Deep-Sea Science and Governance: State of the art and future prospects

Third meeting of the HERMES Science-Policy Panel

Brussels, March 26th, 2009

Workshop Report

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This report follows the order of the presentations along the day. Slides for all presentations are available on the HERMES website (www.eu-hermes.net) in the 'Policy Advice' section. Annex 1 and 2 of the report contain the workshop agenda and participant list, respectively.

It emerged from the day's presentations and discussions that key HERMES results are relevant to the preparation of the report of the Secretary General on oceans and the law of the sea for the 64th session of the UN General Assembly (Autumn 2009). As a result, HERMES prepared a document (April 2009) entitled "Some key policy-relevant results from the HERMES Project", which was sent to the UN Division for Ocean Affairs and the Law of the Sea (UNDOALOS) and EC DG MARE and DG ENV. It is included in this report (Annex 3) and is available on the HERMES website[1].

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[1] http://www.eu-hermes.net/policy/Key_HERMES_results_May09.pdf.

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List of Acronyms

ABNJ	Areas Beyond National Jurisdiction
BAT	Best Available Technology
BEP	Best Environmental Practice
CBD	Convention on Biological Diversity
CCS	Carbon Capture and Storage
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CFP	Common Fisheries Policy
CoralFISH	Ecosystem based management of corals, fish and fisheries in the deep waters for Europe and beyond
CWC	Cold Water Coral
DG MARE	European Commission Directorate-General for Maritime Affairs and Fisheries
DG ENV	European Commission Directorate-General for Environment
DPSIR	Driving forces/Pressure/States/Impacts/Responses
EEZ	Exclusive Economic Zone
EC	European Commission
EIONET	European Environmental Information and Observation Network
ETC	European Topic Centre
EU	European Union
FP7	7th EU Framework Programme for Research and Technological Development
GES	Good Environmental Status
HERMES	Hotspot Ecosystem Research on the Margins of European Seas
HERMIONE	Hotspot Ecosystem Research and Man's Impact on European Seas
IMO	International Maritime Organisation
ISA	International Seabed Authority
IPBES	Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
MPA	Marine Protected Area
NEAFC	North East Atlantic Fisheries Commission
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
QSR	Quality Status Report
RFMO	Regional Fisheries Management Organisation
ROV	Remotely Operated Vehicle
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice of CBD
SCIs	Sites of Community Importance (under the EU Habitats Directive)
SIP	HERMES Science Implementation Panel
SPA	Special Protection Area (under the EU Birds Directive)
SPP	HERMES Science-Policy Panel
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNCLOS	United Nations Convention on the Law of the Sea
UNDOALOS	UN Division for Ocean Affairs and the Law of the Sea
UNEP-WCMC	United Nations Environment Programme - World Conservation Monitoring Centre.
UNGA	United Nations General Assembly
VMS	Vessel Monitoring Systems

1. Welcome and introductions

Dr. Jurgen Tack, Director of the Flemish Research Institute for Nature and Forest (INBO) welcomed the participants on behalf of the Flanders Authority. He informed participants that in Flanders, the marine research budget is continuously increasing.

Dr. Sybille van den Hove introduced the meeting on behalf of the HERMES community. She reflected on the factors that made HERMES so successful. These include: the funding, support and trust of DG Research of the European Commission; the support from many member states and associated countries in terms of funding, human resources and technical means; the outstanding and enthusiastic team of scientists from across Europe and beyond, including extremely dynamic PhD students and post-docs; the interdisciplinarity of the team and of the research, ranging from geology, oceanography, biology, ecology, all the way to socio-economics and law; and the trust, interest and inputs from policy-makers and other stakeholders, including in particular the Science-Policy Panel (SPP) and the Science Implementation Panel (SIP). On the science side, she identified several additional ingredients of success: a beautiful and challenging topic; new discoveries; state of the art and rapidly evolving technologies; and teamwork towards a peaceful objective.

She recalled the critical stakes in relation to the deep sea: the expansion of human activities and the rising anthropogenic impacts, with the consequent need for improved governance and integrated management to shift towards a more sustainable relation with our oceans and seas. Hence, the timeliness of the HERMES project.

2. Deep-Sea Research in Europe

EU-funded deep-sea research

Professor Manuela Soares, Programme Director, Environment and Sustainable Development Research at the European Commission Directorate General for Research, gave a presentation on the future of European marine research. She stressed that HERMES is widely seen as one of the great successes of the environment programme of FP6. The Science-Policy Panel has played an important role throughout the duration of HERMES to address stakeholders dealing with the deep-sea environment.

She described the forthcoming 2010 joint marine call under the 7th framework programme (FP7) for research, entitled 'Ocean of tomorrow: Joining research forces to meet challenges in ocean management'. The Environment Theme will be the largest contributor to this call in financial terms. A particular emphasis will be given to the issue of how research forces can be joined to respond to the challenges of the sustainable management of the ocean. The call will promote interdisciplinary approaches and multi-sectoral partnerships.

Manuela Soares stated that HERMES has tackled many of the issues identified in the EU strategy for marine and maritime research and it has addressed the complexity of the deep-sea environment. It has promoted excellence, as well as inter-disciplinary and multi-sectoral research. It has also contributed to the dialogue between scientists, policy makers, industrialists and representatives from society at large. The Science-Policy Panel has played a key role in this. For these reasons, HERMES appears as a precursor for the type of research projects that the marine and maritime strategy aims to promote.

The Commission, said Manuela Soares, is committed to continue to support the work of the deep-sea research community. In the immediate future, the HERMIONE project (Hotspot

Ecosystem Research and Man's Impact on European Seas)[2] will carry forward the work of the HERMES consortium, including the efforts to interface between science and policy. Moreover, the environment programme and the capacity programme, through the ESONET Network of Excellence and the EMSO infrastructure project, will support the community working on deep-sea observatories[3]. The Commission has also proposed a coordination action in its 2009 call to support the activities of the community involved in the Deep-Sea Frontier. Thus, all components of deep-sea research are taken into account.

The Deep Sea Frontier initiative focuses on research through the deep ocean water column down to the deep seabed and below. The Commission will organize a workshop in Brussels, on 25th May, to build upon the various science plans that have been produced by the deep-sea research community (e.g. the Deep Sea Frontier foresight document, the Science Objectives and Design of ESONET, the science plan of the Trans-Atlantic Coral Ecosystem Study (TRACES)). Other science plans will be produced in the relatively short term, including the strategy document that will be prepared by the HERMIONE project. The objective of the workshop will be to extract the key components of a future initiative.

Manuela Soares concluded that the work of HERMES is at the forefront of European research and that HERMES is an example of what the European Research Area can deliver. We are only at the beginning of moving towards the sustainable management of deep-sea ecosystems, she said. However, with HERMES, and its Science-Policy Panel, we have made important first steps in the right direction.

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Highlights from the HERMES project

A group of six HERMES scientists presented some key results from the HERMES project.[4]

Professor Phil Weaver, coordinator of HERMES, stressed that it is not possible to present all results of HERMES in less than an hour. The major project results are published in high-ranking scientific journals, as well as in a special issue of Oceanography, which was given to the participants during the meeting.[5]

He then presented ongoing research aiming at mapping and assessing impacts of human activities in the NE Atlantic. He showed preliminary estimates of areas impacted by bottom trawling, dumping of munitions and chemical weapons, marine scientific research, and submarine cables. He explained the difficulties of accessing human activities data, particularly concerning fishing, radioactive waste dumping, and military activities. Key issues regarding data on human activities impacting on the deep sea include questions on the existence of data, accessibility of data, ownership, relevance, quality, validity, formats, compatibility of datasets, and completeness. He concluded by speaking about the need for meta-datasets.

Dr. David Billett took the participants for a visual tour down Nazaré canyon, on the Portuguese margin. He emphasized the lack of knowledge about fauna in canyon systems and explained how species distributions are controlled by water depth. By using new technologies, in particular Remotely Operated Vehicles (ROVs), it is now possible to make detailed charts and maps of the seafloor, including in complex environments such as canyons. We can map where species are relative to features, and start combining them with maps of uses and maps of impacts, when they become available. This is an important step

[2] www.eu-hermione.net.

[3] www.esonet-emso.org.

[4] More detailed information on the HERMES project and research results is available from the HERMES website www.eu-hermes.net .

[5] *Oceanography*, volume 22 (1), March 2009. Access to electronic versions of the papers is possible via the Oceanography website at www.tos.org/oceanography.

towards the management of margins. He showed how different management schemes are needed for different areas of canyons.

David Billett presented a preliminary sensitivity analysis of the Nazaré canyon, in which various anthropogenic impacts were assessed using a traffic light system. He stressed that we should refrain from compartmentalizing the different anthropogenic pressures on the system, as synergetic effects are likely to be important too.

David Billett then showed results from other HERMES researchers indicating that commercial fishing in the North East Atlantic is harming deep-sea fish populations a kilometre below the deepest reach of fishing trawlers. Researchers started mapping the distribution of deep-water fish on the slopes off the west coast of Ireland in 1977 up until 1989 - before any fishery was established in the region - and again from 1997 until 2002. As part of HERMES, the researchers then compared the abundance of fish in the two different periods. Unexpectedly, they found that deep-sea fish numbers down to 2500 metres – almost a kilometre below the maximum depth of commercial fishing (1600 m) – were lower in the later 1997 to 2002 period. In addition, both target species and non-target species were affected. This phenomenon has important consequences for fisheries and marine reserve management, as this would indicate that the impacts of fisheries could be transmitted into deep offshore areas that are neither routinely monitored nor considered as part of the managed fishery areas.

Professor Roberto Danovaro focused on the links between deep-sea biodiversity and ecosystem functioning. A broad scale study based on nematodes shows that ecosystem functioning (e.g. prokaryote carbon production or nutrient regeneration) is positively and exponentially related to biodiversity in all deep-sea regions investigated (Mediterranean, North and Central Atlantic, Tropical and Equatorial Pacific, South Pacific, Southern Ocean). Such relationships between biodiversity and ecosystem functioning and efficiency suggest that a higher biodiversity supports higher rates of ecosystem processes and an increased efficiency with which these processes are performed. The exponential relationship between biodiversity and ecosystem efficiency supports the hypothesis of the existence of mutually positive functional interactions (ecological facilitation). So far, this relationship between biodiversity and deep-sea ecosystem functioning is different from those observed in manipulative experiments.

Deep-sea ecosystems provide goods (including biomass, bioactive molecules, oil, gas, minerals) and services (climate regulation, nutrient regeneration and supply to the photic zone, food). Their profound involvement in global biogeochemical and ecological processes is essential for the sustainable functioning of the biosphere and for human wellbeing. It has been estimated that a biodiversity loss of ~ 20-25 % can result in a 50-80 % reduction of deep-sea ecosystem key processes, and their consequent collapse. This would have significant consequences in terms of the services provided by these ecosystems. These results suggest that the conservation of deep-sea biodiversity can be crucial for the sustainability of the functions of the largest ecosystem of our biosphere.

During the discussion, it was clarified that at this stage the study only covered small benthic invertebrates and not all species. The exponential relationship was found at all sampled sites, demonstrating consistency across sites, although in some systems the exponential rates were higher than in others (e.g. in canyons).

Professor Miquel Canals reported on thermal shocks in the Western Mediterranean Sea and the North East Atlantic (Tisler Reef) and their effects on benthic communities, especially cnidarians and sponges. He explored what these situations have in common. Thermal shocks are positive temperature anomalies that penetrate the water column and that last only a matter of weeks to months. The first observations of thermal shocks were recent, e.g. dating back to 1999 in the Western Mediterranean and 2007 in Tisler Reef. They seem to be quite frequent (every 4 years in the Western Mediterranean, 2 years in the Tisler Reef region) and appear to increase their penetration depth with time (e.g. Tisler Reef). Thermal

shocks seriously damage or have lethal effects on sedentary, long-lived organisms (50-100y for gorgonians) that play crucial roles in sustaining complex benthic communities (e.g. the Mediterranean corralligenous communities). In both cases, community recovery becomes difficult or impossible ('no return') because of low recruitment and growth rates, and low mortality rates under 'normal' conditions. These shocks also favour the settling of alien species, which may further compromise recovery. In both cases, the direct cause of death seems to be disease, induced by thermodependent opportunistic pathogens. This has been proved for gorgonians in the Mediterranean and is suspected for sponges (*G. baretti*) in the Tisler Reef.

Overall, and in combination with other observations, these results illustrate how global warming is having an increased impact on the ocean ecosystem, from shallow to deep waters.

Professor Ann Vanreusel explored the role of active deep-sea mud volcanoes in methane emission to the hydrosphere. Methane emission from the seafloor can be recorded in the form of gas bubble escape (geophysical signals), upward floating of hydrates (observation), and diffusive transport of dissolved methane (chemical measurements). Modern *in situ* tools allow us to quantify methane emission in different deep-water habitats.

She explained how methanotrophic microorganisms act as a filter, hence representing an important barrier against methane emission from the seafloor. In most types of seabed, the biological filter against methane is 100% efficient (0% methane escape). However, at cold seeps, because of the high upward fluid flow, the efficiency of the microbial filter can be reduced to less than 20%. The reason for this reduction could be lack of electron acceptors, chemical composition of the fluids, or high mass transport of methane (bubble escape).

It is possible to estimate average methane emission from the centre of different active mud volcanoes: the annual emission of only 60-100 active mud volcanoes in the Black Sea explains its total aquatic methane content. Today, the total number of mud volcanoes in Europe remains unknown. When methane reaches the mixed upper water layer, it will enter the atmosphere and act as greenhouse gas. Moreover, global warming will cause increased methane release from the upper continental margin, as is currently observed around Svalbard. For this reason, Ann Vanreusel concluded there is a need to increase our knowledge and to monitor methane hydrate-rich regions on the European margins.

Dr. Anthony Grehan focused on HERMES socio-economic and immediately policy-relevant work. The current governance shift towards ecosystem-based management and the ecosystem approach (e.g. in the new Maritime Policy of the EU) requires the integration of fisheries, conservation, and other sectoral approaches, supported by robust marine spatial planning. This must build in particular on more integration between natural and social sciences. Such integration has been successfully developed in HERMES and will be strengthened in projects such as CoralFISH and HERMIONE.

He then gave some examples of socio-economic work in the HERMES project, including identification of deep-sea ecosystem goods and services, economic valuation of cold-water corals, and the combination of models of biological ecosystem interactions with economic models of human behaviour in the case of habitat-fisheries interactions to ascertain how different management strategies affect social welfare.

From the regulatory point of view, Anthony Grehan indicated that in Europe the basis for conservation of hotspot ecosystems of the type studied in HERMES can be found in the Annex 1 of the Habitats Directive which lists habitats of Community importance. In particular, 'reef' habitat including both biogenic concretions and rocky substrates and 'submarine structures made by leaking gas' are relevant, especially since the definition of 'reefs' has been clarified and extended in the 2007 Guidelines for the establishment of the Natura 2000 network. Cold seeps and mud volcanoes may currently be under low threat but their conservation is fundamental for science in well studied areas, in order to ensure payback from investment in long-time studies.

Anthony Grehan concluded by saying that the forthcoming HERMES and HERMIONE partial inventories of hotspots can be used to help Member States to identify potential sites for designation of conservation areas under Natura 2000 or international conventions. This is an example of potential direct economic and policy benefit accruing to individual Member States from HERMES research.

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During the ensuing discussion, participants suggested that the key HERMES results that are relevant to the preparation of the report of the Secretary-General on Oceans and the Law of the Sea for the 64th Session of the United Nations General Assembly (Autumn 2009) be sent to the UN Secretary General. In April 2009, HERMES prepared a short document entitled *"Some key policy-relevant results from the HERMES Project"* (Annex 3)[6], which has been transmitted to the UN Secretary General, DG MARE and DG ENV.

3. Deep-Sea Research and Governance

Deep-Sea Research for International Ocean Governance

In her presentation, **Ms. Kristina Gjerde**, High Seas Policy Advisor for the International Union for Conservation of Nature (IUCN), gave an IUCN perspective on deep-sea research needs for international ocean governance. She started by recalling the situation of the deep ocean as the largest biosphere on Earth with the highest biodiversity, and its many roles, e.g. as a reservoir of natural resources or for climate regulation. However, the deep ocean is also subject to various types of exploitation and is increasingly affected directly or indirectly by human activities. She stressed the importance of combined effects of human impacts, e.g. pollution, climate change, ocean acidification, invasive and alien species, and diseases. She also highlighted the emergence of potential or actual new uses of the oceans, including iron fertilisation and carbon sequestration.

She then addressed the governance framework for the deep sea. Governance includes fundamental goals, institutional processes and structures, and planning and decision-making. Science needs to inform both fundamental goals, and planning and decision-making. The fundamental goals of the United Nations Convention on the Law of the Seas (UNCLOS), as stated in its preamble, are to establish a legal order to facilitate international communication and to promote, *inter alia*, the peaceful uses of the seas and oceans, equitable and efficient utilisation of their resources, conservation of their living resources, and the study, protection and preservation of the marine environment.

The international legal framework also comprises a whole range of relevant treaties and institutions beyond UNCLOS, including: the Convention on Biological Diversity (CBD), the UN Fish Stocks Agreement, the Convention on Migratory Species (CMS), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Antarctic Treaty System, Regional Seas conventions and action plans, Regional Fisheries Management Organisations (RFMOs), the International Maritime Organization (IMO), and the International Seabed Authority (ISA).

UNCLOS defines a number of rights and duties that are now generally accepted as reflecting customary international law. In the High Seas, rights include the freedom to fish, navigate, lay submarine cables and pipelines, conduct marine scientific research, construct artificial islands, and authorize vessels to fly their national flag, while Parties have duties to conserve

[6] Also available at: http://www.eu-hermes.net/policy/Key_HERMES_results_May09.pdf.

living marine resources, protect and preserve the marine environment, cooperate, control vessels and citizens, and comply with other international legal obligations. Kristina Gjerde questioned whether such balance of rights and duties is appropriate for the 21st century since duties are not being implemented and the exercise of rights without effective State control can interfere with the rights and duties of others.

She also recalled that the mineral resources of the seabed in the Area are covered by a different regime, whereby mineral resources are 'the common heritage of mankind'; hence, resource rights are vested in mankind as a whole and environmental regulations have to precede mining activities.

At the 2002 Johannesburg World Summit on Sustainable Development, global commitments were taken to halt the decline of biodiversity by 2010; to encourage the application of the ecosystem approach in the marine management by 2010; to establish representative marine protected area (MPA) networks by 2012; and to restore depleted fish stocks to maximum sustainable yields by 2015, where possible, and to eliminate destructive fishing practices.

Despite this rich governance framework, challenges remain, particularly because current institutional processes and structures result in poor implementation, fragmented management, and flawed rulemaking. The problem is further compounded because of the existence of free riders and of many unregulated activities, which proceed despite a lack of basic knowledge or understanding of ocean processes, ecosystems, and anthropogenic impacts.

Previously, said Kristina Gjerde, marine conservation was seen as a luxury or, worse, a provocation. It is now becoming accepted that our planet's ecological systems are at risk of unravelling – and with that, life support for human beings will be jeopardized. Future governance goals will need to reflect a new imperative: maintain functioning ecosystems to enhance resilience to change. In a changing ocean, we need to update international oceans governance and bring institutions together to be able to base decisions on science, to act effectively, even in the absence of full knowledge, and to adapt to rapidly changing knowledge. Our institutions need to enable informed planning and decision-making based on: ecosystem-based approaches to management; environmental impact assessments; cumulative impact assessment; strategic environmental assessments; spatial planning; and the implementation of tools such as marine protected areas. We need to anticipate and minimize impacts, factor in the effects of past impacts (e.g. overfishing), and anticipate potential future influences (e.g. ocean warming, acidification). With good spatial planning, we can plan ahead, and across a range of scales, minimize conflicts of use, and develop a framework for responding to new and emerging activities.

Kristina Gjerde then listed a series of international activities that require input from the research community. In the context of deep-sea bottom fishing on the high seas, these include: UN General Assembly Resolution 61/105, whereby States and RFMOs have to "sustainably manage fish stocks and protect vulnerable marine ecosystems (…) from destructive fishing practices, recognizing the immense importance and value of deep-sea ecosystems and the biodiversity they contain" (§ 80); and the UN Food and Agriculture Organization (FAO) *International Guidelines for the Management of Deep-sea Fisheries in the High Seas*, which include criteria for 'Vulnerable Marine Ecosystems', significant adverse impacts, procedure for prior impact assessment, and encounter rules and thresholds.

In 2008, the CBD adopted scientific criteria for identifying ecologically or biologically significant marine areas in need of protection in open-ocean waters and deep-sea habitats, and guidance for designing a representative network of marine protected areas, including open ocean waters and deep-sea habitats (COP9, decision IX/20). There will be a follow up workshop in Ottawa on 29th September to 2nd October 2009 to provide scientific and technical guidance on the use and further development of biogeographic classification systems, and guidance on the identification of ecologically and biologically significant areas beyond national jurisdiction. To assist in its preparation and provide scientific support to the process,

IUCN is facilitating a new 'CBD Criteria Initiative' with support from the German government to engage scientists to provide comments and advice on applying the scientific criteria, provide illustrations of how individual criteria can be interpreted and mapped, and develop regional case studies.

In conjunction, UNEP-WCMC is developing an *'Interactive High Seas Viewer'* that will enable high seas information to be available to assist in improved spatial management decisions by a wide variety of users and sectors.

Kristina Gjerde concluded by identifying a series of pressing research needs. These include research on:

- the importance of biodiversity for ecosystem functions and structure;
- connectivity between ecosystems;
- direct, indirect, and cumulative effects of human activities;
- climate change;
- ocean acidification; and
- the role of deep-sea ecosystems in the Earth system.

She also flagged a number of meetings where discussions between scientists and policy-makers must continue, in particular:

- the regular process for reporting and assessing the state of the marine environment, which will have a meeting in New York in August 2009;
- the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen in December 2009;
- the 3rd UN Ad Hoc Working Group on Biodiversity Beyond National Jurisdiction (BBNJ), in early 2010;
- the meeting of the CBD Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) in April 2010;
- and the next meeting of the Conference of the parties to the CBD in Nagoya, Japan, in October 2010.

Kristina Gjerde also indicated that IUCN can act as a conduit between science and policy in many of these processes.

During the discussions, it was stressed that RFMOs need scientific input to be able to do impact assessments of deep-sea bottom fishing.

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Deep-Sea Research for European Ocean Governance

The EU Maritime Policy and the Strategy for Marine and Maritime Research: State of the art and prospects

Mr. Waddah Saab, Coordinator for the EU Marine and Maritime Research Strategy, DG Research, European Commission, spoke of the new strategy for marine and maritime research, adopted in September 2008, designed to be the scientific pillar of the European Union Integrated Maritime Policy.

The drivers for the marine and maritime research strategy are: a recognition of the importance of the maritime economy and the need to further develop it; an increasing environmental pressure from human activities and climate change; and an increasing

competition for a limited marine space. The research strategy aims at contributing to the conservation of the marine environment while facilitating the development of maritime activities such as shipping and fisheries.

The objectives of the marine and maritime research strategy are to understand the Good Environmental Status (GES) of our seas and to maximise the value we extract from our seas in a way that is compatible with their GES. Moving towards GES of our seas or the new frontier of deep seas would help address a crucial societal issue, help meet a legal obligation, and help develop new services and activities. Waddah Saab stated that there is no magic formula for the GES but rather a dynamic process of refining scientific knowledge and understanding complex mechanisms.

He explained that to achieve the objectives of the research strategy and ultimately of the Maritime Policy, the research strategy is structured along four axes: (i) the need to improve marine research infrastructure in order to observe and understand the impact of human activities and climate change on the marine environment; (ii) better integration of knowledge; (iii) better synergy between member states to maximise funding potential; and (iv) a new form of governance to deal with inter-disciplinary, multi-sector scientific and industrial communities. These elements are also requisites for a scientific approach to the Good Environmental Status. Along these lines, Waddah Saab mentioned the possibility to use structural funds for research infrastructure; joint programming by which Member States can jointly address issues of high importance; Article 169 initiatives such as BONUS169 for the Baltic Sea; a specific support action to develop a "Maritime Partnership" for the marine and maritime science communities; and better coordination of bi-lateral cooperation between Member States and third countries.

On the science-policy interface, Mr. Saab recalled that the Galway process, which led to the Galway and later the Aberdeen declaration, was significant because the scientific community took the lead and their messages were heard by the policy-makers, hence the science-policy interface worked informally. He also praised the work of DGRTD Unit I.4 (Management of Natural Resources). We now need a more organised science-policy interface, he said; in particular, this will lead to a better understanding of the stakes of the Marine Strategy. He concluded that it is important to keep reminding policy-makers that the Maritime Policy should be science-based.

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Moving towards a sustainable European marine data infrastructure

Dr. Iain Shepherd, Policy Officer in DG Maritime affairs of the European Commission, presented on the current status and steps towards a European Marine Observation and Data Network (EMODNet). He started by summarising why scientific and monitoring data is underused, and put forward suggestions on how to overcome this issue.

Data is underused for several reasons, including, *inter alia*, lack of knowledge of existence of data; difficulties in accessing data because of confidentiality, reluctance to share or desire to exploit data; costs of data; coherence of data, especially cross-disciplinary or cross-border; and quality and quantity of data.

European environmental law provides a framework to address some of these issues. In particular, discovery is covered by the INSPIRE Directive (2007/2/EC), access by the Environmental Information Directive (2003/4/EC), and use by the Public Sector Information Directive (2003/98/EC). However, these directives apply to bodies exercising public authority and not necessarily to research establishments. Another issue is the maintenance of data repositories (e.g. catalogues, websites …) after funding for research projects stops.

To develop incentives to make data available in EMODNet, the European Commission has identified eight design principles:

1. Collect data once and share it many times. This is especially important if funding for data collection is paid by public money. Of course, this does not obviate the need for confirmatory measurements.
2. Develop interoperable standards between different disciplines as well as within communities.
3. Focus on sea-basins (e.g. ICES) and process at laboratory level, national level, sea-basin level, and European level. European level is connected to sea-basin level.
4. Ensure sustainable funding at EU level.
5. Build on existing structures such as Eurogeosurveys, International Hydrographic Organisation, regional sea conventions, and EuroGOOS.
6. Ensure links between those collecting data and those using it ('user driven'), and develop feedback mechanisms and well-defined priorities.
7. A statement concerning ownership, rights of use, precision, and accuracy should accompany data. This allows further recognition of data providers.
8. Freedom of use for publicly funded data.

Ian Shepherd then presented the agenda and the next steps for EMODNet, including the preparatory actions, the public consultation in spring 2009, the preparation of a policy impact assessment for the end of June and the adoption of an action plan by February 2010. He also stressed that issues of intellectual property rights still constitute a big barrier to the distribution of data.

During the discussion, some participants agreed that data are the foundation for decision-making, and asked whether the European Commission would be looking at replacing existing arrangements. The Commission replied that it would build what is already there. It would encourage interoperability but it may require some new structures at sea-basin level to monitor quality, analyse gaps and prepare layers. Furthermore EMODNET is not supposed to be a tool only for public authorities - it should also help private business and the research community.

HERMES participants also indicated how HERMES and HERMIONE are putting a lot of effort to keep their data 'alive' past the end of projects, in particular through the systematic use of the information system PANGAEA[7] as an archive, publisher and library for its data.

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Experiences with off-shore marine protected areas in Norway

Dr. Jan Helge Fosså, Senior Scientist, HERMES and Institute of marine Research, Norway, discussed the protection of offshore vulnerable marine ecosystems in the context of coral Marine Protected Areas in Norway, and the use of Vessel Monitoring Systems (VMS) for planning and monitoring MPAs.

He started by describing the destructive effects of bottom trawling on *Lophelia* reefs. He then showed an updated coral distribution map of cold-water corals in Norwegian waters which has been sent to the Pangaea information system through HERMES.

Currently, there are three offshore and three coastal/fjord coral MPAs in Norway. Three more are proposed and are currently on hearing, of which two are HERMES study sites. The legal basis for protection includes the Seawater Fisheries Act, an Act related to Norway's EEZ, by which intentional destruction of coral reefs is forbidden, special precaution is required when

[7] http://www.pangaea.de/

fishing in the vicinity of known reefs, and bottom trawling can be excluded from specified areas through the establishment of coral MPAs. The other relevant piece of legislation is the Nature Conservation Act under which protection can be granted against (all) human activities in coastal waters (<12 nm).

The guiding criteria used to propose MPAs are: (i) potential threats by fishing activities; (ii) vulnerability (e.g. reefs living in sub optimal environmental conditions); (iii) uniqueness; (iv) representativity (to which degree the occurrence in question represents an area with special environmental conditions, such as north/south, fjord/coast, deep/shallow, shelf/shelf edge); (v) seeding capacity (contribution to the spreading of larvae); and (vi) scientific reference (access, existence of time series, uniqueness, etc).

Jan-Helge Fosså then discussed VMS as a tool to identify, and monitor compliance with, MPAs. At the identification stage, VMS can serve to evaluate conflicting interests from a management point of view, and to evaluate the likely condition of coral fields (level of impact if any) from a scientific point of view. As for monitoring, plots derived from VMS data indicate that there is a high degree of compliance by trawlers within MPAs, yet in coral fields with no MPA, a very different situation arises. It was suggested that VMS is a cost-effective tool in planning and monitoring of MPAs, and that the development of Marine Spatial Planning is an important way forward for effective ocean governance.

Jan-Helge Fosså then presented the case of the Sula coral MPA, which is protected from bottom trawling, proposed as an MPA in a national system of protected areas, and nominated by Norway as an OSPAR MPA. Nevertheless, oil and gas exploration may soon be licensed in the area and there are conflicting interests between the fisheries, environment, and energy sectors. One weak point in the system, said Dr. Fosså, is the difficulty to operate across sectors.

He concluded that further research is needed for the documentation of vulnerability and ecological importance of marine ecosystems, and impacts on marine ecosystems. Thus, research should not only be (strongly) supported by the government, but also fishers and the public alike. As for management solutions, they should include all relevant sectors. Integrated and effective management requires openness in the transfer of information and knowledge, by which all stakeholders must receive the same information (industry, environmental NGOs, fishers, etc).

During the discussions, Jan-Helge Fosså indicated that MPAs are only currently protected against fisheries. Furthermore, there is not really a network of MPAs, but rather a series of sites chosen from different geographical regions, as we know too little about interconnectedness to build a network. He also stressed the need to protect pristine reefs first to avoid a situation whereby fishers move away from newly protected areas to pristine ones. Yet, fishers and managers know that biodiversity has to be protected. The CoralFish project will look more closely at the ecosystem services provided by corals and different fish species.

It was also asked whether HERMES research has been fed into policy to identify MPAs. Indeed, the areas mapped during HERMES cruises form the basis of information provided to the ministry.

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4. Marine Environmental Assessment, Monitoring, Risks, Exploitation and Management

Assessing deep sea ecosystems in Europe as a tool for conservation

Professor Jacqueline McGlade, Executive Director of the European Environment Agency, reflected on how the results from the HERMES project can be used to increase the quality of environmental assessments. She stressed the need to consider ecosystems as part of Europe's heritage.

The European Environment Agency (EEA) is the EU body dedicated to providing sound, independent information on the environment. Its main tasks are: (i) networking, based on tools such as the European Environmental Information and Observation Network (EIONET) or European Topic Centers (ETCs); (ii) Reporting on the state and trends of Europe's environment, based on tools such as indicators and assessments; and (iii) providing access to environmental information, based on tools such as information systems.

EEA also has some additional 'entry points' for ecosystem assessment work within its mandate to carry out analysis of EU policy effectiveness and its role as a science-policy interface.

Jacqueline McGlade highlighted the status of Natura 2000 in the marine environment. The marine territory of the 27 EU member states is bigger than its terrestrial counterpart, accounting for 59% of the EU 10.5 million km². Nevertheless, progress with the establishment of the marine component of the Natura 2000 network is slow. Currently, not only are there very few 'marine' sites (defined as those sites in which a marine part is noted), but most of these are just a continuation of a 'coastal' site. Extremely few are offshore, hence fully marine, both for technical and political reasons (linked to legal issues in relation to the countries' EEZ). The EC has been supporting further marine designations by producing guidelines and interpretation of the habitat type definitions**.**

The figures for the EU as a whole, as of June 2008, indicate that:

- For Special Protection Areas (SPAs) under the Birds Directive: of the 531 'Marine' SPAs (out of 5,004 in total), about 40 are truly marine (offshore) sites.
- For Sites of Community Importance (SCIs) under the Habitats Directive: of the 1,294 'Marine' SCIs (out of 21,612 in total), about 200 are truly marine (offshore) sites.

The marine component of the Habitats Directive annexes is not sufficiently developed. It would need revision at some point with help from scientific experts. Specifically for the deep-sea, very few habitats are covered, as indicated by Anthony Grehan in his presentation. The EC will need more information on the distribution and the conservation status of deep-sea habitats from Member States. As well as the Habitats Directive, Regional Conventions such as Barcelona and OSPAR are also in the process of prioritising habitats and species for protection, and developing maps.

Jacqueline McGlade expressed how the integrated studies produced by HERMES are helping to gain new insights into the biodiversity, structure, function, and dynamics of ecosystems along Europe's deep-ocean margin, and to feed into the marine assessments of EEA. In particular, there is a need to identify the drivers of ecosystem changes, which constitute key building blocks for environmental assessments.

Regarding marine assessments, the EEA is enriching its Driving forces-Pressure-States-Impacts-Responses (DPSIR) approach with an approach in terms of ecosystem services based on the Millennium Ecosystem Assessment framework. Furthermore, future assessments need to reflect the fact that key environmental regulations are now building on an ecosystem approach (e.g. the Water Framework Directive, the Marine Strategy Framework Directive and the Integrated Maritime Policy). In particular, this will allow to better

account for land and marine interactions (e.g. land-based inputs to the marine environment) and to provide a more integrated picture of the situation. EEA is also striving to increase the pan-European coverage of assessments, aiming at a deeper and more balanced treatment of the four regional seas.

Jacqueline McGlade then briefly introduced the 2012 EEA Ecosystem Assessment (EURECA), which is currently being prepared and for which a marine component is under consideration. It could focus on fishing impacts on marine ecosystem services, to support the 2012 reform of the Common Fisheries Policy (CFP).

On the integration of deep-sea issues in EEA assessments, some possible improvements were suggested:

(i) As part of fisheries assessments: highlighting which of the fish stocks accounted for in the indicator on the status of fish stocks are deep-sea stocks. Eventually adding a 'sea bottom' impact aspect and linking to deep-sea ecosystem status.

(ii) For acidification: using examples of deep-sea impacts and/or indicators and mapping European cold-water corals.

(iii) For Natura 2000: identifying which are the deep-sea areas designated, if any; highlighting that the status of some deep-sea habitats (e.g. cold-water coral reefs) should have been reported by member states; and asking why their status is still unknown. Additionally, including a general statement on progress made regarding MPAs and halting marine biodiversity loss in the deep-sea, hence linking with the commitments made under the CBD.

Currently, the data used by the Agency for the (small) deep-sea components of its assessments comes mainly from research for which funding is often ephemeral. There are also issues of loss of data when projects end or people move on. There is a need for more incentives to store data for the long term. Systems that give credit for data based on unique identifiers with intellectual property rights may help here. Such systems exist in other fields, e.g. in the cancer research community in the US, and could be applied to ecological research communities.

WISE-Marine (the marine component of the Water Information System for Europe) was introduced. This scheme - under development since 2007 - should allow access to data and information, although it mainly aims at providing an 'interpretation' of this information, e.g. indicators and assessments. It will be important to ensure a good link with FP projects. The EEA views the European Marine Observation and Data Network (EMODNET) as the future primary provider of marine data for WISE-Marine. EMODNET will eventually provide a set of principles for sharing data: HERMES data could then also be included. HERMES can also contribute data to the seabed-mapping project, in particular to expand the classification.

Jacqueline McGlade then informed participants about the recently completed draft 'Assessment of Assessments' [8], a step towards a regular process for global reporting and assessment of the state of the marine environment, as called for by the UN General Assembly. The draft stresses that the deep sea needs more attention. A meeting will be held in New York, from 31 August to 4 September 2009 to recommend a course of action on the Regular Process to the General Assembly at its 64th session. It is likely that a global assessment will be produced every five years.

During the discussions, it was proposed that HERMIONE could contribute a case study on deep-sea ecosystem services to EURECA and/or a case study on the deep sea for SOER 2010, the next European Environment State and Outlook Report. A meeting between HERMIONE and EEA can be organised.

[8] http://www.unga-regular-process.org/

The current process towards an Intergovernmental science-policy platform on biodiversity and ecosystem services[9] (IPBES) was mentioned. At this preparatory stage, there are still many opportunities to ensure that the deep sea is taken into account in the design of IPBES. This will imply worldwide collaboration on the deep-sea components as well as more research to document the goods and services provided by the deep sea and the broader value of the deep sea. HERMIONE can contribute significantly in this regard.

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Environmental challenges in Arctic oil and gas exploration and production

Mr. Arne Myhrvold, Environmental Advisor, StatoilHydro, started his presentation by stressing that HERMES has inspired StatoilHydro to initiate more research into how its operations are having an impact on the environment, and how to monitor and assess impacts, but also on how to do such research. He then presented an overview of the challenges relating to the progression of oil and gas exploration and production in the Arctic, from the perspective of StatoilHydro.

The company believes that the Arctic region contains significant oil and gas resources both in terms of discovered oil and gas reserves and yet to find resources. In a global context, the arctic region is not as distant as often perceived. It is close to three large energy markets: the North American, the European, and the Asian markets. Hence, StatoilHydro recognises that the Arctic will play a significant role in the long-term global energy supply and is now putting some extra focus on the area, beyond its current operations in the Norwegian Barents Sea. Yet with these opportunities, the company is aware that there are also significant challenges. The presentation focused on the environmental issues, but challenges are also associated with operating on ice, in dark and remote locations, and with societal issues.

StatoilHydro acknowledges that its activities can adversely affect the environment. Impacts may result from emissions, discharges, or land use threatening biodiversity or cultural heritage. Impact on the environment is determined by state and capacity of the area affected, type of activity, technology applied, and operational standards. StatoilHydro recognises the link between the use of fossil fuels and anthropogenic changes in climate. They also consider biodiversity conservation as a key element of sustainable development. Their activities may sometimes harm individual organisms, but this does not mean a failure to conserve biodiversity, provided significant impacts on natural habitats and ecosystem functions are avoided. Overall, said Arne Myhrvold, the company aims at 'Zero harm' to the environment. To achieve that, one needs to know the environment. StatoilHydro uses environmental monitoring to follow up and document any effects of their activities.

More specifically, in the Arctic the company is using a stepwise approach to development. The current timeline aims at the development of a toolbox for risk assessment in 2009; implementation of real-time environmental monitoring in 2010; one or two operational test sites where installations could be used as seabed observatories in 2011; the development of an 'Arctic Oil Spill Response Toolbox' by 2012; an environmental impact evaluation system by 2013; and implementation of a total environmental management system by 2014.

An important goal is to assess the actual environmental impact from regular and accidental discharges on arctic ecosystems. This is done by exposure/dilution modelling relevant for Arctic conditions; tuning risk assessment tools to the Arctic; arctic ecosystem modelling of multispecies (integrating risk/impact of discharges in ecosystem models); and integrating environmental monitoring to validate and update models.

[9] http://www.ipbes.net

StatoilHydro is also developing an 'Arctic Oil Spill Response Toolbox' with the aim of widening the array of available tools, hence the window of opportunity to fight oil spills. For ice-covered waters, it will include: mechanical recovery equipment; in-situ burning; use of dispersant; knowing fate and behaviour of oil; detection and monitoring of oil in ice; and modeling. In coastal areas, it will include oil detection and surveillance in darkness; technology for oil cleaning on shorelines; knowing fate and effects of dispersant use in coastal areas; knowing fate and weathering of oil on shorelines; improved oil spill response technology; improved modeling tools; and oil spill contingency plan for Arctic waters.

StatoilHydro wishes to establish guidelines for environmental monitoring in Arctic areas by building on existing knowledge from other climatic conditions (North Sea/Norwegian Sea) with a focus on reliability in extreme weather conditions. It will include mapping of environmental status; sampling and analysis of contaminants in air, soil, sediments, groundwater, and in biological tissues; and assessing other relevant ecological parameters (e.g. sensitive species).

Arne Myhrvold concluded by mentioning some of the successful cooperation schemes that exist between StatoilHydro and HERMES or HERMES partners. CORAMM (coral risk monitoring and modelling) focuses on possible impacts of drill cuttings on corals, and environmental monitoring methodologies for corals. On another front, landers have been deployed in Nordland VII for the mapping of baseline situation, assessing physical and chemical parameters, and studying the biology. Meanwhile, an interesting monitoring effort takes place along a deep to shallow water transect in Kongsfjord – Hausgarten, to study changes in faunal composition with depths and possible impacts of higher temperatures on faunal composition.

During the discussion, it was stressed that science envies the day to day exploratory work and monitoring made by oil companies. If such data could be shared more systematically, it would be of high value to the scientific community. We are however not yet there, partly because of lack of resources, partly maybe also because collaborations need to be geared up.

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OSPAR: The Quality Status Report 2010

Professor David Johnson, Executive Secretary, OSPAR Convention, provided an overview of the Quality Status Report 2010. He started by a brief introduction on the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention). The main objectives of the Convention are: to prevent and eliminate pollution; to protect the sea from adverse effects of human activities; to safeguard human health; to conserve marine ecosystems; and to restore affected marine areas. In doing so, OSPAR applies an ecosystem approach, the precautionary principle, the 'polluter pays' principle, best available technology (BAT) and best environmental practices (BEP). OSPAR adopts and implements programmes and measures, and carries out periodic general assessments of the quality status of the North-East Atlantic and its sub-regions, namely Quality Status Reports (QSR).

QSRs include analyses of: the hydrodynamics, chemistry, habitats, and biota; the impact of humans over space and time against the background of natural variability; and the cumulative and relative impact of all the human pressures on the marine environment. They also include an evaluation of the effectiveness of the measures taken and identification of priorities for action.

Early North Sea Quality Status Reports were published in 1987 and 1993. They drew together for the first time all available information on inputs to the sea, concentration levels and effects of pollutants. In 2000, the QSR 2000 provided a comprehensive assessment of

the environmental quality of the North-East Atlantic, based upon regional QSRs prepared for each of the five OSPAR regions. It built on six years of scientific work on monitoring and assessment, supported by monitoring over a much longer period. The major issues identified at the time were the impact of fisheries and the need to continue work to combat hazardous substances.

The Quality Status Report 2010 will be launched at the 2010 OSPAR Ministerial Meeting in Bergen, Norway. Its main objectives are: (i) to assess the quality status of the marine environment of the North-East Atlantic; (ii) to evaluate progress in applying the ecosystem approach to the management of human activities which may affect the marine environment, and (as part of this) in implementing the OSPAR Strategies; (iii) to highlight any new, changed or emerging threats to the marine environment; (iv) to identify priorities for regulatory action; (v) to identify significant gaps in knowledge in order to define priorities for further scientific, economic and/or social investigations; and (vi) to cover, as far as possible, the initial assessment requirements of the EU Marine Strategy Framework Directive.

The report will examine all aspects of human influence on the sea, including contaminants, nutrient pollution and radioactive substances and the effects of human activities such as the offshore oil and gas industry, offshore wind farms, maritime transport, and fisheries. Compared to previous QSRs, it will include some new elements, notably climate change impacts, mitigation and adaptation; new human uses, e.g. marine renewable energies and carbon sequestration; and the protection and conservation of biodiversity and an ecosystem approach assessment. The report is now in its compilation and drafting phase, until October of 2009. In November 2009, there will be a stakeholder e-consultation, followed by a scientific peer review. The publication phase will last from January to April of 2010, and the launch will take place in Bergen in September of 2010. QSR 2010 is to serve as a platform for decision, for prioritisation of actions and for revising management strategies.

David Johnson stressed some of the challenges associated with the production of the QSR. Integration of information about different impacts is not straightforward, for instance how to integrate fisheries impacts with radioactive impacts. The QSR has to be holistic but take site-based information (e.g. from HERMES) into account. It also has to ensure that there are no significant gaps. There are also issues linked to the fact that some states are not contracting parties, but have a right to operate in Areas Beyond National Jurisdiction (ABNJ). For instance, Russia is interested in minerals from international waters. ABNJ represent 40% of the OSPAR area. Furthermore, the knowledge available in the five different OSPAR regions is not homogenous.

In the context of the Quality Status Report 2010, David Johnson noted that OSPAR relies on evidence. In this context, it is important for OSPAR to capture the key results of projects such as HERMES and ensure consistency with other results. For instance, HERMES and its follow-up projects can help answer questions such as which impacts take precedence and what are the cumulative impacts in the deep sea. In this manner, some core results from HERMES have the potential to influence the strategy for the next ten years. They can also change specific policy decisions, for instance by triggering establishment of bigger protective zones around cold-water coral areas or providing analogues for areas where we have no data. HERMES results could also feed in the report as case studies. It is particularly important that HERMES contributes to the stakeholder consultation in November 2009.

David Johnson concluded by stating that the oceans are at a tipping point and there is a need for bold action from politicians. The period 2010-2014 will see a host of activities on ocean governance, which makes the QSR 2010 extremely timely.

During the discussion, it was asked how QSRs relate to the future regular process for reporting and assessing the state of the marine environment. This process will inform the QSRs which are decadal, whereas the regular process is likely to be a 6 year reporting cycle.

It was also asked whether the QSR will look at fisheries and fisheries management. Fisheries are not in purview of OSPAR but the QSR will need to look at where fisheries do have an

impact on what is in the remit of the convention. For that, OSPAR needs to strengthen its relations with the North East Atlantic Fisheries commission (NEAFC).

The network of marine protected areas that OSPAR is developing was discussed, particularly as regards potential conflicts with other regulatory regimes, such as ISA, NEAFC or the IMO that may have different agendas. This is a complex and time-consuming process but progress is being made regarding integration across regimes.

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Storage of CO_2 below the Seabed

Professor Klaus Wallmann, Head of the Research Unit "Marine Geosystems", IFM-GEOMAR, gave a presentation on the potential storage options of CO_2 below the seabed, and the risks associated with such a prospect.

Natural and manmade reservoirs were described and the potential risks of the latter explored, in particular possible leakage pathways. Examples were given of natural gas seeps in the Black Sea. The Sleipner Field (Norway) was presented, where 1 Mt of CO_2 has been injected each year since 1996. The monitoring by StatoilHydro shows that there is a lateral spread of the CO_2 stored in the subsurface towards the North, but there seems to be no pressure increase. It is also possible that natural seeps of natural gas exist at Sleipner. In the North Sea, natural gas seepage is common, but natural CO_2 seepage was also observed, e.g. off the German, East Frisian Island of Juist at 35 m water depth, which has a similar geology as Sleipner. The CO_2 in natural seepage is a leftover from sulphate/methane anaerobic reactions. A more recent storage site is Snoehvit, in the Barents Sea. There, CO_2 separated from natural gas has been injected in the slope sediments since 2009 at 0.7 Mt CO_2/a, in a water depth of 330 m and a sediment depth of 2600 m. Possible leakage pathways to the ocean were discussed, including through faults and drill holes.

Klaus Wallmann identified the key research and policy needs, from a geoscience perspective, as:

- Understand the geological, physical, and chemical controls on leakage of CO_2, formation fluids, and natural gas from sub-seabed geological formations through faults, fractures, boreholes and other high permeability conduits.
- Study natural seepage as precursor and analogue for future CO_2 leakage from sub-seabed storage sites.
- Survey the seafloor above geological formations currently used for CO_2 storage (Sleipner, Snoehvid) for natural and manmade seepage.
- Refine the specific requirements for the assessment of cap rock and cap sediment integrity from a marine geo-scientific perspective.
- Develop a monitoring scheme for the safe operation of present and future sub-seabed CO_2 storage sites.

Klaus Wallmann then explained how the volcanic CO_2 seeps in the Mediterranean and the natural CO_2 seeps in the North Sea provide grounds for research on effects of CO_2 leakages on the surrounding biota. The environmental impact of CO_2 leakage at the seafloor can be local, affecting just the seafloor; regional, affecting the ocean more broadly; or global, affecting the atmospheric system. Hence, criteria for the maximum permissible CO_2 flux from submarine CO_2 disposal sites must ensure that CO_2-leakage does not affect: (i) benthic ecosystems at the disposal site; (ii) pelagic ecosystems and seawater pH; and (iii) global atmospheric pCO_2-values.

Research and policy needs from a bioscience perspective were identified as:

- Determine the sensitivity and resilience of benthic organisms towards enhanced CO_2 values in bottom waters and pore waters.
- Identify indicator organisms featuring a strong response to elevated CO_2 levels.
- Unravel the chemical parameters controlling the response of biota to elevated CO_2 (pH, saturation state with respect to $CaCO_3$, pCO_2, H_2CO_3 concentration,…).
- Characterize and model the effects of CO_2 leakage on local benthic ecosystems for different CO_2 emission rates.
- Identify sensitive areas in the European EEZ that should be excluded from off-shore CO_2 storage activities (potential marine protected areas).
- Define a maximum permissible CO_2 leakage rate from a benthic perspective.

In general terms, the deeper you go, the safer you are, said Klaus Wallmann, but the higher the costs; in particular the risk of leakage decreases with increasing depth. There is a need to balance between risks to the environment and global advantages. From a legal perspective, the precautionary principle should be applied.

From an economic perspective, research and policy needs include:

- Assess the full cost of sub-seabed CO_2 storage (CO_2 transport, development of the storage site, injection, monitoring, CO_2 leakage).
- Study the trade-off between storage costs and storage safety, i.e. injecting deeper with lower leakage risk but higher cost, or saving cost at a higher leakage risk.
- Specify the trade-off between monitoring requirements and costs.
- Compare the full cost of storage to other mitigation costs in a future global climate policy architecture.

From a legal perspective, research and policy needs were identified as:

- Provide a general overview of the international and European legal framework within which carbon capture and storage (CCS) activities may lawfully be performed.
- Investigate how the existing legal rules address the issue of CO_2 leakages, and analyze whether these rules are appropriate.
- Develop an understanding of the precautionary principle as the primary tool for balancing the risks for the environment arising from CO_2 leakages, the global environmental advantages of sub-seabed carbon storage, and the economic costs of such activities.
- Develop minimum standards for the authorization of sub-seabed CO_2 storage projects, and for the implementation of an effective monitoring scheme introduce, if necessary, amendments to the existing legal rules.

In general, the seep research community has to team up with the reservoir geologists, socio-economists, and law experts to provide integrated research on, and assessment of, CO_2 storage below the seabed.

During the discussions, it was asked for an estimate of how much CO_2 we would need to sequester to make a difference to climate change. A large power plant creates 6-8 Mt of CO_2 per year, which is more than the current storage rate at Sleipner. To make a difference we would need to store the CO_2 from 100 of these power plants.

It was also asked whether CO_2 hydrates would not melt. At 400 to 1000 metres, they can stay stable; they do have a larger temperature stability window than methane.

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5. Summary of the day

Dr. Jeff Ardron, Director High Seas Program, Marine Conservation Biology Institute (MCBI), concluded by summing up the key points from the presentations and discussions of the day, and offering his final thoughts.

Five key themes that transpired from all presentations and discussions were:

1) the deep sea is broadly recognised as an emerging frontier of scientific research;

2) access to data is a common focal point across studies, especially when attempting to understand the human footprint of activities;

3) the increasing value of interdisciplinary cooperation, particularly in marine spatial planning, was emphasised;

4) there is increasing interest in assessments related to ecosystem health (e.g. Marine Strategy Framework Directive *good environmental status*; OSPAR 2010 quality status report; Assessment of Assessments, UN General Assembly resolution 61/105 relating to *vulnerable marine ecosystems*, and identifying the Convention on Biological Diversity's *ecologically or biologically significant areas*); and

5) in order to carry out assessments and other related work, a core set of commonly agreed-upon ecological indicators will need to be developed.

Today, we are witnessing a blurring of boundaries and barriers between NGOs, science, policy, and the private sector. Data is the starting point of everything, said Jeff Ardron, all these actors hold data and data exchange amongst them is increasing.

There is a lot of good science and expertise currently available, but this has not yet been sufficiently interpreted and incorporated into marine policy and spatial planning. Despite the increasing number of assessments, we are still failing to meet our environmental objectives and targets. Thus, the production of ecological assessments should not be confused with the achievement of our ecological goals.

While we are moving towards the implementation of regional marine spatial planning, we have not yet managed to do this. EU governance remains fragmented and sector-based. That said, Europe is leading the world towards more holistic integrated approaches, notably in overarching regulatory mechanisms such as the Marine Strategy Framework Directive, the Maritime Policy and the INSPIRE Directive. For Europe, said Jeff Ardron, the central challenge is to combine a cross-sectoral approach with a cross-national approach bringing together 27+ countries.

As regards data, he noted that while the collection of data is a starting point, it should not be seen as the end point. Databases need to be set up based on open data standards (e.g. www.opengeospatial.org), to be made inter-operational. This can be done relatively quickly, e.g. within two years.

On the interfaces between science and policy, he stressed that science-policy integration needs to be improved. Research should be seen as a public service. Science has to try a bit harder to answer policy-relevant questions and to interpret this knowledge for policy-makers and stakeholders. Likewise, policy-makers should be a bit more serious about making decisions based on science. Instead, we are often delaying difficult questions, especially when we do not like the answers...

Jeff Ardron emphasised the fact that the deep sea is characterised by huge uncertainties and at times, he said, we have to admit that 'we simply don't know,' hence the importance of a precautionary approach. But, even in this context of uncertainty and ignorance, we need to

talk more about why the good functioning of deep-sea ecosystems is so important, notably in terms of goods and services, and to make the risks and the trade-offs more visible.

He also called for a core set of generally accepted ecological baseline indicators, which could be augmented with other indicators specific to a region. Transatlantic cooperation on this matter would greatly strengthen science's ability to evaluate broad issues, such as climate change, at an ocean basin scale.

Jeff Ardron concluded by wondering whether we should really 'tame' our last frontier. Like past frontiers, will we as scientists also passively chronicle the decline of deep-sea biodiversity and abundance? Will we count the last Orange Roughy just as we did with the last Sea Cow or the last Dodo? Mankind is at a crossroads, a dangerous intelligence one might say, which allows it to develop 'cool tools,' but still lacking the wisdom to know how to best use them. He closed his presentation with two quotations:

For he that gets hurt
Will be he who has stalled
There's a battle outside
And it is ragin'.
It'll soon shake your windows
And rattle your walls
For the times they are a-changin'

Bob Dylan, The times they are a-changin', 1963

That we are in the midst of crisis is now well understood […] a consequence of greed and irresponsibility on the part of some, but also our collective failure to make hard choices and prepare the nation for a new age […] On this day, we come to proclaim an end to the petty grievances and false promises, the recriminations and worn out dogmas, that for far too long have strangled our politics […] We will restore science to its rightful place […].

US President Barack Obama's Inaugural Address, 20 January 2009

Closing

Professor Phil Weaver, coordinator of HERMES, thanked all participants and closed the meeting.

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Annex 1: Workshop Agenda

Morning Session:

Chair: Sybille van den Hove HERMES & Median

09:00 - 09:05 Welcome
Jurgen Tacks – Research Institute for Nature and Forest (INBO) & Flanders Authority, Belgium

09:05 - 09:15 Welcome, introduction to the workshop and introduction of participants
Sybille van den Hove, HERMES & Median

09:15 - 09:30 The Ocean of Tomorrow: Research Challenges
Manuela Soares, Director, Directorate I (Environment), DG Research, European Commission

09:30 - 10:30 Results of the HERMES project and future prospects. A rolling presentation by HERMES Scientists
Phil Weaver, David Billett, Roberto Danovaro, Miquel Canals, Ann Vanreusel, Anthony Grehan

10:30 - 11:00 Coffee break

11:00 - 11:25 Deep-sea research needs for international ocean governance: an IUCN perspective
Kristina Gjerde, High Seas Policy Advisor, International Union for Conservation of Nature (IUCN)

11:25 - 11:50 The EU Maritime policy and the Strategy for marine and maritime research: State of the art and prospects
Waddah Saab, Coordinator for the EU Marine and Maritime Research Strategy, DG Research, European Commission

11:50 - 12:05 Moving towards a sustainable European marine data infrastructure
Iain Shepherd, Policy Officer, Unit C1 (Maritime policy - Atlantic, outermost regions and Arctic), DG Maritime, European Commission

12.05 - 12:20 Experiences with off-shore marine protected areas in Norway
Jan Helge Fosså, Senior Scientist, HERMES & Institute of marine Research, Norway

12:20 - 12:45 General Discussion

12:45 - 14:00 Buffet lunch
with Presentation of HERMES posters and videos

Afternoon Session:

Chair: Phil Weaver, HERMES & National Oceanography Centre, Southampton (NOCS)

14:00 - 14:25 Data, monitoring, indicators, assessment and research needs in support of policy
Jacqueline McGlade, Executive Director, European Environment Agency

14:25 - 14:50 Arctic oil and gas exploration and production: Prospects and research need on environmental issues
Arne Myhrvold, Environmental Advisor, StatoilHydro

14:50 - 15:15 OSPAR: The Quality Status Report 2010
David Johnson, Executive Secretary OSPAR

15:15 - 15:40 Subseabed CO_2 storage: Research and policy needs and prospects
Klaus Wallmann, Head of the Research Unit "Marine Geosystems", IFM-GEOMAR

15:40 - 16:10 Coffee break

16:10 - 16:50 Summary of the day by external rapporteur and general discussion on way forward
Jeff Ardron, Director High Seas Program, Marine Conservation Biology Institute (MCBI)

16:50 - 17:00 Closing
Phil Weaver, HERMES & National Oceanography Centre, Southampton (NOCS)

17:00 End of the workshop

Annex 2: List of participants

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Annex 3: Some key policy-relevant results from the HERMES Project

Commercial fishing has significant impacts on fish populations in deeper layers and on non-target species

(Bailey et al. 2009)

- Commercial fishing in the NE Atlantic could be harming deep-sea fish populations a kilometre below the deepest reach of fishing trawlers. Scientists have long known that commercial fishing affects deep-water fish numbers, but its effects appear to be felt twice as deep as previously thought. Populations of NE Atlantic commercial deep-water fish have dwindled since deep-water fishing started in the area in the late 1980s, but it was not until 2003 that catch quotas were recommended. Researchers started mapping the distribution of deep-water fish on the slopes off the west coast of Ireland in 1977 up until 1989 - before any fishery was established in the region - and again from 1997 until 2002. As part of HERMES, the researchers then compared the abundance of fish in the two different periods. They unexpectedly found that deep-sea fish numbers down to 2500 metres – almost a kilometre below the maximum depth of commercial fishing (1600 m) - were lower in the later 1997 to 2002 period. In addition, both target species and non-target species were affected. Numbers of one species of eel has dropped by half. This unexpected phenomenon has important consequences for fisheries and marine reserve management, as this would indicate that the impacts of fisheries can be transmitted into deep offshore areas that are neither routinely monitored nor considered as part of the managed fishery areas.

The importance of deep-sea biodiversity on European Margins

(See also HERMES Deep-sea brief "Record-breakers of the deep: Facts and figures of deep-sea biodiversity")[10]

- **Biodiversity on oceanic margins is high, vastly unknown and already threatened by direct and indirect anthropogenic impacts.** *(Weaver et al. (eds.) 2009; van den Hove and Moreau 2007; Grehan et al. 2009)*

  The deep seafloor is much more heterogeneous in time and space than originally thought. There is very high (and often still barely known) biodiversity in the deep sea, associated with different types of habitats such as coral reefs, canyons, open slopes, cold seeps and mud volcanoes. There is still limited knowledge of ecological and biogeochemical processes in the deep (e.g. carbon flow and food web interactions).

  Direct and indirect anthropogenic threats are rising, in particular in areas such as canyons, coral areas, and slopes. This suggests protection of a broad variety of habitats, as well as integrated and precautionary management in non-protected areas is fundamental to ensure sustainable uses. Currently, of all the activities directly affecting the seabed, bottom trawling has the highest impact.

- **Deep-sea ecosystem functioning and efficiency increase exponentially where there is higher biodiversity.** *(Danovaro et al. 2008)*

  It has been estimated that a biodiversity loss of ~ 20-30 % can result in a 50-80 % reduction of deep-sea ecosystem's key processes and their consequent collapse *(Danovaro et al. 2008b).* This would have significant consequences in terms of the services provided by these ecosystems (e.g. *climate regulation, nutrient regeneration and*

[10] All HERMES Deep Sea Briefs are available at: www.eu-hermes.net.

supply to the photic zone, food). This suggests that the conservation of deep-sea biodiversity can be crucial for the sustainability of the functions of the largest ecosystem of our biosphere. The current knowledge on the contribution of deep-sea ecosystems to the provision of goods and services is sparse *(Annex 3.2; see also van den Hove & Moreau 2007).*

- **Deep-sea ecosystem functioning is crucial to global biogeochemical cycles** *(Dell'Anno & Danovaro 2005; Danovaro et al. 2008; Cochonat et al. 2007).* The significant contribution of deep-sea ecosystems to global biogeochemical and ecological processes are essential for the sustainable functioning of our biosphere as a whole and for human wellbeing.

- **Open slopes are "hotspots" of biodiversity in which species richness is higher than that reported for bathyal and abyssal plan ecosystems.** *(Danovaro et al. 2009)*

  Continental slope ecosystems represent one of the major repositories of benthic marine biodiversity. The enhanced levels of biodiversity along slopes are hypothesized to be a source of biodiversity for continental shelves and deeper basins. Continental margins are increasingly altered by human activities but the consequences of these anthropogenic impacts on benthic biodiversity and ecosystem functioning are almost completely unknown.

- **Evidence to date suggests that faunal diversity throughout canyons is high and that canyons represent biodiversity "hotspots".** *(Tyler et al. 2009)*

  The considerable habitat heterogeneity found throughout canyon systems, such as the Nazaré Canyon (Portuguese margin), is affected, to varying degrees, by strong currents and high turbidity. This, together with a great variation of the physical environment (canyon morphology, differing proportions of rocks and sediment types), is reflected by varied and highly adapted fauna. Certain groups, such as the gorgonians and sea lilies, tend to be found on rocky surfaces, while large protozoans dominate the sediments, and there is a continual replacement of species with depth.

  Canyons not only represent biodiversity 'hotspots' but may also represent a preferential habitat for certain species. However, more research is necessary to reveal if canyons harbour endemic fauna.

  Although there is little evidence of fishing practices in the Nazaré canyon, long lines have been observed (*pers. com.*). Yet, improved fishing-gear technologies, such as rockhoppers, allow fishers to trawl in structurally complex habitats like canyons, and will soon allow for their exploitation.

  'Flushing' of pollutants from the coastal zone into submarine canyons, brought about by dense shelf water cascading (*Canals et al. 2006; 2009*. Further discussed later), is likely to impose stress on canyon fauna at all trophic levels, and ultimately have a negative influence on biodiversity.

  An integrated ecosystem approach to management is therefore fundamental, accounting for direct (e.g. fishing) and indirect (e.g. pollution from the coastal zone) anthropogenic impacts, to sustain and conserve submarine-canyon biodiversity. However, the complex vertical and horizontal distribution of canyon species poses difficulties in identifying and implementing suitable management strategies, and the designation of MPAs.

- **Cold seeps and anoxic systems in the deep present a unique fauna and because of the harshness of these environments, they are important to understand further the limits of life.** *(Vanreusel et al. 2009)*

  Multidisciplinary research on seeps and related structures (mud volcanoes, pock marks, and brine pools) provides evidence of high variability in ecosystem processes and associated biodiversity at different spatial scales, illustrating the 'hotspot' nature of these deep-water systems.

Every seep region along the European margin is different in terms of community composition and biodiversity. Moreover, organisms inhabiting these ecosystems require distinct environmental cues to maintain their populations (such as the presence of sulphide and methane).

In a changing ocean, it becomes critical to assess variations in biodiversity across all such habitats in order to distinguish between natural and anthropogenic effects. It is now recognised that the deep seafloor responds dynamically to climate change (*HERMES Deep-sea brief "A warning from the deep"*[11]; *Danovaro et al. 2004*), and a warming of the oceans could lead to an increase in methane release from the sediment. The response of seep ecosystems to climate change, and likewise, their recovery from direct impacts such as fishing pressure, is not understood inferring a precautionary approach is necessary. The first long-term observations are planned (within HERMIONE), and will provide data on the link between environmental fluctuations and the fate of the benthic ecosystem.

- **Microbial deep-sea biodiversity has a high ecological significance and is poorly known.** (*Dell'Anno & Danovaro, 2005); Jørgensen & Boetius 2007; HERMES Deep-sea brief "Microbes in the ocean: The hidden majority")*
  Deep-sea habitats are the largest reservoir of prokaryotic diversity on the planet (prokaryotes are micro-organisms without a cell nucleus). Despite their ecological importance, our understanding of deep-sea ecosystem functioning is still severely constrained by the lack of adequate information on prokaryotic metabolism and biodiversity.

Mapping of anthropogenic activities and impacts on the deep seabed is impeded by data availability problems.

(Benn, A., Billett, D., van den Hove, S. and Weaver, P., unpublished work in progress, see Annex 3.1)

On-going mapping of human activities impacting directly on the seafloor in the deep North East Atlantic (OSPAR area, depth > 200 m) began under the HERMES project and will continue under HERMIONE. Mapped activities include: scientific research, submarine cables, dumping of conventional and chemical munitions and radioactive waste, military activities, oil and gas installations and bottom trawling.

Availability (existence or accessibility) of data was discovered to be a major impediment to the production of informative maps, which could potentially support decision-making and management. Within some sectors, data sets were found to be non-existent, inadequate or incomplete. The most problematic sector is fisheries.

Preliminary calculations based on currently available and accessible data indicate that bottom trawling on Hatton and Rockall Banks has a direct impact on an area approximately 11000 times greater than scientific activities and submarine cables in the whole deep OSPAR region (> 200 m depth).

A large part the North East Atlantic containing waters deeper than 200 m lies outside national jurisdictions and no single organization has responsibility for the collection and management of data. There is a need for an easily accessible metadata set to develop integrated management strategies that will allow for potential synergetic effects to be taken into account.

[11] All HERMES Deep Sea Briefs are available at: www.eu-hermes.net.

GIS-based maps of habitats and ecosystems of the deep are useful tools in support of the conservation and sustainable uses of deep-sea ecosystems

(De Mol et al. 2009; see also HERMES Deep-sea brief "Mapping the European seabed: Current status and major issues")

The HERMES GIS system includes a constantly updated inventory of margin hotspots identified by HERMES scientists (e.g. canyons, cold water corals, cold-seep sites, landslides) superimposed on seafloor maps at various scales. *(Grehan et al. 2009)*

GIS is also very useful to assist predictive modelling efforts to predict the distribution of particular types of habitats or ecosystems. This has been done in HERMES for instance, to predict the geographical distribution of cold-water corals at different scales. *(Davies et al. 2008)*

Efforts to develop GIS tools in support of research and management should be pursued and coordinated amongst the various actors in science and in policy.

Major natural events such as dense shelf water cascading events are important from an environmental, an ecological and a societal point of view

(Canals et al. 2006; Canals et al. 2009)

Dense shelf water cascading (DSWC) is a dynamic mechanism of massive and quick transfer of matter and energy to the deep ocean. It contributes to carbon sequestration (through the transport of fresh organic matter to the deep), fuels the deep ecosystem, influences deep-water fisheries and population structure of particular species, cleans the continental shelf by exporting pollutants to the deep, and it plays an important role in driving deep-water circulation, erosion, and sediment transport and accumulation. These findings may have global implications.

- **Commercial deep-sea species populations can be significantly influenced by geophysical events** *(Company et al. 2008)*

  This has been shown for instance in the case of dense shelf water cascading events in the Gulf of Lyons and the population of the deep-sea shrimp, *Aristeu antennatus* (gamba roja), which is one of the most valuable fishing resources for the regional fleets of the Catalan coast. DSWC has a regenerating effect on the shrimp population, initially causing the resource to disappear and the fishery to collapse, followed by recovery and population peaks three to five years after the cascading event. This has implications for fisheries management strategies.

  Engaging with the stakeholders has enabled the obtainment of a long-time series real catch dataset. This is necessary to correlate the cascading event with population collapses and subsequent recoveries, as well as jointly developing a long-term sustainable management plan for the fishery, accounting for the cyclic fluctuations of the population.

- **Dense shelf water cascading is suspected to be sensitive to climate change as, more generally, does deep-water formation.**

  According to predictive models, climate change holds the potential to significantly modify DSWC.

- **Dense shelf water cascading transports contaminants from anthropogenic activities to the deep sea.**

Climate change in the deep

(See deep sea brief "a warning from the deep"[12])

- **Thermal shock can have significant influence on deep-sea species**

  Recent observations have indicated the existence of thermal shock in deep ocean areas. For instance, first observations were made in 1999 in the West Mediterranean. They have since been taking place every four years. The phenomenon was also observed in 2007 in the Tisler cold water coral reef in the Skagerrak (between Norway and Sweden).

  Such phenomena can seriously damage or have lethal effects on very long-lived organisms, such as gorgonian corals with low dynamics. Such organisms are key for the sustainment of complex benthic communities. Community recovery becomes difficult or impossible ("no return") because of low recruitment and growing rates, and low mortality rates under "normal" conditions.

  Thermal shocks may also favor invasion by aliens, which may further compromise recovery. A direct cause of death may be disease from thermodependent opportunistic pathogens. This has been proven for gorgonians (*Vibrio collilyticus*) (Bally and Garrabou, 2007) and is suspected for sponges at the Tisler Reef.

  Overall, jointly with other observations (e.g. DSWC), this illustrates how global warming is having an increased impact on the ocean ecosystem, from shallow to deep waters.

- **More research into the impacts of climate change on deep-sea ecosystems is planned under the HERMIONE project.**

[12] All HERMES Deep Sea Briefs are available at: www.eu-hermes.net.

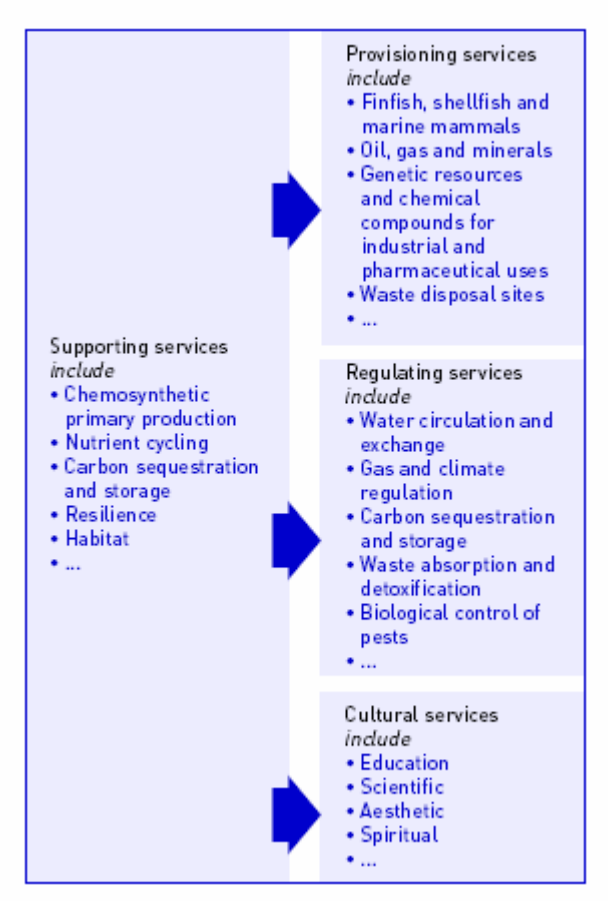
Annex 3.1: Human activities in the deep North East Atlantic

Angela Benn

Note: this section has been removed due to the sensitivity of unpublished data

Annex 3.2: Deep-Sea Ecosystem Goods and Services

(Source: van den Hove & Moreau 2007; See also HERMES Deep-sea brief "What's it worth? Valuing the deep sea)



Examples of deep-sea ecosystem goods and services

Table 2.2: Knowledge of the contribution of some deep-sea habitats and ecosystems to goods and services

HABITATS ECOSYSTEMS	GOODS and SERVICES: Organic matter input/chemo-synthetic primary production	Nutrient cycling	Resil-ience	Habitat	Food, minerals, oil, gas	Micro organ-isms	Climate regulation	Bio-remediation	Educational, scientific, spiritual
Continental shelves	good knowledge	some knowledge	little knowledge	some knowledge	some knowledge	no knowledge	no knowledge	little knowledge	little knowledge
Continental slopes	some knowledge	little knowledge	no knowledge	little knowledge	some knowledge	no knowledge	no knowledge	little knowledge	little knowledge
Abyssal plains	some knowledge	little knowledge	no knowledge	little knowledge	little knowledge	no knowledge	no knowledge	little knowledge	little knowledge
Submarine canyons	little knowledge	little knowledge	no knowledge	little knowledge	little knowledge	no knowledge	no knowledge	little knowledge	little knowledge
Deep-sea trenches	little knowledge	no knowledge	no knowledge	little knowledge	little knowledge	no knowledge	no knowledge	little knowledge	no knowledge
Seamounts	some knowledge	little knowledge	no knowledge	some knowledge	some knowledge	no knowledge	no knowledge	no knowledge	little knowledge
Carbonate mounds	little knowledge	little knowledge	no knowledge	little knowledge	no knowledge	no knowledge	no knowledge	no knowledge	no knowledge
Hydrothermal vents	some knowledge	no knowledge	no knowledge	some knowledge	some knowledge	some knowledge	no knowledge	no knowledge	some knowledge
Cold seeps	little knowledge	little knowledge	little knowledge	little knowledge	some knowledge	some knowledge	little knowledge	little knowledge	little knowledge
Mud volcanoes	little knowledge	little knowledge	no knowledge	little knowledge	little knowledge	some knowledge	little knowledge	no knowledge	little knowledge
Cold-water corals	some knowledge	no knowledge	little knowledge	some knowledge	some knowledge	no knowledge	no knowledge	no knowledge	some knowledge
Deep-sea sponge fields	little knowledge	no knowledge	no knowledge	little knowledge	no knowledge	no knowledge	no knowledge	no knowledge	little knowledge
Whale falls	some knowledge	little knowledge	little knowledge	little knowledge	little knowledge	little knowledge	no knowledge	no knowledge	no knowledge

Key: State of knowledge

good knowledge | some knowledge | little knowledge | no knowledge

Knowledge of the contribution of some deep-sea habitats and ecosystems to goods and services *(Source: van den Hove & Moreau 2007)*

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