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HERMES

Promoting Ecosystem-Based Management and the Sustainable Use and Governance of Deep-Water Resources

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ABSTRACT. HERMES is much more than a scientific research project. The overall goal of the project is to improve the scientific basis for the sustainable use of Europe's offshore resources with due regard for the need to conserve vulnerable deep-sea ecosystems. This objective is being achieved through the development of a number of tools and approaches specifically aimed at providing information that can be used directly by resource managers and policymakers. To address issues pertinent to sustainable management in the deep sea, HERMES brought together people from the natural and social sciences to ensure that coherent and realistic policy support is forthcoming. Given the sense of urgency arising from evidence of damage to vulnerable ecosystems in the deep sea, HERMES has placed a high priority on linking with stakeholders and on the timely delivery of appropriate policy advice as relevant new science becomes available. Here, we review some HERMES initiatives that support implementation of a more holistic ecosystem approach to the management of offshore resources and conservation of vulnerable marine ecosystems.

INTRODUCTION

To promote the sustainable use of Europe's offshore resources and conservation of deep-sea ecosystems, one of the major objectives for the HERMES project is to provide the scientific basis and policy support to ensure the protection and preservation of the marine environment. The ultimate aim is to maintain biodiversity and habitat integrity to ensure that the sea remains healthy and productive. This task is of crucial importance as the quality of the deep marine environment is adversely affected or threatened, directly by many human activities including deep-sea fishing, offshore hydrocarbon exploration and production, shipping, waste disposal, and the placement of submarine cables for telecommunications and energy purposes; and indirectly by anthropogenic global environmental change—in particular climate change and ocean acidification. The increased urbanization of European coasts has also had an adverse impact on the quality of the marine environment.

Today there exists an array of legal instruments that aim to mitigate human impacts on the marine environment as a means to ensure the sustainable use of offshore resources. Some of the means by which international law is used to protect the marine environment include the establishment of marine protected areas (MPAs) under legislation such as the EC Habitats Directive, implementation of the many international conventions such as the OSPAR Convention for the Protection of the Marine Environment in the Northeast Atlantic and the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, as well as the broad family of conventions adopted by the International Maritime Organization to prevent pollution from shipping. Effective implementation of these multilateral environmental agreements is essential for achieving the goals set down by the World Summit on Sustainable Development held in Johannesburg in 2002.

In the European Union, there are a diverse range of policies that focus on particular activities, such as the emerging European Maritime Policy and the well-established Common Fisheries Policy. In recent years, the European Council has adopted some sophisticated legal instruments, including the Water Framework Directive and the Marine Strategy Framework Directive, to protect both coastal and offshore waters from various sources of pollution. These instruments will contribute to ensuring the conservation and sustainable use of biodiversity. Importantly, they provide the means for implementing an ecosystem-based approach to management of the marine environment and applying other environmental principles that are codified in the EC Treaty, such as the precautionary principle and the principle of sustainable development. The scientific information acquired from HERMES research is directly relevant to the assessment of the status of the marine environment, and it provides a basis for the valuation of ecosystem goods and services. These considerations facilitate integration of environmental concerns into the different policies, agreements, and legislative measures that regulate human activities impinging upon or threatening the quality of the marine environment.

A wide array of stakeholders and policymakers is increasingly involved in issues pertaining to the sustainable use of deep-sea resources and conservation of ecosystems. They urgently need integrated, interdisciplinary natural and social science knowledge to prioritize and guide action in support of policy development and implementation strategies. Two recent reports, *The Deep-Sea Frontier Initiative* (Grehan et al., 2007) and a joint UNEP/HERMES study (UNEP, 2007), highlighted the types of socio-economic and governance research required to support the sustainable use of deep-sea resources.

HERMES has started to develop genuine interdisciplinary natural-social science research to allow integration of knowledge emerging from the natural sciences into the socio-economic and governance work of the project and to feed back results of the latter into the natural science work. HERMES includes bio- and socio-economists and a marine law expert within its consortium. They have an important dual role: (1) to carry out, in collaboration with natural scientists, economic and legal research on deep-sea ecosystems, the goods and services they provide, the impact of human activities on them, and their governance and sustainable management, and (2) to inform HERMES about relevant policy issues as they emerge in various international forums at the regional and global level, to identify policy-relevant scientific research results and breakthroughs under HERMES, and then to promptly make them accessible, in a concise and comprehensible format, to managers and policymakers (Figure 1). The remainder of this article provides examples of how the interplay between the natural and social sciences in the HERMES project delivers science in support of the implementation of a more holistic approach to the management of offshore resources and conservation of ecosystems.

HERMES RAPID POLICY DELIVERY MECHANISM

The rapid rise of human activities that impact or threaten deep-sea ecosystems and the consequent need to develop policies (at international, regional, and national levels) to manage them require effective and prompt policy-advice mechanisms. HERMES developed science-policy interfaces to enhance connectivity between research and policy, and ensure that policymakers and stakeholders have access to good, relevant,

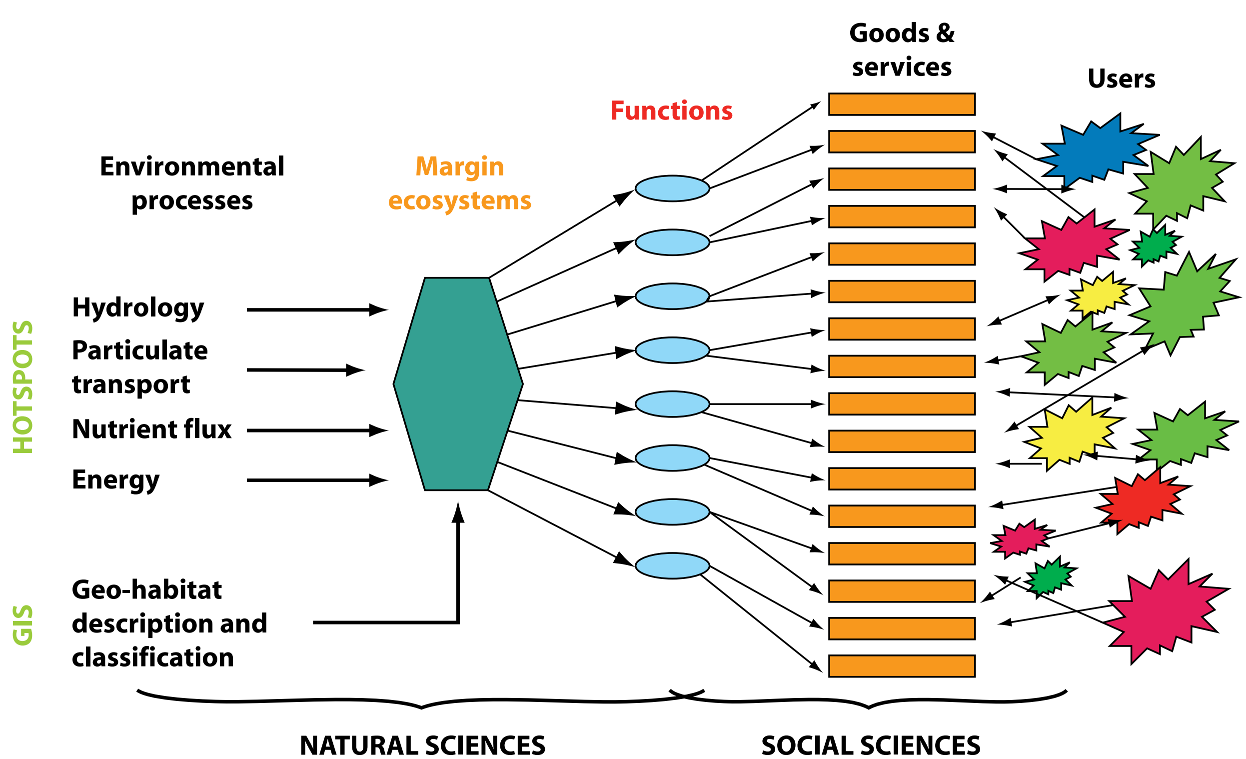

Figure 1. The integration of natural and social sciences in HERMES. *Adapted from Burbridge, p. 51, in ESF, 2002*

and timely scientific knowledge in support of policy developments.

HERMES science-policy interfaces included several mechanisms:

- the Science Implementation Panel
- the Science-Policy Panel
- ad hoc meetings with policymakers and stakeholders on specific topics
- participation of HERMES scientists as experts in various international forums
- national or regional scientist/stakeholder partnerships

These mechanisms were aimed at: (1) ensuring policy relevance of the research through constant dialogue with stakeholders during the entire lifetime of the project; (2) creating partnerships to facilitate rapid translation of research into policy advice at national, European, and international levels; and (3) providing a primary channel for dissemination of results to policy circles and other users.

The Science Implementation Panel (SIP) was composed of seven members who attended the HERMES annual general science meetings to enable in-depth discussions with partners and scientists. Members were representatives from the European Commission Directorate General for the Environment and Directorate General for Maritime Affairs and Fisheries, the United Nations Environment Programme (UNEP), non-governmental organizations (NGOs), the oil industry, and Census of Marine Life. SIP members informed the HERMES community about key political and societal issues and milestones, and provided HERMES with input concerning policy needs, relevance of research questions, and other important information. The panel was asked two key questions: what value has HERMES research produced to date and what areas should be the focus for future research activities and data collection? The SIP also made suggestions to the Project Steering Committee regarding the adjustment of the work program in order to focus research efforts in areas with the most relevance to pressing policy issues.

The SIP was a subset of the high-level Science-Policy Panel (SPP). The SPP was composed of key European policymakers and high-level international policymakers, stakeholders from industry and NGOs, representatives of international institutions, and leading scientists (Figure 2). The SPP's objective was to establish strategic dialogue between the spheres of research and policy and to ensure that research progress and results were promptly brought to the attention of relevant European and international

Figure 2. Participants in the Science Policy Panel meeting in Brussels in 2008.

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decision-makers so that policy evolution and formulation could take place through constant iteration during the project's lifetime. The SPP first met in Brussels in 2006, and again in 2008, and will hold a final meeting before the end of the project in 2009. During its first meeting, the SPP discussed critical scientific, socio-economic, governance, and management issues for the deep sea. It provided HERMES with input on policy needs and priorities, and was informed of HERMES' aims and early results. The second meeting focused on "Deep Sea Research in Support of Ocean Governance," and the third meeting will present the final results of the project and plan the future work of the SPP under two EU Framework Seven follow-up projects, HERMIONE (http://www.eu-hermione.net) and CoralFISH (http://www.eu-fp7-coralfish.net).

A third HERMES science-policy interface comprised a series of ad hoc meetings with policymakers and/or stakeholders to discuss policy or management issues as they arose. Meetings were organized, for instance, with the European Commission's Directorate General for Maritime Affairs and Directorate General for the Environment, and with the oil industry, and a participatory workshop was organized at the International Union for Conservation of Nature (IUCN) 2008 World Conservation Congress. HERMES scientists have also participated in numerous international forums and expert groups, such as the International Seabed Authority, International Council for Exploration of the Seas (ICES), and the OSPAR and Barcelona Conventions.

"ONE OF THE MAJOR OBJECTIVES FOR THE HERMES PROJECT IS TO PROVIDE THE SCIENTIFIC BASIS AND POLICY SUPPORT TO ENSURE THE PROTECTION AND PRESERVATION OF THE MARINE ENVIRONMENT."

Finally, individual project partners, with relevant authorities at the national level, formed ad hoc stakeholder-scientist partnerships. These varied in form from country to country but they all permitted focused policy dialogue and research dissemination at the national level.

An important factor leading to the success of the HERMES science-policy interfaces was the integration of UNEP as a full partner in the project. UNEP provides HERMES with a global perspective, informing the partnership about relevant global policy processes and discussions, such as those taking place under the United Nations General Assembly or under the Convention on Biological Diversity. UNEP also facilitated the dissemination of HERMES results far beyond Europe, using the global UNEP networks and programs, such as the Regional Seas Conventions and Action Plans.

An example is UNEP's prompt dissemination of HERMES research related to the dense shelf water cascading effect in the Gulf of Lion (Mediterranean) described by Canals et al. (this issue). UNEP collaborated with HERMES scientists to integrate their findings into a UNEP Rapid Response Assessment, *In Dead Water* (Nelleman et al., 2008). This report was launched at the Tenth Special Session of the UNEP Governing Council/Global Ministerial Environment Forum (February 20–22, 2008, Monaco), which was attended by ministers and high-level government delegates from over 138 countries, as well as representatives of UN agencies, international organizations, business and industry, academia, and NGOs. HERMES results were highlighted at a special side event during this meeting, and they played a key role in the international press conference organized by UNEP on February 22.

UNEP also collaborated with HERMES partners to produce a joint UNEP/HERMES report on the socio-economy, management, and governance of deep-sea biodiversity and ecosystems (UNEP, 2007). The report was published in February 2008 in the UNEP World Conservation Monitoring Centre Biodiversity Series and the UNEP Regional Seas Reports and Studies. Electronic and hard copies of the report were disseminated via the contact networks of both organizations and at several international meetings, ensuring a broad, worldwide distribution in policy circles. A second joint report will be prepared to inform marine managers and decision-makers about the key scientific results of HERMES; the experiences gained and lessons learned in managing an international, interdisciplinary scientific project; and how the program interfaces with policy and society in general; all with a view toward stimulating similar integrated marine deep-water research projects or initiatives in other regions of the world.

INFORMING STAKEHOLDERS AND THE GENERAL PUBLIC

Ultimately, policymakers' choices are influenced by their democratic mandate. It is therefore of utmost importance that all genuine stakeholders and indeed the public in general, are fully informed about the latest science developments so that they can understand, and fully participate in, the decision-making process. Information and education are essential to raise awareness and willingness to act. With this purpose in mind, HERMES has invested considerable effort in making new information available to all stakeholders (see Gunn and Thompson, this issue). Information dissemination has chiefly been achieved through the use of a continuously updated Web site (http://www.edu-hermes.org), and the wide distribution of quarterly newsletters (also available for download from the Web site) that provide an attractive summary (Figure 3) of the most recent scientific advances and policy developments. HERMES has also published a series of briefing documents—*Deep-Sea Briefs*—that provide basic information, facts, and figures on various "hot" topics affecting the deep-sea environment. Although these documents are aimed at policymakers and government advisors, they are presented at a level suitable for a range of audiences and will be expanded through the lifetime of HERMES' successor, the HERMIONE project.

PRINCIPAL ECONOMIC ACTIVITIES IN THE DEEP SEA

Although a remote environment, the deep-sea is already host to a variety of economic and scientific activities, and resources from the deep are increasingly targeted. Oil and gas exploration takes place in more than 3000-m water depth while deep-sea fishing occurs down to 1500-m depth. There is also likely to be a significant ramp-up in interest in deep-sea mining for heavy metal sulfides and manganese nodules in the coming decades as land-based metal ore deposits are exhausted. In addition, the potential and use of the deep oceans for the sequestration and storage of atmospheric CO_2 are being investigated. In the recent foresight reports (Cochonat et al., 2007; UNEP, 2007), HERMES helped

Figure 3. HERMES newsletters.

to identify the nature of future research required to support development of economic activities in the deep sea in an environmentally sustainable manner.

Already, evidence of direct and indirect anthropogenic impacts has been accumulating for many vulnerable deep-sea ecosystems and habitats. Direct impacts are caused by extraction or harvest activities (e.g., fisheries, hydrocarbon exploration/exploitation, mining, bioprospecting), seabed utilization (e.g., pipelines, cable laying, carbon sequestration), and pollution (e.g., contamination from land-based sources/activities, waste disposal, dumping, noise, impacts of shipping and maritime accidents). Indirect effects and impacts relate to climate change, ocean acidification, and atmospheric ozone depletion. Although impacts are increasingly documented, they are as yet poorly quantified. This limitation is a serious source of concern because deep-sea processes and ecosystems are not only important for the marine web of life but also fundamentally contribute to global biogeochemical cycles that support all life on Earth.

More research and monitoring will be needed to map activities and to assess impacts on specific systems. To study direct threats or impacts on deep-sea ecosystems, several factors have to be taken into account: (1) the nature of the interactions between the activity and the habitats or ecosystems—extraction, pollution, noise, permanent infrastructures; (2) the type of impacts (including their potential irreversibility); (3) the deep-sea areas or habitats targeted by the activity—some areas are more fragile or unusual than others; (4) the activity's frequency; and (5) the geographic area involved, as well as the proportion of the area that is (potentially) impacted—for example, cables are laid in all oceans but the ratio of the ocean floor surface occupied is small. When attempting to rank activities' differing impacts, all of these factors need to be taken into account, together with information on the current stage of development and foreseeable development in the coming decades. As of today, fishing—in particular deep-sea trawling—and pollution top the list of human impacts on the deep sea. But, the impacts of other activities, and their cumulative effects, are rising sources of concern.

Although the impact of scientific research is insignificant when compared to that of some industrial and fishing activities, scientists are willing to adopt practices that will minimize their environmental footprint. To accomplish this endeavor, in consultation with marine scientists (including HERMES partners), the OSPAR Commission developed a Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area; it was adopted in June 2008 (Box 1). The need for notification and research planning is of particular interest. Here, scientists are asked to avoid activities that could disturb the experiments and observations of other scientists (and eliminate wasteful duplication) by: (1) making themselves familiar with the status of current and planned research in an area; and (2) ensuring that their own research activities and plans are known to the rest of the international research community via appropriate public domain databases and Web sites. HERMES management structures are already largely compliant with this code (see Weaver et al., this issue). As the majority of European margin scientists are part of the HERMES consortium, good internal communications ensure that scientists are well aware of prior research in an area of interest. A key tool in this respect is the HERMES Geographic Information System (GIS) in combination with the PANGAEA data archive (see De Mol et al., this issue) as it facilitates near-real-time (metadata) online reporting of research cruise activities. For any given area, a scientist can immediately view a map that shows the position of past sampling stations and contains an inventory of what samples have already been collected.

VALUING DEEP-SEA GOODS AND SERVICES

A key approach in understanding the societal "value" or importance of deep-sea ecosystems is to look at what they provide. Ecosystem goods and services are the benefits that humans derive (either directly, such as the supply of food, or indirectly, such as production of oxygen through photosynthesis) from ecosystem functions—in other words, the processes, products, or outcomes arising from biogeochemical activities that take place within an ecosystem. Even though much research remains to be done, we now know that the deep sea provides an array of goods and services essential to human wellbeing. It provides *supporting services,* such as chemosynthetic primary production, nutrient cycling, resilience, and habitats; *provisioning services*, such as food, oil, gas and minerals, chemical compounds for industrial and pharmaceutical uses, and waste disposal sites; r*egulating services*, such as water circulation and exchange, gas and climate regulation, carbon sequestration and storage, and waste absorption and detoxification; and *cultural services* of an educational, scientific, aesthetic, and spiritual nature (Figure 4).

Highlighting the economic values of deep-water resources is fundamental for improved management and conservation of these relatively unknown ecosystems.

Failure to assess ecosystem values (quantitatively or qualitatively) could result in their being assumed to have zero value and not factored in decision-making processes. As scientific research on deep-sea ecosystems is relatively recent, valuation studies of these resources are as yet practically nonexistent. Nonetheless, a growing number of recent valuation papers on coastal and ocean resources provide a good starting point for studies of deep-water ecosystems (Costanza et al., 1997; Beaumont et al., 2008). Of course, ecosystems have values other than those directly beneficial to humans, but we will only deal with the anthropocentric values here.

The Total Economic Value (TEV) of a good or service can be divided into two categories—use values (actual or potential consumptive or nonconsumptive use of resources) and nonuse values (the value people attach to a good or a service, regardless of its actual or future use). Use values encompass the valuation of the human use of an environmental good or service. Direct use values are derived from both consumptive and nonconsumptive uses of the resource. Apart from exploitation of deep-sea fish stocks and bioprospecting for deep-sea organisms (e.g., sponges) for biomedical, pharmaceutical, and industrial uses, there is little direct use of deep-sea biodiversity, ecosystems, and services. Taking deep-water coral as an example of a "hotspot" deep-sea ecosystem

Box 1: OSPAR Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area

OSPAR, the Convention for the Protection of the Marine Environment of the North-East Atlantic includes large areas of the deep and high seas. OSPAR recognizes that protection and sustainable use of the oceans is best served by a fundamental understanding of its complex marine ecosystems, which can only be achieved through marine research. Nonetheless, there remains the possibility that some scientific activities could have unwanted, negative side effects on particular regions or animals if research activities are not carefully planned and executed. In addition, because only a limited number of sites are currently known and scientists from a wide variety of disciplines frequently work at these single locations, there is the potential for conflicting effects among studies, and multiple impacts, particularly at sites where scientific activity is intense. OSPAR requests all scientists working in the deep seas and high seas of the OSPAR maritime area to adhere to the code of conduct when planning and carrying out their research.

CODE OF CONDUCT (abridged)

Species: Avoid, in the course of scientific research, activities that could lead to long-lasting changes in regional populations or substantially reduce the number of individuals present.

Habitats: Avoid, in the course of scientific research, activities that could lead to substantial physical, chemical, biological, or geological changes or damage to marine habitats.

Threatened and/or declining features: When working in areas of particular ecological vulnerability, utmost care should be taken not to disturb or damage the features as far as possible.

Management areas/marine protected areas: When working in areas of ecological importance and/or sensitivity, care has to be taken not to disturb or damage the protected features.

Notification and research planning: Avoid activities that could disturb the experiments and observations of other scientists.

Methods: Use the most environmentally friendly and appropriate study methods that are reasonably available.

Transport of biota: Ensure that transport of biota between different marine regions, which could lead to changes in the environment or the composition of marine communities, does not occur.

Collections: Avoid collections that are not essential to the conduct of the scientific research, and reduce the number of samples to the necessary minimum. Scientists should consider available existing biological and physical data and/or samples from the target site.

Collaboration and cooperation: Ensure the fullest possible use of all biological, chemical, and geological samples through collaborations and cooperation within the global community of scientists. Samples that can be archived should be placed in accessible repositories for future use.

Data-sharing: Practice international sharing of data, samples, and results in order to minimize the amount of unnecessary sampling and to further global understanding of the marine environment.

(Figure 5), it is clear that there is no direct-use value today, as these resources are mainly found at ocean depths that would require submarine transport for direct intervention. Though direct-use values of deep-water coral are not available, there may be indirect use values, such as ecosystem and biodiversity values that may benefit species of commercial interest, such as fish (Armstrong et al., this issue).

Given that our understanding of deep-sea ecosystem function is still very much a work in progress, and valuation will to some degree always depend on what we know about the resource in question, estimating the future value of such a resource becomes even more problematic. Economic theory allows for the fact that we may not know the full value of some resources in the future, requiring assignment, in such cases, of option and quasi-option values. Option value measures the value attached to guarantee the availability of a future environmental good or service, and quasi-option value relates to the value attached to avoidance of an irreversible loss of some possible future value. There is some value in preserving a resource until there is more knowledge available regarding its benefits. An example of this would be the potential of deep-sea ecosystem hotspots to be repositories of species that in the future could yield novel biocompounds of use to the biotechnology and pharmaceutical industries.

With regard to nonuse values, there are a plethora of possible reasons, such as cultural and aesthetic, for valuing the pure existence of deep-water coral. Economists usually lump these issues into two types of nonuse values—existence and bequest values. Existence value is the satisfaction an individual gets from knowing that deep-water corals exist, despite the fact that the individual may never see them or use them in any way. Bequest value is based on the desire to preserve the resource so that it can be enjoyed by future generations. It is clear that deep-water corals have both existence and bequest values. Deep-water coral is a nontraded good. Estimating the value of indirect or nonuse goods and services can be difficult, and this is particularly true of deep-water corals as research is relatively new and data availability is limited. Furthermore, marine systems

GOODS and SERVICES

HABITATS ECOSYSTEMS	Organic matter input/chemosynthetic primary production	Nutrient cycling	Resilience	Habitat	Food, minerals, oil, gas	Micro organisms	Climate regulation	Bio-remediation	Educational, scientific, spiritual
Continental shelves	Some	Little	Little	Some	Some	No	No	Little	Little
Continental slopes	Some	Little	No	Little	Some	No	No	Little	Little
Abyssal plains	Some	Little	No	Little	Little	No	No	Little	Little
Submarine canyons	Little	Little	No	Little	Little	No	No	Little	Little
Deep-sea trenches	Little	No	No	Little	Little	No	No	Little	No
Seamounts	Some	Little	No	Some	Some	No	No	No	Little
Carbonate mounds	Little	Little	No	Little	No	No	No	No	No
Hydrothermal vents	Some	No	No	Some	Some	Some	No	No	Some
Cold seeps	Little	Little	Little	Little	Some	Some	Little	Little	Little
Mud volcanoes	Little	Little	No	Little	Little	Some	Little	No	Little
Cold-water corals	Some	No	Little	Some	Some	No	No	No	Some
Deep-sea sponge fields	Little	No	No	Little	No	No	No	No	Little
Whale falls	Some	Little	Little	Little	Little	Little	No	No	No

KEY State of knowledge: Good knowledge | Some knowledge | Little knowledge | No knowledge

Figure 4. Knowledge of the contributions of some deep-sea habitats and ecosystems to goods and services. *From UNEP, 2007*

that lie further offshore or are unrelated to people's experiences make the task of valuation more difficult. Economists have responded to the need to evaluate environmental and natural resources in the absence of explicit markets by studying implicit market behavior. One way of doing this is to study ecolabeling.

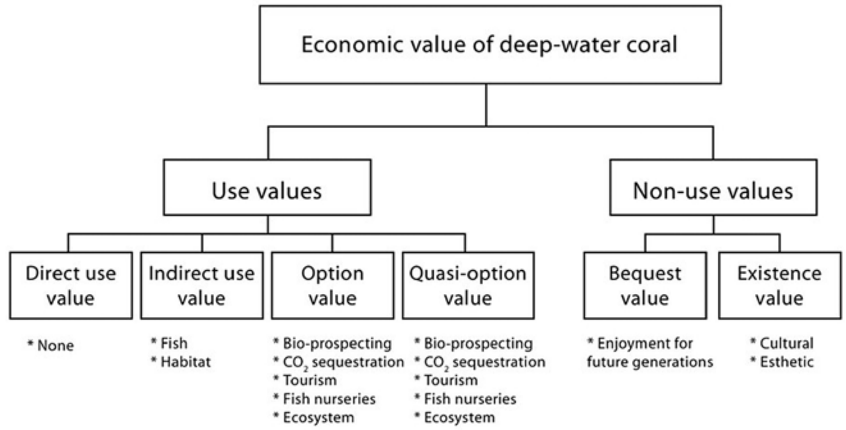

Figure 5. Economic valuation of deep-water corals. *Adapted from Barbier (1994) and Cesar (2002)*

ECOLABELING

Modern consumers may take account of unobserved environmental attributes in their purchasing decisions. Consequently, a number of studies have focused on the use of ecolabeling for sustainable management practices, and on whether consumers are willing to pay a price premium for this attribute. However, most of these labels are concerned with so-called socially responsible production (fair trade) or with agricultural and forest systems, especially organic farming or forest certification (Nimon and Beghin, 1999; Loureiro et al., 2002; Pivarnik et al., 2005; De Pelsmacker and Janssens, 2007). There are still only a few studies involving fisheries management practices, and these are largely confined to hypothetical "willingness to pay" type approaches in view of the lack of actual market data (e.g., Gudmundsson and Wessells, 2000; Jaffry et al., 2004). The full implementation of an ecosystem management approach will undoubtedly lead to reductions in maximum sustainable yields for many fish stocks and will require a shift toward more environmentally friendly fishing techniques. Accordingly, price-premium-linked ecolabeling of fish caught in ecologically well-managed fisheries might go some way toward offsetting the loss of revenues from a reduction in total catch. A good example of this type of approach is the Marine Stewardship Council Certification program. The Council is an international organization based in London that aims to promote healthy and sustainable fisheries. As part of its healthy fishery program, the Council offers certification to fisheries and has an extensive education campaign to encourage consumers to think about the sources of their fish. Award of the certification follows a series of inspections and continued monitoring, and indicates to consumers that the product they are purchasing was produced with healthy and sustainable aims in mind.

Another example relates to the recent adoption by the EU Agriculture and Fisheries Council of a regulation establishing a European system to prevent, deter, and eliminate illegal, unreported, and unregulated (IUU) fishing; it will go into effect January 1, 2010 (EC, 2008). One of the main tools of the regulation will be the establishment of a certification scheme covering all imports of fishery products. The onus will be on the flag state of the vessel supplying fish to the EC to certify that the fish have been caught in accordance with accepted norms.

While it is clear that as of today the ecolabeling of fish as a means to promote coral habitat conservation is not possible, as the link between deep-coral habitat and relevant commercial species is still too tenuous, and general knowledge of deep-water coral is limited, there are indications that this kind of approach could be a possible option for the future. The HERMES follow-up project CoralFISH will study the interactions among corals, fish, and fisheries in detail.

It is also clear that much of the use value connected to deep-water coral and other deep-sea ecosystems is to be found in the option and quasi-option values described above. These examples illustrate the complexity of valuing deep-water ecosystems today, but they also underline the potential for their loss over time, if only direct and indirect use values are applied in management decision-making.

ECOSYSTEM-BASED MANAGEMENT

Ecosystem-based management (EBM) represents the ultimate goal for marine resource managers. When a number of sectors impact an ecosystem, management of all activities should be addressed simultaneously within a broad EBM (MEAM, 2009) so that cumulative impacts on the ecosystem are minimized and the overall integrity of the ecosystem, at regional scale, is ensured. Traditionally, human activity in the deep sea has been managed on a sector-by-sector basis, but given the rapid increase in competing economic activities in the deep sea, the need for integrated, holistic management is now recognized. In Europe, a key goal of the proposed Integrated Maritime Policy (http://ec.europa.eu/maritimeaffairs) is the sustainable use of the ocean and seas through adoption of an ecosystem-based approach. An important tool for the development of the Integrated Maritime Policy in Europe is maritime spatial planning (MSP). The recently communicated roadmap for MSP (COM, 2008) provides a framework for arbitrating between competing human activities and managing their impact on the marine environment. Its objective is to balance sectoral interests and achieve sustainable use of marine resources in line with the EU Sustainable Development Strategy.

Assessment of the success of the Integrated Maritime Policy with regards environmental sustainability will require monitoring and evaluation of the health of the deep-sea environment. This will be achieved through the Marine Strategy Framework Directive—the environmental pillar of the Union's future Maritime Policy, which aims to achieve good environmental status in all of the EU's marine waters by 2021 and to protect the resource base upon which marine-related economic and social activities depend. A schema of the relationship among the various policies is given in Figure 6.

HERMES is contributing to the implementation of the Maritime Policy by helping to provide the natural and social science base for EBM of deep-sea resources. The HERMES GIS as a visualization and data catalogue linked to the PANGAEA database provides an inventory of the most recent margin research activities and results for Europe. When combined with socio-economic data, the HERMES GIS can be a very valuable resource for managers engaged in marine spatial planning activities such as the siting of marine protected areas under the Habitats Directive (Box 2) and application of the Strategic Environmental Assessment Directive (Box 2). Both follow-on projects, HERMIONE and CoralFISH, will continue to develop the HERMES GIS and archive data in PANGAEA, thus building on the outstanding legacy of the HERMES project.

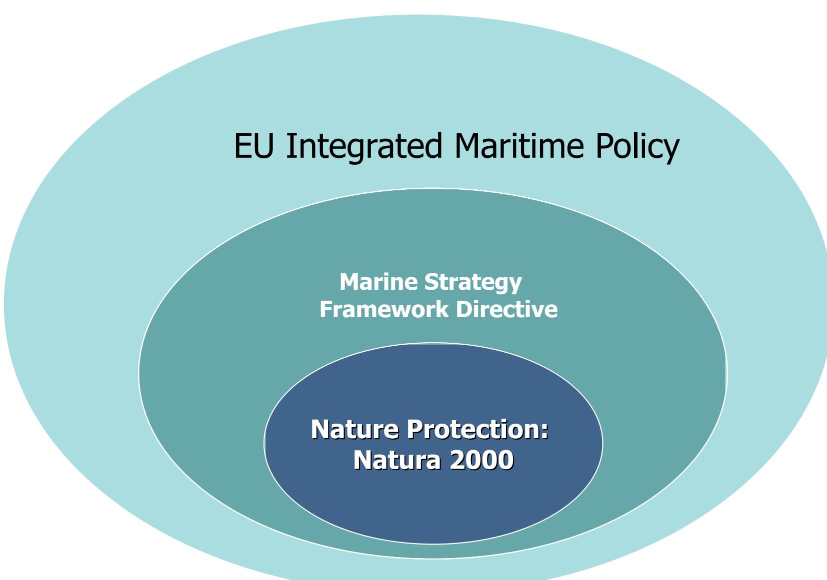

Figure 6. The relationships among the Maritime Policy, the Marine Strategy, and nature conservation within the European Union.

CONCLUSION

HERMES has developed a genuinely interdisciplinary approach to natural science and social/economic research, and has set up processes and mechanisms to inform and receive feedback from policy-makers and decision-makers. Internally, HERMES has facilitated the integration of knowledge emerging from the natural sciences into the project's socio-economic and governance work, with feedback from this sector to increase the relevance of the natural science research undertaken. Externally, HERMES has successfully linked this work to policy-making and decision-making at European and global levels. HERMES is playing a crucial role by contributing to the scientific knowledge base for making informed decisions on whether, when, and how (1) exploitation of deep-sea resources should be allowed, (2) exploitation should be restricted or prohibited for conservation purposes, or (3) offshore marine protected areas should be designated, as well as other issues.

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Box 2. Strategic Environmental Assessment and the Habitats Directive

The *Habitats Directive (92/43/EEC) on the conservation of natural habitats and of wild fauna and flora* is one of the European Union's two directives in relation to wildlife and nature conservation (the other is the Birds Directive). It aims to protect some 220 habitats and approximately 1000 species of European importance. The directive has led to the establishment of a network of Special Areas of Conservation, which together with Special Protection Areas established under the Birds Directive, form a network of protected sites across the European Union called Natura 2000.

The *Strategic Environmental Assessment* (SEA) is a legally enforced assessment procedure required by Directive 2001/42/EC (known as the SEA Directive) in the European Union. The directive is aimed at ensuring systematic assessment of the potential cumulative environmental impacts of intended plans or projects in a region with a view to ensuring balanced and sustainable land use in that region.

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