environmental Outlook 5. Environment for the Future we Want. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2013a): UNEP Year Book 2013: Emerging Issues in our Global Environment. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2013b): Regional Seas Conventions and Action Plans: A Framework for Regional Coordination and Cooperation to Protect Shared Marine and Coastal Resources. Factsheet. Nairobi: UNEP.

UNEP – United Nations Environment Programme (2013c): 'Minamata' Convention agreed by Nations. Global Mercury Agreement to Lift Health Threats from Lives of Millions Worldwide. Press Release 19 January 2013. Internet: http://www.unep.org/hazardoussubstances/Portals/9/Mercury/Documents/INC5/press_release_mercury_Jan_19_2013.pdf (viewed 23. January 2013). Nairobi: UNEP.

UNEP-AMAP – United Nations Environment Programme - Arctic Monitoring and Assessment Programme (2011): Climate Change and POPs: Predicting the Impacts. Report of the UNEP/AMAP Expert Group. Nairobi: UNEP-AMAP.

UNEP – United Nations Environment Programme and GPA – Global Programme of Action for the Protection of the Marine Environment (2006): The State of the Marine Environment: Trends and Processes. Nairobi: UNEP, GPA.

UNEP MAP – United Nations Environment Programme – Mediterranean Action Plan (2005): Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean and its Protocols. Nairobi, Athens: UNEP MAP.

UNEP MAP – United Nations Environment Programme – Mediterranean Action Plan (2013): Mediterranean Action Plan for the Barcelona Convention. Internet: http://unepmap.org/ (viewed 10. January 2013). Athens: UNEP MAP.

UNEP-WCMC – United Nations Environment Programme – World Conservation Monitoring Centre (2011): Marine and Coastal Ecosystem Services. Valuation Methods and Their Practical Application. UNEP-WCMC Biodiversity Series No. 33. Nairobi: UNEP-WCMC.

UNESCO – United Nations Educational Scientific and Cultural Organization (2012a): Intergovernmental Oceanographic Commission: Resources, Meetings, Documents, People. Internet: http://www.http://ioc-unesco.org/ (viewed 24. January 2013). Paris: UNESCO.

UNESCO – United Nations Educational Scientific and Cultural Organization (2012b): Marine Spatial Planning Initiative. Internet: http://www.unesco-ioc-marinesp.be/ (viewed 12. March 2012). Paris: UNESCO.

UNESCO – United Nations Educational Scientific and Cultural Organization (2013a): World Heritage Marine Programme. Internet: http://whc.unesco.org/en/marine-programme/ (viewed 24. February 2013). Paris: UNESCO.

UNESCO – United Nations Educational Scientific and Cultural Organization (2013b): Welterbekonvention: Dokumente und Richtlinien. Internet: http://www.unesco.de/welterbekonvention.html (viewed 15. February 2013). Paris: UNESCO.

UNGA – United Nations General Assembly (2001): Road Map Towards the Implementation of the United Nations Millennium Declaration. Report of the Secretary-General. New York: UNGA.

UNGA – United Nations General Assembly (2006): Sustainable Fisheries, Including through the 1995 Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and Related Instruments. RES/61/105. New York: UNGA.

UNGA – United Nations General Assembly (2010): Report of the Resumed Review Conference on the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. A/CONF.210/2010/7. New York: UNGA.

UNGA – United Nations General Assembly (2011): Oceans and the Law of the Sea. Report of the Secretary General. New York: UNGA.

UNSCEAR – United Nations Scientific Committee on the Effects of Atomic Radiation (2000): Sources and Effects of Ionizing Radiation. UNSCEAR 2000 Report to the General Assembly. Volume I: Sources. New York: UNSCEAR.

UNU – United Nations University (2007): Marine Genetic Resources: Scientific Research, Commercial Uses and a Database on Marine Bioprospecting. New York: UNU.

US DOE – U.S. Department of Energy (2006): An Interagency Roadmap for Methane Hydrate Research and Development. Washington, DC: US DOE.

USGS – U.S. Geological Survey (2008): Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle. Denver, CO: USGS.

Valiela, I., Bowen, J. L. and York, J. K. (2001): Mangrove forests: one of the world's threatened major tropical environments. Bioscience 51 (10), 807–815.

van den Ende, K. and Groeman, F. (2007): Blue Energy. Arnhem: Leonardo Energy, KEMA Consulting.

van Sebille, E., England, M. H. and Froyland, G. (2012): Origin, dynamics and evolution of ocean garbage patches from observed surface drifters. Environmental Research Letters 7, 1–6.

Vaquer-Sunyer, R. and Duarte, C. M. (2008): Thresholds of hypoxia for marine biodiversity. Proceedings of the National Academy of Sciences 105 (40), 15452–15457.

Vázquez-Rowe, I., Moreira, M. T. and Feijoo, G. (2010): Life cycle assessment of horse mackerel fisheries in Galicia (NW Spain): comparative analysis of two major fishing methods. Fisheries Research 106, 517–527.

Vega, L. A. (2002): Ocean thermal energy conversion primer. Marine Technology Society Journal 36, 25–35.

Veitch, L., Dulvy, N. K., Koldewey, H., Lieberman, S., Pauly, D., Roberts, C. M., Rogers, A. D. and Baillie, J. E. M. (2012): Avoiding empty ocean commitments at Rio+20. Science 336, 1383–1385.

Vidas, D. (2010): Responsibility for the seas. In: Vidas, D. (ed): Law, Technology and Science form the Oceans in Globalisation. Leiden, Boston: Martinus Nijhoff Publishers, 3–40.

Vié, J.-C., Hilton-Taylor, C. and Stuart, S. N. (2008): Wildlife in a Changing World: An Analysis of the 2008 IUCN Red List of Threatened Species. Gland: International Union for Conservation of Nature (IUCN).

Villasante, S., Morato, T., Rodriguez-Gonzalez, D., Antelo, M., Österblom, H., Watling, L., Nouvian, C., Gianni, M. and Macho, G. (2012): Sustainability of deep-sea fish species under the European Union Common Fisheries Policy. Ocean & Coastal Management 70, 31–37.

Vogler, J. (2012): Global commons revisited. Global Policy 3 (1), 61–71.

Vogt-Beheim, C. (2004): Flexibilisierung von Umweltstandards. Baden-Baden: Nomos.

von Nordheim, H. and Boedeker, D. (1998): Umweltvorsorge bei der marinen Sand- und Kiesgewinnung. BfN-Skripten 23. Vilm: Federal Agency for Nature Conservation (BfN).

von Rotterdam, E. (1521): Ein Klag des Frydens (Leo Jud, Übers. der Querela Pacis von 1521) [Zürich 1969] XXIIIf.

Wahl, T., Jensen, J., Frank, T. and Haigh, I. D. (2011): Improved estimates of mean sea level changes in the German Bight over the last 166 years. Ocean Dynamics 61, 701–715.

Wallmann, K. (2012): Marine Gashydrate. CO_2-Speicherung und Erdgasgewinnung. Powerpoint-Präsentation Zukunftsprojekt Erde, 18.10.–19.10.2012, Berlin. Kiel: IFM-GEOMAR.

Wallmann, K., Haeckel, M., Bohrmann, G. and Suess, E. (2011): Zukünftige kommerzielle Nutzung von Methanhydratvorkommen im Meeresboden. In: Lozán, J. L., Graßl, H., Karbe, L. and Reise, K. (eds): Warnsignal Klima: Die Meere – Änderungen & Risiken. Hamburg: Wissenschaftliche Auswertungen, 285–288.

Walsh, J. E. and Chapman, W. L. (2001): Twentieth-century sea ice variations from observational data. Annals of Glaciology 33, 444–448.

Walsh, M. R., Hancock, S. H., Wilson, S. J., Patil, S. L. and Moridis, G. J. (2009): Preliminary report on the commercial viability of gas production from natural gas hydrates. Energy Economics 31 (5), 815–823.

Walters, C. and Maguire, J.-J. (1996): Lessons for stock assessment from the northern cod collapse. Reviews in Fish Biology and Fisheries 6, 125–137.

Wang, X., Schröder, H. C., Wiens, M., Schloßmacher, U. and Müller, W. E. G. (2012): Biosilica: molecular biology, biochemistry and function in demosponges as well as its applied aspects for tissue engineering. Advances in Marine Biology 62, 231–271.

Ward, P. and Myers, R. A. (2005): Shifts in open-ocean fish communities coinciding with the commencement of commercial fishing. Ecology 86 (4), 835–847.

Ward, T. J. (2008): Barriers to biodiversity conservation in marine fishery certification. Fish and Fisheries 9, 169–177.

Ware, D. M. and Thompson, R. E. (2005): Bottom–up ecosystem trophic dynamics determine fish production in the Northeast Pacific. Science 308, 1280–1284.

Wassmann, P., Slagstad, D. and Elingsen, I. (2010): Primary production and climatic variability in the European sector of the Arctic Ocean prior to 2007: preliminary results. Polar Biology 33, 1641–1650.

Wassmann, P., Duarte, C. M., Agusti, S. and Sejr, M. K. (2011): Footprints of climate change in the Arctic marine ecosystem. Global Change Biology 17, 1235–1249.

Watson, A. J. and Orr, J. C. (2003): Carbon dioxide fluxes in the global ocean. In: Fasham, M. J. R. (ed): Ocean Biogeochemistry. The IGBP Series. Berlin, Heidelberg: Springer, 123–143.

Wavenet (2003): Results from the Work of the European Thematic Network on Wave Energy. Energy, Environment Sustainable Development (E.E.S.D.). Study Within the Fifth (EC) RTD Framework Programme (1998–2002). Brussels: European Community.

WBGU – German Advisory Council on Global Change (1995a): The Threat to Soils. Flagship Report 1994. Bonn: Economica.

WBGU – German Advisory Council on Global Change (1995b): Scenario for the Derivation of Global CO_2-Reduction Targets and Implementation Strategies. Special Report 1995. Berlin: WBGU.

WBGU – German Advisory Council on Global Change (1999a): WaysTowards Sustainable Management of Freshwater Resources. Flagship Report 1997. Berlin, Heidelberg: Springer.

WBGU – German Advisory Council on Global Change (1999b): Environment and Ethics. Special Report 1999. Internet: http://www.wbgu.de/en/special-reports/sr-1999-environment-and-ethics/. Berlin: WBGU.

WBGU – German Advisory Council on Global Change (2001): Conservation and Sustainable Use of the Biosphere. Flagship Report 1999. Berlin, Heidelberg, New York: Springer.

WBGU – German Advisory Council on Global Change (2002): Charging the Use of Global Commons. Special Report 2002. Berlin: WBGU.

WBGU – German Advisory Council on Global Change (2004): Towards Sustainable Energy Systems. Flagship Report 2003. Berlin, Heidelberg, New York: Springer.

WBGU – German Advisory Council on Global Change (2005): Fighting Poverty through Environmental Policy. Flagship Report 2004. Berlin, Heidelberg, New York: Springer.

WBGU – German Advisory Council on Global Change (2006): The Future Oceans – Warming Up, Rising High, Turning Sour. Special Report 2006. Berlin: WBGU.

WBGU – German Advisory Council on Global Change (2009): Solving the Climate Dilemma: The Budget Approach. Special Report 2009. Berlin: WBGU.

WBGU – German Advisory Council on Global Change (2010): Future Bioenergy and Sustainable Land Use. Flagship Report 2008. Berlin, Heidelberg, New York: Springer.

WBGU – German Advisory Council on Global Change (2011): A Social Contract for Sustainability. Flagship Report 2011. Berlin: WBGU.

WBGU – German Advisory Council on Global Change (2012): Financing the Global Energy-System Transformation. Policy Paper. Berlin: WBGU.

Weaver, A. (2005): The McDonaldization thesis and cruise tourism. Annals of Tourism Research 32, 346–366.

WEC – World Energy Council (2010): Survey of Energy Resources. London: WEC.

Weigelin-Schwiedrzik, S. (2004): Der indische Ozean: Das afro-asiatische Mittelmeer als Kultur- und Wirtschaftsraum. Wien: Promedia.

Weihe, P. and Joensen, H. D. (2008): Recommendations to the Government of the Faroe Islands Concerning the Pilot Whale. Tórshavn: Landslægen.

Weiland, U. and Wohlleber-Feller, S. (2007): Einführung in die Umwelt- und Raumplanung. Paderborn: Schöningh, UTB.

Weimann, J. (2010): Politikberatung auf einem Bein: Der wissenschaftliche Beirat des Bundesfinanzministeriums und die Verhaltensökonomie. Working Paper No. 13. Magdeburg: University Magdeburg.

Welt Online (2011): Meereis in der Arktis schrumpft dramatisch schnell. Internet: http://www.welt.de/wissenschaft/umwelt/article13587392/Meereis-in-der-Arktis-schrumpft-dramatisch-schnell.html (viewed 18. October 2011). Hamburg: Die Welt.

Westerberg, H. and Begout-Anras, M.-L. (2000): Orientation of silver eel *(Anguilla anguilla)* in a disturbed electromagnetic field. In: Moore, A. and Russell, I. (eds): Advances in Fish Telemetry. Proceedings of the 3rd Conference on Fish Telemetry. Lowestoft: CEFAS, 149–158.

Westerberg, H. and Lagenfelt, I. (2008): Sub-sea power cables and the migration behaviour of the European eel. Fisheries Managment and Ecology 15, 369–375.

Wetzel, C. R. and Punt, A. E. (2011): Model performance for the determination of appropriate harvest levels in the case of data-poor stocks. Fisheries Research 110, 342–355.

WFC – The WorldFish Center (2011a): Aquaculture, Fisheries, Poverty and Food Security. Penang: WFC.

WFC – The WorldFish Center (2011b): Financing Smallholder Aquaculture Enterprises. Policy Brief 7. Penang: WFC.

White, M. and McGrail, P. (2009): Designing a pilot-scale experiment for the production of natural gas hydrates and sequestration of CO_2 in class 1 hydrate accumulations. Energy Procedia 1, 3099–3106.

Whitlow, J. (2004): The social dimension of IUU fishing. In: OECD – Organisation for Economic Co-operation and Development (ed): Fish Piracy: Combating Illegal, Unreported and Unregulated Fishing. Paris: OECD Publishing, 231–238.

Whitmarsh, D. and Palmieri, M. G. (2009): Social acceptability of marine aquaculture: the use of survey-based methods for eliciting public and steakholder preferences. Marine Policy 33, 452–457.

WHO – World Health Organization (2007a): The World Health Report. A Safer Future: Global Public Health Security in the 21st Century. Geneva: WHO Library.

WHO – World Health Organization (2007b): Preventing Disease Through Healthy Environments. Exposure to Mercury: A Major Public Health Concern. Geneva: WHO.

Wijffels, R. H. and Barbosa, M. J. (2010): An outlook on microalgal biofuels. Science 329, 796–799.

Wijkström, U. N. (2009): The use of wild fish as a aquaculture feed and its effects on income and food for the poor and the undernourished. In: Hasan, M. R. and Halwart, M. (eds): Fish as Feed Inputs for Aquaculture: Practices, Sustainability and Implications. Rome: Food and Agriculture Organization (FAO), 371–407.

Wilkinson, C. (2008): Status of Coral Reefs of the World: 2008. Townsville, Australia: Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre.

Wille, D. (2009): Raumplanung in der Küsten- und Meeresregion. Das Konzept des Integrierten Küstenzonenmanagements (IKZM) als Herausforderung für das deutsche Raumordnungs-, Zulassungs- und Umweltplanungsrecht. Baden-Baden: Nomos.

Wilson, D. T., Curtotti, R. and Begg, G. A. (eds) (2010): Fishery Status Reports 2009: Status of Fish Stocks and Fisheries Managed by the Australian Government. Canberra: Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences.

Winchester, S. and Müller, M. (2012): Der Atlantik. Biographie eines Ozeans. Munich: Albrecht Knaus Verlag.

Winkelmann, I. (2008): Feste Spielregeln für die Aufteilung des Arktischen Ozeans. SWP-Aktuell 53, 4.

Wiser, R., Yang, Z., Hand, M., Hohmeyer, O., Infield, D., Hensen, P. H., Nikiolaev, V., O'Malley, M., Sinden, G. and Zervos, A. (2011): Wind energy. Chapter 7. In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., Zwickel, T., Eickemeier, P., Hansen, G., Schlömer, S. and von Stechow, C. (eds): IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge, New York: Cambridge University Press, 535–608.

WMO – World Meteorological Organization (2010): Provisional Statement on the Status of the Global Climate. 2011: World's 10th Warmest Year, Warmest Year with La Niña on Record, Second-Lowest Arctic Sea Ice Extent. Internet: http://www.wmo.int/pages/mediacentre/press_releases/gcs_2011_en.html (viewed 16. December 2012). Geneva: WMO.

Wolf, S. (2006): Neue Tendenzen zur Ausdehnung küstenstaatlicher Umweltkompetenzen auf See: Eine Untersuchung am Beispiel der französischen "zone de protection ecologique" im Mittelmeer. Zeitschrift für ausländisches öffentliches Recht und Völkerrecht 66, 73–141.

Wolfrum, R. (1983): The Principle of the Common Heritage of Mankind. Heidelberg: Max Planck Institute for Comparative Public Law and International Law.

Wolfrum, R. (2006a): Hohe See und Tiefseeboden (Gebiet) – Rechtsstatus und Nutzung des Tiefseebodens (des Gebiets). In: Graf Vitzthum, W. (ed): Handbuch des Seerechts. Munich: Beck, 333–342.

Wolfrum, R. (2006b): Das Streitbeilegungssystem des VN-Seerechtsübereinkommens. In: Graf Vitzthum, W. (ed): Handbuch des Seerechts. Munich: Beck, 461–489.

Wolfrum, R. (2008): Ansätze eines allgemeinen Verwaltungsrechts im internationalen Umweltrecht. In: Trute, H.-H., Groß, T., Röhl, H. C. and Möllers, C. (eds): Allgemeines Verwaltungsrecht – zur Tragfähigkeit eines Konzepts. Tübingen: Mohr Siebeck, 665–679.

Wolfrum, R. and Fuchs, J. (2011): Ocean Governance und das Seerechtsübereinkommen der Vereinten Nationen. Expertise for the WBGU Report "Governing the Marine Heritage". Internet: http://www.wbgu.de/wbgu_jg2012_Expertise_Wolfrum.pdf. Berlin: WBGU.

Woolf, D. K. (2011): Environment, Regulation and Legislation. Caithness: Environmental Research Institute (ERI).

World Bank (2009): Resource Rent as a Central Concept in Fisheries Management: The Case of Namibia. Good Management Practice in Sustainable Fisheries. Policy Briefs 9. Washington, DC: World Bank.

World Bank (2012a): Helping to Better Manage the World's Oceans. The World Bank and the Drive for "Blue Growth". Washington, DC: World Bank.

World Bank (2012b): A New S-O-S: Save Our Seas. Remarks of Robert B. Zoellick, President, The World Bank Group, at The Economist World Oceans Summit, Singapore, February 24, 2012. Internet: http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:23126181~pagePK:34370~piPK:42770~theSitePK:4607,00.html (viewed 2. October 2012). Washington, DC: World Bank.

World Bank (2013): Behind the Numbers: A Closer Look at GEF Achievements. Washington, DC: World Bank.

World Bank and FAO – Food and Agriculture Organization (2009): The Sunken Billions: The Economic Justification for Fisheries Reform. Advance Edition. Washington, DC: World Bank.

World Bank, FAO – Food and Agriculture Organization and WFC – World Fish Center (2010): The Hidden Harvest: The Global Contribution of Capture Fisheries. Rome, Washington, DC: World Bank.

World Shipping Council (2012): About the Industry. Global Trade. Internet: http://www.worldshipping.org/about-the-industry/global-trade (viewed 8. February 2012). Washington, DC: World Shipping Council.

Worm, B. and Branch, T. A. (2012): The Future of Fish. Halifax, Washington, DC: Dalhousie University, School of Aquatic and Fisheries Sciences.

Worm, B. and Lotze, H. K. (2009): Changes in marine biodiversity as an indicator of climate change. In: Letcher, T. (ed): Climate and Global Change: Observed Impacts on Planet Earth. Munich: Elsevier, 263–279.

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., Jackson, J. B. C., Lotze, H. K., Micheli, F., Palumbi, S. R., Sala, E., Selkoe, K. A., Stachowicz, J. J. and Watson, R. T. (2006): Impacts of biodiversity loss on ocean ecosystem services. Science 314, 787–790.

Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., Fogarty, M. J., Fulton, E. A., Hutchings, J. A. and Jennings, S. (2009): Rebuilding global fisheries. Science 325, 578–585.

Woyte, A., De Decker, J. and Thong, V. V. (2008): A North Sea Electricity Grid (r)Evolution: Electricity Output of Interconnected Offshore Wind Power Generation in the North Sea. A Vision on Offshore Wind Power Integration. Brussels: Greenpeace, 3E.

WSSD – World Summit on Sustainable Development (2002): Johannesburg Plan of Implementation. Geneva, New York: WSSD.

WTO – World Trade Organization (1994): Agreement on Subsidies and Countervailing Measures. Geneva: WTO.

WTO – World Trade Organization (2010): World Trade Report 2010. Trade in Natural Resources. Geneva: WTO.

Wunder, S. (2005): Payments for Environmental Services: Some Nuts and Bolts. CIFOR Occasional Paper No. 42. Jakarta: Center for International Forestry Research (CIFOR).

WVS – World Values Survey (2011): Online Data Analysis. Internet: http://www.wvsevsdb.com/wvs/WVSAnalize.jsp (viewed 27. January 2013). Stockholm: World Values Survey Association.

WWF – World Wildlife Fund (2007): Benchmarking Study: Certification Programmes for Aquaculture. Environmental Impacts, Social Issues and Animal Welfare. Zurich, Oslo: WWF International.

WWF – World Wildlife Fund and Accenture (2009): Assessment of On-Pack, Wild-Capture Seafood Sustainability Certification Programmes and Seafood Ecolabels. Zurich: WWF, Accenture.

Yamamoto, K. and Nagakubo, S. (2009): Environmental impacts of methane hydrate field development in the eastern Nankai Trough (in Japanese). Gekkan Chikyu 31 (9), 476–485.

Yamamoto-Kawai, M., McLaughlin, F. A., Carmack, E. C., Nishino, S. and Shimada, K. (2009): Aragonite undersaturation in the Arctic Ocean: effects of ocean acidification and sea ice melt. Science 326, 1098–1100.

Young, L. C., Vanderlip, C., Duffy, D. C., Afanasyev, V. and Shaffer, S. A. (2009): Bringing home the trash: do colony-based differences in foraging distribution lead to increased plastic ingestion in Laysan albatrosses? PLoS ONE 4, 10.

Youngson, B. A. F., Dosdat, A., Saroglia, M. and Jordan, W. C. (2001): Genetic interactions between marine finfish species in European aquaculture and wild conspecifics. Journal of Applied Ichthyology 17 (4), 153–162.

Zeller, D. and Pauly, D. (2005): Good news, bad news: global fisheries discards are declining, but so are total catches. Fish and Fisheries 6, 156–159.

Zhang, J., Gilbert, D., Gooday, A. J., Levin, L. A., Naqvi, S. W. A., Middelburg, J. J., Scranton, M., Ekau, W., Peña, A., Dewitte, B., Oguz, T., Monteiro, P. M. S., Urban, E., Rabalais, N. N., Ittekkot, V., Kemp, W. M., Ulloa, O., Elmgren, R., Escobar-Briones, E. and van der Plas, A. K. (2010): Natural and human-induced hypoxia and consequences for coastal areas: synthesis and future development. Biogeosciences 7, 1443–1467.

Zürn, M. (1998): Regieren jenseits des Nationalstaates. Frankfurt/M.: Suhrkamp.

Glossary

10

Anthropocene
Anthropocene means the 'age of man' and is partly derived from the concept of geological ages like the Palaeocene or the Holocene. The term was coined in 2000 by Nobel Prize laureate Paul Crutzen together with Eugene Stoermer, and refers to a geological era in which the effects of human activities on the environment have reached a global dimension. This leads to – in some cases considerable – changes in ecosystems, even to the extent of their destruction. The most important changes caused by humans include climate change and ozone-layer depletion in the Antarctic (Chapter 1).

Aquaculture
Aquaculture refers to the cultivation of aquatic organisms (fish, mussels and other molluscs, crustaceans, aquatic plants, as well as crocodiles, turtles and amphibians) involving various forms of controlled intervention in the breeding process with the aim of increasing production (Chapter 4.3.1).

Area
According to UNCLOS (Article 1, para. 1, no. 1) the 'Area' comprises the seabed and the subsoil thereof beyond the limits of national jurisdiction.

Areas beyond national jurisdiction (ABNJ)
ABNJ are ocean waters over which no nation state exercises sole jurisdiction, i.e. all parts of the sea that are not included in the →exclusive economic zone, the →territorial sea or the internal waters of a state, or in the archipelagic waters of an archipelagic state (Article 86 of UNCLOS).

Artificial upwelling
Artificial upwelling is a technique by which the nutrient-rich, cold deep-sea water is brought to the surface layers of the ocean. This technology can be used to pursue a range of purposes, e.g. to increase primary production, to generate energy, in CO_2 sequestration or for cooling systems (Box 4.1-2).

Benthic
Benthic organisms are organisms that live on or in the bottom of water bodies.

Blue carbon
The term 'blue carbon' is used in the context of international climate policy to mean the carbon captured or stored by marine or coastal ecosystems. There is some debate on whether the protection of these ecosystems should be recognized as a climate-protection measure (Box 1.2-2).

Carbon dioxide capture and storage (CCS)
CCS is a process by which CO_2 from combustion processes in energy generation (or from industrial processes) is separated, transported to a storage location and stored. The aim is to isolate the CO_2 from the atmosphere for a very long time.

Common heritage of mankind
The common heritage of mankind approach for global →public and common goods (such as outer space, the sea, the atmosphere or the Antarctic) was developed in the 20th century. It requires that all current and future generations have access these spaces and that no state can claim national sovereignty rights (Section 3.1.5).

Common-pool resource
Common-pool resources or 'commons' are resources such as fish stocks, oil fields or water supplies which can be used by everyone, i.e. no one can be excluded from using them (→public and common good). However, they are subject to rivalry in consumption. The resulting negative externalities can contribute to the overuse of the resource (Sections 1.4, 3.1).

Continental shelf
According to the UNCLOS definition (Article 76), the continental shelf of a coastal state comprises the seabed and subsoil of the submarine areas that extend beyond its →territorial sea throughout the natural prolonga-

tion of its land territory to the outer edge of the continental margin, or to a distance of 200 nm from the baselines from which the breadth of the territorial sea is measured, where the outer edge of the continental margin does not extend up to that distance (Section 3.2.1.4).

Dead zones
Dead zones, also known as 'low-oxygen zones', are marine regions where the concentration of oxygen in the water is low, destroying the structure and function of ecosystems. They can occur naturally, although dead zones are increasingly forming as a result of human activities, e.g. →eutrophication. Climate change also contributes to the formation of dead zones.

Ecosystem approach
The ecosystem approach was developed in the context of the Convention on Biological Diversity and describes a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use (CBD, 2000).

Ecosystem services
Ecosystem services are benefits that people derive from ecosystems. They include supply services such as food or water; regulatory services such as flood protection or protection against the spread of disease; cultural and recreational services; and support services like the nutrient cycle that maintain the basis of life on Earth.

Eutrophication
Eutrophication refers to an excessive input of nutrients into waters resulting in a higher rate of primary production, an increase in biological degradation processes, and oxygen depletion. In extreme cases, this can lead to the development of →dead zones.

Exclusive economic zone (EEZ)
The EEZ is an area beyond and adjacent to the →territorial sea subject to a specific legal regime according to →UNCLOS (cf. Article 55 of UNCLOS). The rights and jurisdictions of the coastal state that declares such a zone are extended to this zone, although they only relate to the exploitation and conservation of the living and non-living natural resources in the zone in question, including those on the seabed and in its subsoil.

Fish Stocks Agreement (FSA)
FSA stands for the 'Convention for the Implementation of the Provisions of the United Nations Convention of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks'. 79 states and the European Union have acceded to the Convention (as of November 2012; Section 4.1.4.4).

Governance
Governance refers to the system of management and control of a political unit in general; in the context of this report it is related to the seas (ocean governance). The concept originated in contrast to the term 'government' and aims to express the idea that political control is exerted not only hierarchically by the state but also by private players such as associations. Governance capacity refers to the ability to control by means of functioning institutions and regulatory systems.

Great Transformation
WBGU (2011) defines a Great Transformation as a comprehensive change involving a restructuring of national economies and the global economy within the →planetary guard rails in order to avoid irreversible damage to the Earth system and ecosystems and the effects this would have on humanity.

HELCOM
HELCOM is an intergovernmental commission of Baltic Sea states aiming to protect the Baltic marine environment. The Commission issues recommendations and works on the basis of the →Helsinki Convention, which entered into force in 2000 (Section 3.4.2).

Helsinki Convention
The Helsinki Convention is a multilateral environmental agreement which aims to protect the Baltic Sea. The 1974 Helsinki Convention related primarily to technical environmental issues and the pollution of the Baltic Sea, whereas the 'New Helsinki Convention' of 1992 takes into account the Baltic Sea area's entire marine environment (Section 3.4.2).

Heritage of mankind
→Common heritage of mankind

High seas
According to Articles 86 and 89 of UNCLOS, the high seas are those parts of the sea that are not subject to the sovereignty or jurisdiction of any state and as such constitute 'an area under international administration'. The principle of freedom of the high seas applies in this area. This comprises primarily freedom of navigation and of overflight, freedom to lay submarine cables and pipelines, freedom to construct artificial islands and other installations, freedom of fishing and freedom of scientific research. These freedoms may be exercised by all states, including land-locked states. In the area constituting the high seas, no individual state is author-

ized to impose restrictions of any sort on other states relating to use of the high seas.

International Maritime Organization (IMO)
The IMO was created in 1948. Its task is to reduce, and if possible prevent, pollution by shipping, and to improve the safety and security of ships and shipping in general. The UN specialized organisation has 170 member states (2013) and three associate members, and together they represent more than 97% of world merchant shipping tonnage (Section 3.3.1).

International Seabed Authority (ISA)
The ISA was founded in 1994 to manage the mineral resources of the Area as the →common heritage of mankind (Article 1, para. 1, no. 2 of UNCLOS). It is responsible for approving and monitoring activities in the →Area (Section 3.2.3).

International Tribunal for the Law of the Sea (ITLOS)
ITLOS, which was set up in 1996, serves to settle disputes concerning the interpretation or application of →UNCLOS (Section 3.2.3).

London Convention and London Protocol
The London Convention (Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter) of 1972 (87 parties as of May 2013) was extended in 1996 by the addition of the Protocol to the London Convention (London Protocol; 42 parties as of May 2013). While the London Convention prohibits the dumping of certain substances that are on a 'black list', the London Protocol enshrines a general ban on dumping subject to certain exceptions. The exceptions include dredged material, sewage sludge, fishery waste, ships, platforms and other structures erected at sea, CO_2 in geological formations beneath the sea, organic material of natural origin and bulky structures (Section 3.3.2).

Low-oxygen zones
→Dead zones

Marine Strategy Framework Directive (MSFD)
Passed in 2008, the MSFD is an EU directive which places member states under an obligation to "take the necessary measures to achieve or maintain good environmental status in the marine environment" in all European seas (Article 1 para. 1 of MSFD). The European coastal states are called upon to implement the aims of the MSFD in their respective marine regions by developing and carrying out national strategies (Article 1, para. 2 of MSRL).

Marine
Marine is a geological locational name meaning 'in the sea'. By contrast, the term →maritime is used in relation to uses of the oceans, e.g. for maritime technology as opposed to marine ecosystems.

Maritime
The term maritime is used in relation to uses of the oceans, e.g. maritime technology as opposed to marine ecosystems. By contrast, the term →marine is a geological locational name meaning 'in the sea'.

MARPOL Convention
MARPOL is the Convention for the Prevention of Pollution from Ships, and was adopted in 1973 (152 parties as of April 2013). MARPOL primarily targets the ships' owners to stop the discharging of waste from ships into the sea during operations (Section 3.3.2).

Maximum sustainable yield (MSY)
The MSY denotes the maximum catch that can be taken from fish stocks on a regular basis. The idea is to maintain a size of stock that provides a maximum growth rate for the stock (Box 4.1-5).

Ocean acidification
The dissolution of carbon dioxide in seawater leads to considerable acidification (decrease in pH) and thus to changes to the biogeochemical carbonate/carbonic acid equilibrium. The oceans have absorbed about one-third of all anthropogenic CO_2 emissions to date, which has already caused a significant acidification of the seawater. In this way such emissions influence the marine environment directly – without the detour via climate change. Unabated continuation of the trend will lead to a level of ocean acidification that is without precedent in the past several million years and will be irreversible for millennia (Section 1.2.5).

Oceans Compact
The 'Oceans Compact – Healthy Oceans for Prosperity' is an initiative launched in 2012 by UN Secretary-General Ban Ki-moon to increase coherence between all the UN system's sea-related activities and to develop a strategic vision for a sustainable future of the oceans (Box 3.3-1).

OSPAR
OSPAR is the 1982 Convention for the Protection of the Marine Environment of the North-East Atlantic (Section 3.4.2).

Pelagic
Organisms that live in open water are called pelagic.

Planetary guard rails
Planetary guard rails are a concept introduced by the WBGU to describe quantitatively defined damage limits whose transgression would have intolerable or even catastrophic consequences. One example is the climate protection guard rail, which means that an increase in the global mean temperature by more than 2 °C above the pre-industrial level should be prevented. Sustainable development pathways do not transgress these guard rails. The approach is based on the realization that it is hardly possible to define a desirable, sustainable future in terms of a state to be achieved. It is, however, possible to agree boundaries for range that is recognized as unacceptable, and which society agrees to avoid. Compliance with the guard rails is a necessary, but not sufficient, criterion for sustainability

Public and common good
The WBGU uses the term 'public and common goods' as a generic term for both → public goods and → common-pool resources. By definition, no person or state may be excluded from the use of public and common goods for technical or societal reasons.

Public good
Public goods are goods which can be used by everyone, i.e. no one can be excluded from using them (→ public and common good); the benefit of a good id not subject to rivalry, i.e. the benefit that accrues to the individuals from the use of the good is not dependent on the number of users (Section 3.1).

Regional fisheries management organizations (RFMOs)
RFMOs are the central institutions of fisheries governance on the high seas. They offer forums in which the states can negotiate on cooperation for the purpose of the conservation and sustainable use of fish stocks (Section 4.2.4.4).

Regional marine management organizations (RMMOs)
RMMOs are institutions proposed by WBGU which are yet to be established; their primary aim is to organize the protection and sustainable management of all marine resources on the high seas (Section 7.2.2.2).

Seafood
Seafood is defined as all edible marine species including fish and shellfish, i.e. for example mussels, crabs, oysters, squid, sea snails, shrimps or lobsters, and including marine plants, i.e. seaweed or algae.

Social contract
A social contract is a hypothetical construct in which state orders are justified in so-called contract theories. The central idea behind the global social contract developed by the WBGU (2011) is that individuals and civil societies, the states and the international community, business and academia assume collective responsibility for avoiding dangerous climate change and preserving humankind's natural life-support systems.

Territorial sea
The territorial sea (Articles 2 to 32 of UNCLOS) extends up to 12 nm seaward from the baseline. The sovereignty of the coastal state covers this territorial sea and includes territorial jurisdiction over the sea, the air space above it, the seabed and the subsoil (Section 3.2.1.1).

United Nations Convention on the Law of the Sea (UNCLOS)
UNCLOS is the most important legal basis for the conservation and use of the seas under international law. The treaty is also referred to as the 'constitution of the oceans'. It establishes a comprehensive regulatory framework for the conservation and use of all the oceans and, as a framework convention, standardizes rights and obligations on a wide range of different uses of the ocean space and its resources. It was adopted in 1982 and came into force in 1994. 164 states and the European Union have ratified the Convention (as of January 2013; Chapter 3.2).

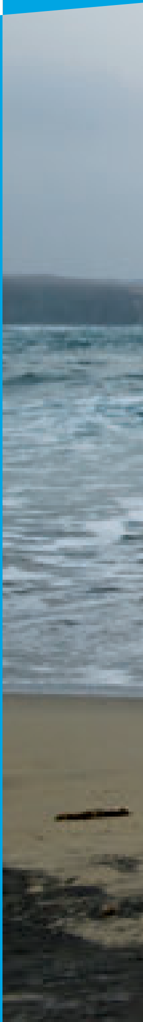
World Oceans Organization (WOO)
The WBGU proposes the creation of a WOO to assume the function of a global steward of the sea as the common heritage of mankind. The WOO would only intervene if the management and monitoring tasks assigned primarily to the UNCLOS states parties, or to regional marine agreements , were not being carried out in accordance with the principles of the → common heritage of mankind under international agreements. The institutions set up to date under → UNCLOS (i.e. the → International Seabed Authority and the Commission on the Limits of the Continental Shelf) should be integrated into the WOO's new organizational structure.

World in Transition
Governing the Marine Heritage

Despite numerous international treaties and voluntary commitments, the seas are still being massively overfished, polluted and increasingly exploited as the Earth´s last resort. In view of the oceans' poor condition the WBGU developed a long-term vision of the conservation and sustainable use of the blue continent: All marine zones with the exception of territorial waters should be declared the common heritage of mankind. In order to move closer to this ultimate goal for ocean governance, the WBGU also makes recommendations for action that link up with ongoing political processes. In this context it examines the example of two focal themes: food (sustainable fisheries and aquaculture) and energy from the sea. The report shows that sustainable stewardship of the oceans is urgently necessary, that the seas can be incorporated into a transformation towards a low-carbon, sustainable society, and that such a transformation can achieve substantial benefits worldwide both for a sustainable energy supply and for food security.

"The ´World in Transition – Governing the Marine Heritage´ report presents a thought provoking look at crucial aspects of oceans governance. It resonates strongly with our thinking in the World Bank and among the partners of the Global Partnership for Oceans. Nation states, civil society and industry need to work together to support more sustainable and productive ocean use. This report makes a valuable contribution to global thinking on how best we might secure a sustainable future from healthy oceans."

Rachel Kyte, Vice President, Sustainable Development, The World Bank



9 783936 191400

ISBN 978-3-936191-40-0