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Position Paper 14

Science dimensions of an Ecosystem Approach to Management of Biotic Ocean Resources (SEAMBOR)

April 2010

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Science dimensions of an Ecosystem Approach to Management of Biotic Ocean Resources (SEAMBOR)

Marine Board-ESF Position Paper 14

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Foreword

"Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs"[1]. This UN definition in 1987 asserted a growing concern "*about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development"*. This statement clearly recognised that environmental problems are global in nature and that it is in the common interest of all nations to establish policies for sustainable development.

In 2005, Europe confirmed its commitment to sustainable development as a key principle governing all of the EU's policies and activities. The European Council approved the *"Declaration on the guiding principles for sustainable development"* as a basis for a renewed sustainable development strategy comprising targets, indicators and an effective monitoring procedure (Gothenburg principles).

In 2006 and 2007, many pan-European (e.g. Marine Board-ESF and EFARO) and international (e.g. ICES) stakeholders contributed greatly to the broad consultation process initiated by the European Commission to stress the paramount role of marine science to inform and support the successful development of an evidence-based maritime policy. This process culminated in October 2007 with the adoption by the European Council of a new policy framework to guide Europe's future interaction with its marine and coastal territories. The Integrated Maritime Policy, also known as the "Blue Book", aims to provide a stable and dynamic policy framework to secure growth, jobs and environmental sustainability on a long-term basis.

Since then, new policy guidelines have generated an ambitious long-term workplan with dedicated tools to address and manage the whole range of marine and maritime activities in European seas. To date, these tools (e.g. the building of a marine knowledge-base, maritime spatial planning and integrated surveillance) have progressed well and have demonstrated effective collaboration between marine and maritime stakeholders in support of the Integrated Maritime Policy.

In addition to the all-embracing Integrated Maritime Policy which aims at developing a dynamic maritime economy, its environmental pillar, the Marine Strategy Framework Directive (MSFD), constitutes the general basis for implementing an Ecosystem Approach to Management (EAM) of Biotic Ocean Resources (BORs), which complements other European Commission directives. The Ecosystem Approach to Management is a key management principle to facilitate sustainable development in its three dimensions, namely, environmental protection, social equity and cohesion and economic prosperity. It implies the application of measures vertically within a sector, horizontally across sectors and finally across different governance systems. The Ecosystem Approach to Management represents a tremendous multidisciplinary and multi-scale challenge. Mutual understanding, trust and confidence must develop between a broad range of actors. This will be necessary to ensure effective communication and to design innovative research programmes with new implementation tools across the different scientific fields and the existing management and governance systems.

Dutch coast

During past meetings and fora, the Marine Board-ESF, ICES and EFARO recognised the importance of breaking down the barriers that exist between disciplines and sectors. These organisations identified the need to address the gaps between the natural, social and economic sciences in order to meet the scientific needs to implement the Ecosystem Approach to Management. In anticipation of the forthcoming challenges of implementing the Integrated Maritime Policy, the organisations agreed in 2006 to develop a dedicated Working Group on "Science dimensions of an Ecosystem Approach to Management of Biotic Ocean Resources (SEAMBOR)".

The SEAMBOR Working Group was not only innovative in its scientific mandate, it was also a pioneering initiative in bringing together different pan-European and inter-governmental marine organisations which clearly demonstrated their willingness to work together to address a common scientific challenge. EFARO and ICES joined with the Marine Board-ESF in an initiative that

1. United Nations General Assembly (1987): *Report of the World Commission on Environment and Development: Our Common Future.*

Foreword

provided their specific knowledge and complementary expertise to form a multidisciplinary tripartite Working Group which addressed:

- New research approaches to further support the implementation of an Ecosystem Approach to Management (e.g. dynamics of human uses from the multiple perspectives of ecology, economy and governance, analysis of the functioning and effectiveness of management and governance systems and new tools for knowledge transfer);
- Existing impediments to the implementation of Ecosystem Approach to Management; and
- Foreseeable and achievable Ecosystem Approach to Management workplans with specific objectives that could lead to an improved science-base for the implementation of the Ecosystem Approach to Management of Biotic Ocean Resources.

One of the benefits of this position paper is its independent scientific advice. A list of key recommendations has been drawn up which, if implemented, will facilitate a more rapid implementation of the Marine Strategy Framework Directive (e.g. assessment of the state of the environment, environmental targets and monitoring programmes, definition of boundaries of sustainability etc.).

This position paper contains useful recommendations directed at the science community, programme managers and high-level policy makers to inform, facilitate and support the implementation of an Ecosystem Approach to Management both nationally and at a pan-European level. Its content highlights the existing challenges in dealing with such a holistic concept as the EAM which calls for integrated knowledge and requires multiple expertise from different sets of stakeholders.

The Marine Board-ESF, ICES and EFARO sincerely thank the SEAMBOR Working Group Chairman, Dr. Jake Rice (ICES), and members of the Working Group for their efforts in addressing such a complex subject area. Their work has been crucial in turning available concepts and principles into operational objectives and paving the way towards the achievement of Good Environmental Status of all European seas by 2020.

Lars Horn
Chair of the Marine Board-ESF

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ICES Executive Secretary

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Chair of EFARO

Use of Terms

A number of terms used in this report have several definitions. The definitions provided below and used throughout the report are often combinations of disciplinary definitions. Some of these are extracted from the “Assessment of Assessments” report made by UNEP and IOC-UNESCO in 2009[2]. More details on the context of the definitions are provided in the main text.

Adaptive management: use of feedback about the effectiveness of past management actions in achieving goals, to guide changes in the management actions and/or to guide changes in the goals or objectives themselves (learning). The changes are intended to increase the effectiveness of management interventions, accommodate unforeseen factors relevant to achievement of the objectives or adjust the objectives being pursued to be more realistic, feasible or cost-effective. The feedback may come from planned and structured monitoring and evaluation, but can also be opportunistic and reactive.

Assessments: formal efforts to assemble selected knowledge with a view to making it publicly available in a form intended to be useful for decision-making:

- ***Impact Assessments*** and response assessments incorporate environmental, economic and social aspects;
- ***Sectoral Assessments*** address a particular sector of human activity such as fishing, tourism or oil and gas development;
- ***Thematic Assessments*** focus on a theme or issue other than a single sector of human activity. They may cover one or more ecosystem component like sea turtles or coral reefs, or they may focus on a particular issue such as land-based sources of marine pollution or marine debris;
- ***Integrated Assessments (IAs):*** this report acknowledges the broad usage but attaches particular importance to ***fully Integrated Assessments***; that is, assessments that integrate across environmental, economic and social aspects, across industry sectors, and across ecosystem components (which may include land-based sources of inputs as well as land-based industries that depend on marine resources).

Biotic Ocean Resources (BORs): living components of marine ecosystems such as fish and algae which can re-stock themselves if not over-harvested.

Dashboard: tool to describe a multivariate view of ecosystem status and changes.

2. UNEP and IOC-UNESCO (2009): *An Assessment of Assessments, Findings of the Group of Experts. Start-up Phase of a Regular Process for Global Reporting and Assessment of the State of the Marine Environment including Socio-economic Aspects.*

Ecosystem Approach (EA): abstract conceptual work to build the knowledge framework in which management will be developed and applied. As soon as one starts to develop policy and management of a single sector, Ecosystem Approach (EA) will turn into ***Ecosystem Approach to Management*** **(EAM)**. EAM considers the entire ecosystem, including humans, in an integrated manner. The goal of an EAM is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need. EAM differs from conventional approaches that usually focus on a single species, sector, activity or concern; it considers the cumulative impacts of different sectors.
Integrated Management taking an Ecosystem Approach aims to improve the coordination of policy and/or management of multiple industry sectors and place the coordination in an ecosystem context. Integration of policy and management across sectors must be done first. Then as details get worked out, the activities become more and more sectoral and independent, within the integrated overall framework.

Ecosystem goods and services: definitions and examples are presented in the Information Box 4, page 33 and Summary Box 5, page 34.

Ecoregion (EU Marine Strategy Framework Directive): definitions and examples are presented in the Marine Strategy Framework Directive Information Box 1, page 20 and in Annex 1.

Externalities: any situation when the well-being of a person or the production of a company depends on real (non-monetary) variables which are affected (even decided) by other agents (persons, companies, governments) without any particular attention given to the potential effects on the person or the company affected. The term “external” refers to the fact that the effect happens outside the relationships voluntarily established between the economic agents on markets. Interactions between fishers represent reciprocal external negative effects meaning that the agents which cause the effects also suffer the consequences. These externalities arise from the specific nature of the resources. Because of their “fugitive” character, fish stocks are technically difficult to allocate to individual users beforehand; however, the use made by some reduces the availability of the resource for others.

Good Environmental Status (GES): definitions and examples are presented in the Marine Strategy Framework Directive Information Box 1, page 20 and in Annex 1.

Governance processes: formal and informal processes that lead to decisions about policies and management options to pursue. Ocean governance is used in this report as a shorthand term for all the institutions (rules, laws, policies and measures, decision-making authorities) that specify how states and other stakeholders undertake human activities in the oceans.

Impacts: direct impacts occur when a pressure (e.g., oil spill) leads to an immediate change of state (e.g., fish and bird mortality) in the location of the pressure. Indirect impacts occur when a pressure propagates through a system, leading to further impacts sometimes in a different place or at a different time: for example catch and by-catch have a direct impact on the populations of the species caught, but can also have an indirect effect on predators whose prey is reduced. Cumulative Impacts accrue when multiple pressures (or stressors) affect the same part of an ecosystem or societal group. They also refer to persistent pressures over time (e.g., build up of toxic pollutants).

Large Marine Ecosystems (LMEs): definitions and examples are presented in the Information Box 2, page 23.

Management processes: formal and informal processes by which a decision, once made, is implemented. Details of which players have which roles in governance and management vary greatly among jurisdictions, but the processes goals, and the types of information necessary to achieve them, have many common properties across jurisdictions.

Multidisciplinary (v. interdisciplinary): multidisciplinary assessments are assessments where specialists in several different fields contribute information collected, analyzed and interpreted according to the standards of the respective disciplines, and the results are aggregated and further interpreted together. An interdisciplinary assessment may have the same basic information as a multidisciplinary assessment, but the central analyses and interpretations are done in a way most appropriate for the goals of the full assessment, and not necessarily according to the practices of any of the constituent assessments.

North Atlantic Oscillation (NAO): climatic phenomenon in the North Atlantic Ocean of fluctuations in the difference of atmospheric pressure at sea-level between the Icelandic low and the Azores high. Through east-west oscillation motions of the Icelandic low and the Azores high, it controls the strength and direction of westerly winds and storm tracks across the North Atlantic. It is highly correlated with the Arctic oscillation, as it is a part of it.

Pacific Decadal Oscillation (PDO): pattern of Pacific climate variability that shifts phases on at least inter-decadal time scale, usually about 20 to 30 years. The PDO is detected as warm or cool surface waters in the Pacific Ocean, north of 20°N. During a “warm”, or “positive”, phase, the west Pacific becomes cool and part of the eastern ocean warms; during a “cool” or “negative” phase, the opposite pattern occurs.

Regime shift: definition is presented in the Information Box 3, page 27.

Stakeholders: for the purposes of this report, include government officials at all levels, including at the community level, and parliamentarians; users of assessment results in the private sector; representatives of scientific, professional, industrial, environmental and other private organizations; representatives of intergovernmental organizations; civil society and the public; indigenous groups and other holders of traditional and/or local knowledge and the media.

Sustainability: in a broad sense, sustainability is the capacity to endure. In ecology, the word describes how biological systems remain diverse and productive over time. For humans, it is the potential for long-term maintenance of well-being which in turn depends on the well-being of the natural world and the responsible use of natural resources. At the Earth Summit in Rio in 1992, sustainable development was described as *“development which meets the needs of the present without compromising the ability of future generations to meet their own needs”*.

Thermohaline Circulation (THC): water body movements driven by gradients in salinity and temperature.

Transaction costs: overhead incurred in the process taken by the governance participants (institutions and individuals) to come to a decision. Overhead includes both financial costs of preparing material for participants (often in a variety of formats for different audiences), and travel and logistics for consultations and meetings (whether physical or via telecommunications), and the time of all participants in the process to complete all the phases of preparation and dissemination of information, consultation and negotiation, reaching and communicating a decision.

Vulnerability: potential of a system to be harmed by stresses (threats). It depends on the exposure to change (extent of change and impacts) and the sensitivity and capacity to adapt (resilience).

Executive Summary

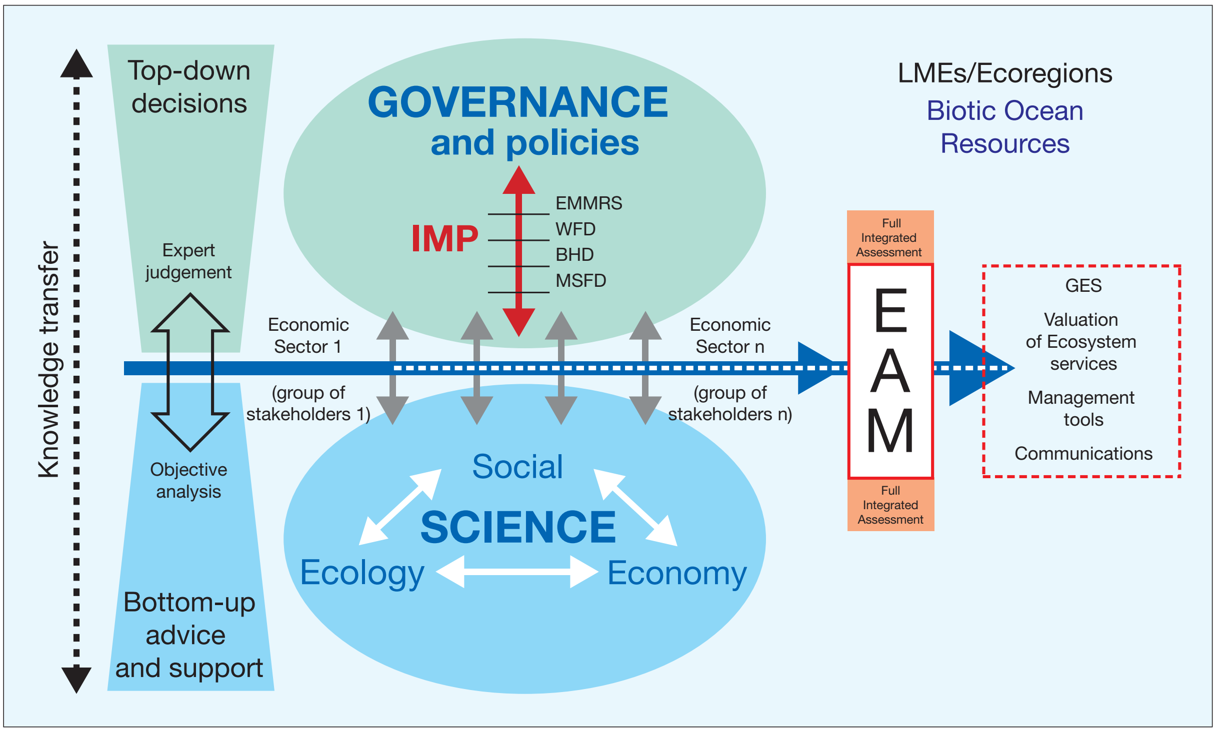
I. Introduction

This report on the science requirements for an **Ecosystem Approach (EA) and Integrated Management of Biotic Ocean Resources (BORs)** has a central organizing theme and a unique identity, giving equal attention to the science needed to understand the **natural system, the social system, and the governance system**. It is these three systems, functioning in a coherent and integrated manner, which will allow the European Union to apply Integrated Management within an Ecosystem Approach to achieve **Good Environmental Status (GES)**, as required by the **Marine Strategy Framework Directive (MSFD)**. This report lays out the science needed to support these efforts, and to make human activities in the seas ecologically, economically, and socially sustainable.

Science provides the ability to assess the impacts of each human activity on all components of the marine ecosystem. It can integrate those assessments, assess the cumulative effects and synergies of the activities and communicate the results to a range of diverse end-users in government, civil society, and the private sector. This capacity is expressed in the following five steps of Integrated Management within an Ecosystem Approach:

- Setting objectives for the overall condition of the ecosystem;
- Monitoring and research;
- Assessment;
- Advice; and
- Adaptive management.

These steps must be based on *"sound marine scientific research and technology, thus supporting evidence-based policy making and furthering the knowledge-economy"* (Commissioner Joe Borg, 2006).



A.Carbonnière SEAMBOR WG (MB-ESF)

Figure 1. Schematic representation of the implementation of an Ecosystem Approach to Management of Biotic Ocean Resources in European Large Marine Ecosystems/Ecoregions (Aurélien Carbonnière and Andrew Kenny)
The Ecosystem Approach to Management (EAM) considers the entire ecosystem, including humans, in an integrated manner. Its goal is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need.
EAM essentially requires the high-level integration of governance in the form of expert judgement (e.g. referred here by the Integrated Maritime policy – IMP) and with science in the form of objective science and knowledge (e.g. towards the 'real' integration between the social, ecological and economic sciences)

BHD: Birds and Habitats Directive
EMMRS: European Marine and Maritime Research Strategy
GES: Good Environmental Status
MSFD: Marine Strategy Framework Directive
WFD: Water Framework Directive

This report considers and describes the necessary science for proper implementation of the Ecosystem Approach in the context of the Integrated Maritime Policy (IMP).

It concludes with a detailed work plan to address identified research gaps and priorities.

To underpin this work plan, the report identifies **the six most critical science goals or priorities** which must be achieved before an Ecosystem Approach to the Management of Biotic Ocean resources (BORs) can be realised.

These six priorities are presented in Box below:

Critical science priorities to underpin the Ecosystem Approach to Management of Biotic Ocean Resources

1. **Develop tools for integrated policy evaluation to improve the ability of decision-making to take account of the important interactions between humans and marine ecosystems;**
2. **Improve the knowledge of how ecological support systems (food webs, physical-biological coupling, etc.) are linked to the provision of goods and services which benefit, and are utilised by, humans;**
3. **Assess the consequences of ecosystem changes for economies/societies, and investigate and develop mitigation and/or adaptation options;**
4. **Evaluate the advantages and limitations of alternative ecosystem conservation policies, including the use of economic incentives;**
5. **Ensure science support for strategic (regional) environmental assessments, including socio-economic factors; and**
6. **Take measures to improve data management and inter-operability of data sources and analytical methods.**

II. Gaps in scientific knowledge and capabilities

Chapter II of this report identifies the major science and knowledge gaps in five topical areas:

- In the marine environment;
- In the social and economic aspects of human uses of the oceans;
- In effective governance of the oceans;
- In integrated assessment; and
- In knowledge transfer.

The report outlines ways that these gaps can be addressed.

1. Understanding the bio-physical marine system

The key issues with regard to understanding the dynamics and resilience of populations, biological communities and ecosystems include:

- ***Scales (in space and time):***
  For policy and management to operate at effective scales, it is necessary to know where natural boundaries occur in ecosystems and the time-scales of major dynamic processes and natural forcers. Understanding which factor or combinations of factors have the greatest influence on ecosystem state across a range of spatial and temporal scales is a fundamental requirement for an effective EAM. **Scaling laws which define such relationships therefore need to be developed and applied in response to regional policy instruments such as the Marine Strategy Framework Directive.**

- ***Critical natural factors and processes to determine ecosystem function and state:***
  Critical biotic (e.g. those affecting the rate of primary production) and physical (e.g. stratification and seasonal fronts) factors associated with climate forcing have a significant influence on the status and dynamics of many European regional marine ecosystems. **All these factors should be central in process-based research to provide the ecological basis for achieving the objectives of the Marine Strategy Framework Directive.**

- ***Process of ecosystem change that may be large and hard to reverse:***
  Large-scale changes, referred to as “regime shifts”, may affect all components of an ecosystem, from the bottom to the top of the food web. Large-scale ocean climate forcings such as those driven by the North Atlantic Oscillation (NAO) and Pacific Decadal Oscillation (PDO) affect the capacity of systems to withstand pressures exerted by human activities (e.g.

fisheries). These factors may mean that the times and conditions when Large Marine Ecosystems (LMEs) may be especially vulnerable to major changes in response to a given level of a human pressure may be predictable. **Hence research should focus on quantifying the relationships between ecosystem changes and combinations of climate forcing and the level of human activities, thus developing an "ecosystem risk indicator".**

- ***Interconnected ecosystems and their dynamics: the importance of complexity and diversity in maintaining healthy seas:***
  The above questions can be investigated for individual European marine ecoregions, but the **interconnections between biological and physical processes among these seas must also be understood and taken into account in making management adaptive and anticipatory rather than only reactive.**

Box A – Understanding the marine environment: key messages for future research

The research needs address identified knowledge gaps in the understanding of the bio-physical system of the Ocean.

These priorities include:
– Climate change and ecosystem processes;
– Scales of spatial and temporal variation of patterns and processes; and
– The dynamics and productivity of complex systems.

2. Understanding the socio-economic system

The key issues with regard to understanding the dynamics of human uses of marine ecosystems include:

- ***Linkages between the state of ecosystems and human well-being:***
  The Millennium Ecosystem Assessment (2005) found that the major drivers of change, degradation or loss of marine and coastal ecosystem goods and services are predominantly anthropogenic. Keeping human uses of ecosystems at sustainable levels must be supported with a better understanding and quantification of the services important to humans that are provided by marine ecosystems. However, **there is a general lack of knowledge regarding the nature and extent of the services provided by marine ecosystems, and consequences of changes in these services for human well-being.**

- ***Understanding the dynamics of socio-economic systems:***
  In many cases, ecosystem degradation cannot be successfully addressed without improving our understanding of the drivers of ecosystem uses, particularly the institutional and economic drivers. **Even when individual, institutional, and economic behaviors are at least partially known, methods to influence those behaviors to improve the likelihood of sustainable choices are often not apparent.**

- ***Placing our knowledge of socio-economic systems into Integrated Management of multiple use frameworks:***
  Policy or management questions which need to take account of the multiple uses of marine biotic resources require analysis of a set of potentially more complex processes, involving many direct and indirect interactions between activities. Difficulties arise from the multiple scales at which interactions can occur, and from the uncertainties which may exist regarding key ecological processes and their dynamic interactions with human activities. **Operational measures of the value of ecosystem services need to be established,** that can be taken into account by both public and private stakeholders in their choices regarding ecosystem uses. **Knowing if and how non-linearities are expressed in social and economic dynamics of marine industries and communities is also necessary to develop effective policies and strategies for sustainability.**

3. Understanding management and governance systems

The key issues with regard to understanding the dynamics and effectiveness of management and governance include:

- ***Use of information as effectively as possible, including information on risks and uncertainties:***
  Research on a variety of scales is needed to inform the development of governance and advisory mechanisms in order to produce objectives and decisions that all sectors of society will support to sustain the use of goods and services from healthy marine environments. Both top-down and bottom-up governance and management should be considered in developing and implementing ocean policies. **Experiences from other jurisdictions should be studied for the lessons they contain, but further research is needed to know how to adapt those lessons to the complex EU governance structure. To operationalise Ecosystem Approach to Management and Integrated Management, a place-based management strategy is needed to best address the fragmen-**

tation of decision-making processes across both sectors and ecosystem components. These, in turn, require efficient, adaptive and flexible governance and management systems.

Box B – Functioning and effectiveness of management and governance processes: key questions for future improvement

The main research components needed to improve the basis for functioning governance systems in the oceans include investigating:

- How to make governance systems more inclusive, transparent and timely;
- How to achieve objectives that are clear, explicit, unambiguous, and coherent across environment, economic, and social aspects of policy and management;
- How to position science appropriately and effectively in these systems;
- How to select an appropriate suite of management tools to achieve all the objectives, and implement them successfully;
- How to evaluate outcomes reliably and provide sound and timely feedback to address shortcomings; and
- How to evaluate the impact that science information and advice is having on governance.

4. Conducting fully Integrated Assessments to support the Integrated Maritime Policy

Fully Integrated ecosystem Assessments (across all ecosystem components, all industry activities and across environmental, economic, and social dimensions of the system being assessed) are necessary for Integrated Management under an Ecosystem Approach. These have two basic requirements:

1. Identify all relevant components for Integrated Assessments and demonstrate how all these elements relate to one another; and
2. Describe and quantify the status and trends in all relevant ecosystem components over varying spatial and temporal scales.

These tasks represent significant science demands. **There are many building blocks for assessment in support of Ecosystem Approach to Management, Integrated Management and the implementation of the Marine Strategy Framework Directive. More effort is needed to pull the pieces together. There is a need for streamlining the national tasks of monitoring and assessment of environmental status.**

Box C – Fully Integrated Assessments: key measures for their management and supervision

The main science gaps and issues arising with regard to Integrated ecosystem Assessments are:

- Preparation of best practice guidance on how to undertake Integrated Assessments (IAs) and how to disseminate the results of these assessments to different stakeholder groups;
- Objective methods which explore, quantify, describe and weight the connectivity and interactions between ecosystem components and quantify, describe and weight the status and trends of ecosystem components;
- A review of methods most suited for dissemination and communication of results; and
- The development of systems which can predict and forecast changes in the interactions and status of ecosystem components against different scenarios.

5. Increasing and improving knowledge transfer

Knowledge transfer of science information and assessments is the final area where research is needed. Key issues and considerations that arise include **research for understanding, improving and facilitating knowledge transfer between different stakeholders.**

Box D – Knowledge transfer: major gaps and key priorities

Three domains or pathways for knowledge transfer are identified:
– Spreading scientific knowledge among scientists and applied technicians (higher education and research and technical training);
– Communication of scientific knowledge to participants in governance processes; and
– Outreach of scientific knowledge for the general public and society.

The development of tools for knowledge transfer between the complex network of participants in science and governance must also focus on three factors:
– Clear identification of relevant actors and their roles in each component, and an understanding of their cultures and customs;
– Clear identification of the inputs required by each component; and
– Clear identification of the products of each component.

The "Best Practices for Communication" from the UN Group of Experts Report* provides a starting point for identifying the work needed to develop these tools.

* Group of Experts for the IOC/UNEP-coordinated Assessment of Assessments, http://www.unga-regular-process.org

III. Supporting the implementation of the Marine Strategy Framework Directive

There is an overall need to develop or diversify strategies and technologies to facilitate the implementation of the Marine Strategy Framework Directive.

Box E – Towards the implementation of the Marine Strategy Framework Directive: key scientific needs

– Preparation of Geographic Information System (GIS)-based marine resource inventories;
– Physical characterization of ocean processes at scales relevant for human exploitation;
– Assessment of goods and services provided by Biotic Ocean Resources (BORs);
– Preparation of an inventory of economic activities and their impacts;
– Economic valuation of the potential of ocean resources;
– Socio-economic studies of multiple ocean uses and their interactions, including conflicts;
– Establishment of monitoring and evaluation programmes including operational oceanography/observatories;
– Development of Good Environmental Status (GES) descriptors;
– Implementation of Marine Spatial Planning (MSP) strategies;
– Establishment of data management information systems;
– Development of (timely) adaptive management capabilities; and
– Development of management paradigms able to cope with scientifically irreducible uncertainty.

IV. Impediments to the Ecosystem Approach to Management

The report also discusses **several impediments to progress in developing the science support needed for implementation of the Marine Strategy Framework Directive.**

Box F – Impediments to Marine Strategy Framework Directive implementation

- Limitations to the scope, mandates and accountabilities of institutions;
- Protective attitudes of institutions towards their mandates and funding sources;
- A reluctance of organizations to change their processes and tools;
- Timing mismatches between policy needs and science capabilities;
- A lack of overarching objectives that clarify priorities among environmental, economic, and social outcomes of policy decisions;
- Lack of agreement on the distribution of costs and benefits from policies for Integrated Management and the Ecosystem Approach;
- Absence of mechanisms for conflict resolution;
- Lack of agreement on the legitimate role of science in policy and decision-making; and
- An overall lack of guidance on the priorities among the wide range of science activities necessary for implementation of the Marine Strategy Framework Directive.

V. Establishing a workplan that could improve the science base needed for an Ecosystem Approach to Management

Box G – Science Workplan

The report concludes with a general workplan for addressing all the science issues raised above. **This science workplan has 66 elements organised under four themes:**

- Workplan for research related to better knowledge of the status and uses of ocean resources (26 structuring elements);
- Workplan for research and science activities related to the management of human activities and conservation of ocean resources (12 structuring elements);
- Workplan for the operational use of tools and provision of ongoing support for the implementation of the Marine Strategy Framework Directive or the Ecosystem Approach generally to achieve sustainability (18 structuring elements); and
- Workplan for addressing the major impediments to improved use of science (8 elements).

To end, the report concludes with **15 top science priorities** that emerge from this review.

1. The Ecosystem Approach to Management in the context of the European marine research policy area

1.1 The Ecosystem Approach to Management

The terms **Ecosystem** and **Ecosystem Approach (EA)**[3] are used in many different ways, and clear definitions are important for effective communication and planning. An ecosystem is defined in Article 2 of the United Nations Convention on Biological Diversity (UN CBD) as *"a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit".*

This definition makes it clear that ecosystems include both the living and non-living parts of nature. It is important to recognize that humans are parts of the ecosystem on which they depend, a concept fundamental to policies and management for sustainable use and conservation. This inclusive perspective gives this report on science requirements for Ecosystem Approach and Integrated Management a central organizing theme and a unique identity. It gives equal attention to the science needed to understand the natural system, the social system, and also to the governance[4] systems necessary to ensure that the natural and social systems thrive. It deals with all three aspects at a high level, with inputs from experts in each field to give credibility to the science needs that are identified. It also gives attention to the capacity-building needs for monitoring and assessing, in thematic and integrated ways, both the natural and the social components of marine ecosystems and their uses. With sustainability[5] universally recognized as having ecological, social, and economic dimensions, a report on science needs for delivery of an Ecosystem Approach and Integrated Management to human activities in the oceans must address all three dimensions and their integration. This report aims to achieve this.

The **Ecosystem Approach to Management** is now broadly accepted as a key management principle. The increased awareness and formalisation of the EA has emerged as a result of international environmental agreements developed by the United Nations (Turrell 2004; Bianchi 2008). An endorsement and call for the application of the EA was declared in Decision V/6 of the Conference of the Parties to the UN CBD at Nairobi, Kenya, in 2000, and by the UN General Assembly Resolution on Oceans and the Law of the Sea in 2001 (Resolution 56/12, Article 27)[6]. The UN CBD decision has an annex[7] with a description, principles and operational guidance for application of the EA.

3. See definition in the Use of Terms section, page 9
4. See definition in the Use of Terms section, page 9
5. See definition in the Use of Terms section, page 10
6. http://www.un.org/Depts/los/general_assembly/general_assembly_resolutions.htm#2001
7. http://www.cbd.int/decisions/view.shtml?id=7148 ; Vierros 2008

Figure 1.1. Fisherman on board a trawler boat

A statement from the first Joint Ministerial Meeting (JMM) of the Helsinki and OSPAR Commissions in Bremen in June 2003[8], defines EA as "*the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity*".

It is worth stressing the emphasis on Integrated Management of human activities in this definition: *"The Ecosystem Approach puts emphasis on a management regime that maintains the health of the ecosystem alongside appropriate human uses of the marine environment, for the benefit of current and future generations"* (JMM 2003). The essential role of Integrated Management makes it clear that the EA has two complementary dimensions; policies and practices need to be integrated vertically within a sector and horizontally across sectors (Bianchi *et al*. 2008; Grafton *et al*. in press). Scientifically this means that we need the ability to assess the opportunities for and impacts[9] of each

8. http://www.ospar.org
9. See definition in the Use of Terms section, page 10

1. The Ecosystem Approach to Management in the context of the European marine research policy area

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Figure 1.2. Finfish aquaculture

commercial sector on all other components of the marine ecosystem, integrate those assessments, assess the cumulative effects and synergies of the sectors, and communicate the results to diverse clients in government, civil society, and the private sector. Institutionally, the sectors need to work closely together to plan and adapt to those assessments, in a transparent and inclusive way.

The Food and Agriculture Organisation (FAO) has prepared "Technical Guidelines for an Ecosystem Approach to Responsible Fishing" (FAO 2003) and has identified requirements and steps to elaborate guidelines for an EA to Aquaculture[10]. These build on the FAO Code of Conduct and the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem (FAO 2OO1) and provide a complete framework for addressing ecosystem considerations within the fisheries and aquaculture sectors. The distinction between within sector and across sectors implementation remains important, but there is growing acknowledgement of the need for coherence of policies implementing an EA across various intergovernmental agencies and levels of government. This coherence has not yet been achieved in many cases, particularly between agencies with regulatory mandates and agencies with solely conservation mandates (Ridgeway and Rice in press).

Integrated Management using the Ecosystem Approach requires science to support five interlinked steps (NSC 2002, Annex1; OSPAR 2006a&b; ICES 2001, 2007):

1. Setting objectives for the overall condition in the ecosystem, translated into operational targets and limits for ecosystem status;
2. Monitoring and research, to provide updated information on the status and trends and insight into the relationships and mechanisms in the ecosystem;
3. Assessment (building on new information from monitoring and research) of the current situation, including the degree of impacts from human activities;
4. Advice, translating the complexities of nature into a clear and transparent knowledge base for decision-makers and the public; and
5. Adaptive management[11], where measures are tailored to the current situation in order to achieve the agreed objectives, and assimilate new information as it becomes available.

The issue of setting ecological objectives is a core element of this approach. After considerable input of advice from ICES[12], a set of 21 Ecological Quality elements with Objectives (EcoQOs) set for 10 of them, were agreed by the Ministers at the 5th North Sea Conference (NSC 2002, Annex 3).

Ecological Quality is defined as *"an overall expression of the structure and function of the marine ecosystem taking into account the biological community and natural physiographic, geographic and climatic factors as well as physical and chemical conditions including those resulting from human activities"* (NSC 2002). It is expressed by a number of ecological quality elements or variables, reflecting the different parts of the ecosystem, against which objectives (EcoQOs) or targets can be set. Taken together, the suite of EcoQOs can be seen as an envelope defining the acceptable state of an ecosystem which can realistically be sustained. This can either be a wide outer envelope of limits which should not be exceeded due to risk of serious or irreversible damage to the ecosystem, or a more restricted inner envelope defined by targets based on some considerations of optimum use of ecosystem goods and services, or a combination of the two. Not all jurisdictions and agencies applying an EA use the terminology of EcoQOs. However, the overall conceptual framework is almost universal.

10. http://www.fao.org/docrep/011/i0339e/i0339e00.HTM

11. See the definition in the Use of Terms section, page 9
12. http://www.ices.dk/products/cooperative.asp

1.2 The Ecosystem Approach to Management concept in the European Marine research policy landscape

On 7 June 2006, the European Commission (EC) adopted a Green Paper on a Future Maritime Policy for the European Union [COM (2006) 275]. The Green Paper examined all of the economic activities of Europe which are linked to, or impact up on, the oceans and seas, as well as all the policies dealing with them, with a view to finding the best way to extract benefit from the oceans in a sustainable manner.

At the time, the Commissioner for Maritime Affairs and Fisheries, Mr Joe Borg, declared that the future European Maritime Policy would be:

- All embracing, aimed at developing a dynamic maritime economy;
- Based on the principles of sustainable development advocated in the Gothenburg Agenda (i.e. in harmony with the marine environment);
- Based on sound marine scientific research and technology, thus supporting evidence-based policy making and furthering the knowledge-economy (Lisbon Agenda); and
- Directed towards human communities that derive their livelihood and quality of life from proximity to and use of marine resources.

The European Commission presented its vision for an Integrated Maritime Policy for the European Union on 10 October 2007: the vision document, also called the

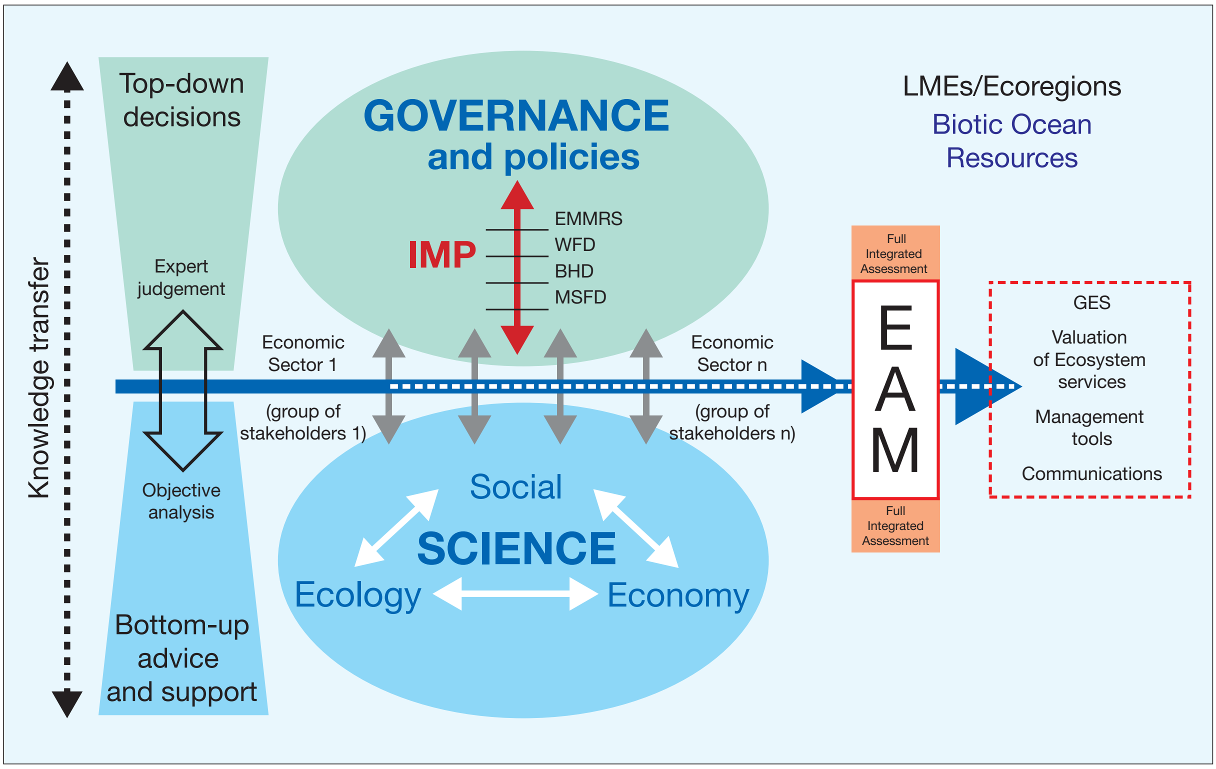

Figure 1.3. Schematic representation of the implementation of an Ecosystem Approach to Management of Biotic Ocean Resources in European Large Marine Ecosystems/Ecoregions (Aurélien Carbonnière and Andrew Kenny)
The Ecosystem Approach to Management (EAM) considers the entire ecosystem, including humans, in an integrated manner.
Its goal is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need.
EAM essentially requires the high-level integration of *governance* in the form of expert judgement (e.g. referred here by the Integrated Maritime policy – IMP) and with science in the form of objective science and knowledge (e.g. towards the 'real' integration between the social, ecological and economic sciences).

BHD: Birds and Habitats Directive
EMMRS: European Marine and Maritime Research Strategy
GES: Good Environmental Status
MSFD: Marine Strategy Framework Directive
WFD: Water Framework Directive

Figure 1.4. From left to right: the Green Paper on a Future Maritime Policy for the European Union, the Blue Book and the Marine Strategy Framework Directive ©EC

Blue book [COM (2007) 575], was accompanied by a detailed action plan.

Following an extensive consultation, the European Parliament and Council adopted in 2008 a new Marine Strategy Framework Directive (MSFD[13], Directive 2008/56/EC). This Directive is intended to be the environmental sustainability pillar of the Integrated Maritime Policy (IMP) and can be seen as the legal and practical implementation of the EAM of human activities in the marine environment.

In line with these regional and European-wide developments, individual sectors are also modifying policies to

13. http://ec.europa.eu/environment/water/marine/index_en.htm

Information Box 1 – The EU Marine Strategy Framework Directive (MSFD)

The central objective of the Marine Strategy Framework Directive (MSFD) is *"to protect and restore European oceans and seas and ensure that human activities are carried out in a sustainable manner so that current and future generations enjoy and benefit from biologically diverse and dynamic oceans and seas that are safe, clean, healthy and productive"* (Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008). At the core of the Directive is the concept of Good Environmental Status (GES), which is the overall expression of ecosystem quality to be achieved by the year 2020. Environmental status is defined as *"the overall state of the environment in marine waters, taking into account the structure, function and processes of the constituent marine ecosystems together with natural physiographic, geographic, biological, geological and climatic factors, as well as physical, acoustic and chemical conditions, including those resulting from human activities inside or outside the area concerned"*(see Annex 1: "Marine Strategy Framework Directive qualitative descriptors for determining the Good Environmental Status").

The MSFD has two main parts. The first, which is called "Preparation", prescribes how environmental status is to be expressed and made operational. The second sets out how programmes of measures are to be developed at Member States level to achieve the goal of GES. The Preparation phase contains four elements: i) initial assessment, ii) determination of environmental status, iii) settings of environmental targets, and iv) monitoring programmes. These elements are to be prepared by Member States by 2012-2014.

European marine regions and subregions will be established as management units for implementation of the Directive. According to Article 4 there are four regions (Baltic Sea, Northeast Atlantic Ocean, Mediterranean Sea, and Black Sea), with four subregions recognized for the Northeast Atlantic Ocean (North Sea, Celtic Sea, Bay of Biscay and Iberian coast, and Macaronesian biogeographical region) and four also for the Mediterranean Sea (Western Mediterranean Sea, Adriatic Sea, Ionian Sea and the Central Mediterranean Sea, and Aegean-Levantine Sea).

For marine waters within each region, EU Member States will be required to develop marine strategies. By 2015, a programme of measures designed to achieve or maintain GES shall be developed. Member States sharing a marine region or subregion, are obliged to cooperate to ensure that the different elements of the MSFD are coherent and coordinated. GES is to be documented through monitoring and reporting, and to be achieved by 2020.

Key requirements and associated timeframes for the Marine Strategy Framework Directive

Milestones	Actions	Phases
By July 2010	Member States to transpose MSFD	Program of measures towards GES (by 2015)
By July 2012	– Description, assessment, analysis of environmental status – Determination of GES – Environmental targets/indicators (with socio-economical analysis)	
By July 2014	National monitoring programs in place	
By 2020	Achieve GES	

make sectoral management coherent and compatible with the MSFD. As part of a plan to reform in 2013 the Common Fisheries Policy (CFP, the European Union's instrument for the management of fisheries and aquaculture), the EC launched a review in 2008 to make the CFP more efficient and more integrated with the Maritime Policy [COM 2009 (163)]. In addition, the Directorate General for Maritime Affairs and Fisheries (DG MARE) will ensure that the new CFP will integrate substantial changes to move effectively towards sustainable fisheries and to support the actions taken under the Birds and Habitats Directive (BHD) and foreseen by the MSFD [COM 2008 (187)].

These policy developments in the EU, building on the framework for EAM from the Bergen Declaration[14] (NSC 2002), put demanding requirements on the scientific community. The tasks include but are not limited to:

- Selecting of variables and information to be used to express environmental status or ecological quality;
- Designing of the required monitoring programmes, through coordination, adjustments, and complementation of existing monitoring;
- Clarifying the mechanisms and interactions within marine ecosystems that give these ecosystems their intrinsic sensitivity, resilience and stability;
- Documenting the impacts of both natural and human stressors on those mechanisms and interactions, and thereby on the environmental sustainability of human activities;
- Understanding the drivers and dynamics of human uses of the marine ecosystems, and thereby the social and economic sustainability of those uses;
- Evaluating the effectiveness of policies and management measures that may be applied to reduce undesirable environmental impacts of human activities, and/or to increase the sustainable benefits that society may take from these ecosystems;

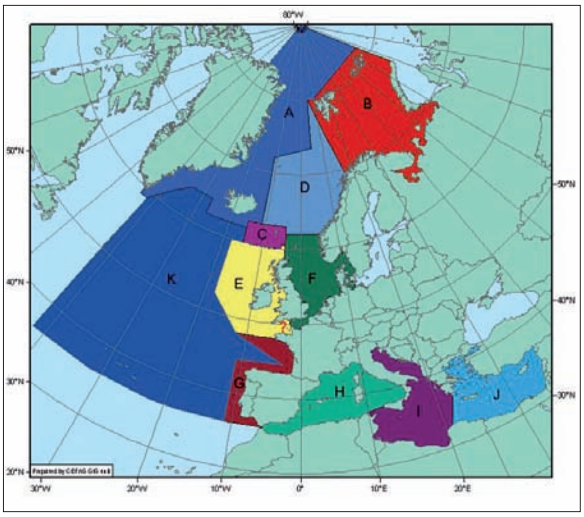

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Figure 1.5. ICES ecoregions

- Developing Integrated Assessments[15] of status and trends of ecosystems, and of impacts from different and simultaneously acting stressors, and evaluation of policy options to address the impacts; and
- Communicating of all results to audiences with diverse needs and levels of knowledge.

The following Chapters lay out the scientific requirements and effort needed to meet these challenges. Chapter 2 outlines the scientific gaps that currently exist. It considers gaps in our understanding and in the current monitoring of the dynamics of marine ecosystems (2.1), the dynamics and dependencies of human interactions within ecosystems (2.2), the governance strategies and institutions needed to ensure those uses are sustainable (2.3), the assessments needed to

14. http://www.ospar.org/html_documents/ospar/html/bergen_declaration_final.pdf

15. See definition in the Use of Terms section, page 9

support the implementation of necessary policies and measures (2.4), and finally the communication strategies and tools needed to apply existing and new knowledge effectively (2.5). Chapter 3 details specific recommendations to inform and support the successful implementation of the MSFD. Chapter 4 outlines the obstacles that must be overcome if we are to expand the knowledge base needed for applying an Ecosystem Approach to Integrated Management, and make better use of the knowledge in policy and management. The Chapters considers obstacles due to institutional impediments to coordination and integration (4.1), reluctance to innovate and take risk (4.2), and lack of clarity about priorities (4.3). Both Chapters 2 and 4 discuss the research needed to address the gaps and obstacles, and the institutional changes that are needed to facilitate the necessary research and application of research results. Chapter 5 concludes with a set of workplans that will promote progress on these research needs and institutional changes in a systematic and feasible manner.

Figure 1.6. Diver and snappers

2. Science dimensions – gaps in knowledge and research priorities

2.1 Understanding the dynamics and resilience of populations, communities and ecosystems

2.1.1 Scales of variation in ecosystem state and function – over what time and space scales do ecosystems vary and by how much?

The view of any system depends on the scale of investigation. Thus, the choice of scale can fundamentally affect the perspective and interpretation of the system's properties, not least because the variability of virtually all ecosystem descriptors is critically dependant upon the scale at which the measurements are made.

It therefore follows that the scale of the area to be assessed for management and policy purposes will have a great influence on the type and mode of descriptor to be measured. For example, measuring molecular processes which operate at small spatial scales (e.g. nm – µm) would add little to understanding the variation in ecosystem dynamics if the area to be assessed is at a broad scale (100 km or more). In this instance, monitoring the status of ocean currents, fronts and seabed type would be more useful.

Knowing where natural boundaries occur in an ecosystem, e.g. those which define specific seabed habitat types or water body masses, is an essential part of understanding and defining the scales of variability and hence defining the scope of associated monitoring and assessment programmes. At one level there is excellent evidence which shows that large scale atmospheric and ocean climate forcing events (such as the North Atlantic

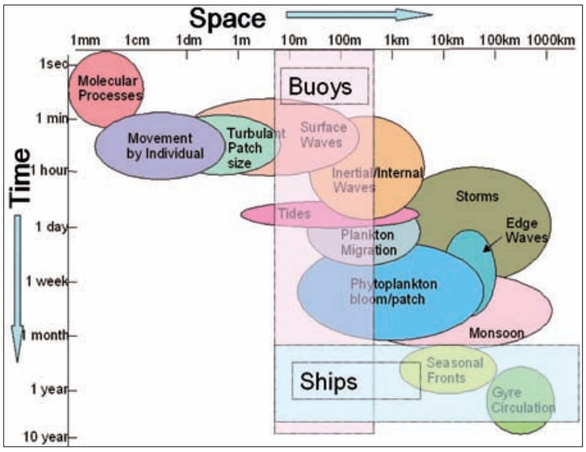

Figure 2.1. Ocean space-time regimes. Events which are associated with large spatial scale processes tend to occur over longer time periods (D. Mills, personal communication)

Oscillation and El Niño, respectively) exert considerable influence on ecological processes. For example, it has been shown for populations of krill in the Southern Ocean that their distribution is patchy on a range of scales. For very large patches of plankton the variations are best explained by large scale ocean processes such as general ocean circulation, upwelling and/or frontal systems, but on finer scales (measured in the order of km) biotic processes such as predator/prey interactions become increasingly important in explaining the complexity of patches.

Furthermore, the biogeographic ranges of species are strongly controlled by gradients in latitude and depth. For example, at the global scale it is well documented that the number of species declines as you move away from the equator (north or south). At the European scale this pattern of variation largely provides the basis for the delineation of biogeographic regions and the latitudinal boundaries between some of the European Large Marine Ecosystems (LMEs[16], see Information Box 2).

However, within biogeographic regions, additional factors become increasingly important such as the sediment or substrate type of the seabed, particularly for the benthos.

Information Box 2 – Large Marine Ecosystems (LMEs) and biogeographic ecoregions

Large Marine Ecosystems (LMEs) are open systems with flux of water and plankton and migration of fishes, birds and marine mammals across their boundaries, making the boundaries indistinct in reality. Nevertheless, there are more or less sharp discontinuities in physical features, such as capes, ridges and fronts, which are reflected in distribution patterns of organisms and can be used when drawing the boundaries of LMEs based on ecological criteria (Skjoldal HR 2004a,b). The Marine Strategy Framework Directive (MSFD) criteria used to define the ecological regions were also similar to those for identifying LMEs. The regions or subregions used in the MSFD are therefore equivalent to LMEs. For consistency with terminology used in other international contexts, this should be recognized.

16. http://dataservice.eea.europa.eu/atlas/

Summary Box 1 – Scales of variation in ecosystem state and function

1. Further quantification and understanding of the scales of natural variation (in space and time) within European regional seas is needed to establish the most effective marine ecosystem management units at scales below the units in the MSFD.
2. At large spatial & temporal scales, factors that exert broad-scale influences on marine ecosystems (e.g. climate forcing and fishing pressure) tend to be of greater importance in predicting and explaining variations in ecosystem state than those whose influence operates on a much more localised scale.
3. Understanding which factor or combinations of factors have the greatest influence on ecosystem state across a range of spatial & temporal scales is a fundamental requirement for effective Ecosystem Approach to Management (EAM). Scaling laws which define such relationships therefore need to be developed and applied in response to regional policy instruments such as the MSFD.

2.1.2 What are the critical natural factors and processes which determine ecosystem function and state?

Productivity and the transfer and recycling of carbon and nutrients between the water column and seabed are arguably among the most pervasive processes acting on the diversity, structure and function of marine ecosystems. The effects of these processes and the factors which control them have received much attention in recent years. For example, biological productivity (often considered as gross primary productivity measured, for instance, by satellite derived Chlorophyll *a* imagery) is known to decrease away from the coastal zones and with increasing depth. In general this means that biological secondary production (to which fisheries production is intimately related) also decreases away from the coast and with increasing depth.

In addition, it has been widely shown that there is a link between ecological productivity and diversity such that at relatively high levels of productivity, there is a tendency towards reduced levels in diversity. For many continental shelf marine ecosystems, maximum biological diversity occurs at intermediate levels of productivity, which, in turn, occur at intermediate oceanic depths, e.g. for megafauna at around 2000m depth in the North Atlantic and around 1000m depth in the Mediterranean. However, all these patterns are general and modulated by "local" (<100 km) conditions.

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Figure 2.2. A phytoplankton bloom off the east coast of Scotland

Estimating primary productivity in pelagic and benthic marine ecosystems is complicated. Recent studies indicate that phytoplankton production in the North Sea may be underestimated by as much as 20 to 50% (Richardson and Pederson 1998; Richardson *et al.* 1998; Weston *et al.* 2004, 2005), largely due to active growth of phytoplankton in subsurface waters, which was overlooked in earlier studies. Similarly, secondary production by copepods (zooplankton) in the North Sea may be higher than previously estimated due to growth associated with subsurface chlorophyll peaks.

Close coupling between nutrients, the microbial food web and the classical diatom-copepod food web suggests that the contribution of the microbial food web to the overall productivity of marine ecosystems has also been underestimated. In upwelling regions, the microbial foodweb has been shown to make an important contribution to the carrying capacity for zooplankton and pelagic fish, particularly when nitrates are depleted after the spring and during the autumn and winter months (Vargas *et al.*, submitted).

By contrast, there is evidence that under certain oligotrophic conditions, microbial loops act to prevent the transfer of carbon and nutrients to higher trophic levels. In essence the microbial loop short circuits the flow of energy in marine ecosystems. For example, it has been shown that in the Eastern Mediterranean the combination of low primary productivity (extremely oligotrophic by European standards) and the dominance of secondary production by the bacterial loop may account for the low fisheries productivity in this area (Danovaro *et al.* 1995; Turley *et al.* 2000; Krom *et al.* 2003). Furthermore, it is suggested that organic carbon and nutrients in open Hellenic seas are mainly recycled within the microbial loop resulting in generally low quantities of higher trophic level biomass throughout the regional marine ecosys-

© Alexander Raths/iStockphoto

Figure 2.3. Bacterial culture

tem (Giannakourou *et al.* 2005). Viruses are important modifiers of the microbial loop, and by extension, of the whole ecosystem (Rohwer *et al.* 2009).

It should be noted, however, that in contrast to the oligotrophic conditions characterizing open sea waters, pollution and eutrophication problems are present in a number of coastal areas of the Mediterranean (and Atlantic) because of municipal, industrial and agricultural effluents.

The occurrence of nuisance mucous substances, foam and oxygen deficiency caused by diatoms and nanoplankton in the Adriatic Sea have been attributed to increased nutrient inputs (Marchetti 1993; Howarth 2008) and ecosystem modification through fishing (Vasas *et al.* 2007). The frequency of red tides in the Mediterranean has measurably increased (UNEP 2008), and widespread deterioration of water quality, as reflected in reduced water transparency, has been reported (Marbá & Duarte 1997). However, studies of eutrophication processes are regionally biased and in the Mediterranean Sea are still lagging behind those in Atlantic waters (Vidal *et al.* 1999).

© Steve Spring/Marine Photobank

Figure 2.4. Sewage outfall discharges 15-20 million gallons of sewage upcurrent of a coral reef

In considering climate forcing alone on ocean productivity, biotic complexity limits the value of directly correlating a single ecosystem component (e.g. a fish stock) with a single large scale environmental driver, such as the North Atlantic Oscillation (NAO)[17]. This is particularly the case when considering ecosystems on a scale such as the Bay of Biscay (Hemery *et al.* 2008) and North Sea (Kenny *et al.* 2009), where other more localised environmental and human pressures may be exerting a greater influence on animal populations. In an attempt to better explain the trends in fish stocks and other faunal components in the southern Bay of Biscay, a subregional multivariate oceanic climate index was developed from an integrated analysis of 44 readily available oceanic variables, including the NAO (Hemery *et al.* 2008). The integrated ocean climate metric (known as the South Biscay Climate Index – SBCI), whilst remaining highly correlated to the NAO, was able to account for trends in animal numbers not previously explained by variations in the NAO alone. In this case, the integrated approach reaffirms bottom-up ocean climate forcing as a major factor regulating ecosystem dynamics in this region.

By contrast, other studies demonstrate a more direct link between large-scale environmental factors (like the NAO) and variability in the status of LMEs, such as the influence of the Pacific Decadal Oscillation (PDO)[18] on fish stocks in the Aleutian Islands and Southeast Alaska ecosystems (Hare and Mantua 2000; Heymans *et al.* 2007), the influence of the NAO on sprat (*Sprattus sprattus*) recruitment in the Baltic Sea (Mackenzie *et al.* 2008), copepods in the Northeast Atlantic Ocean (Beaugrand *et al.* 2002) and Northwest Mediterranean Sea (Molinero *et al.* 2008), and deep-sea shrimp in the Mediterranean Sea (Maynou 2008a, 2008b).

It is evident that the status and dynamics of the North East Atlantic Ocean has a measurable influence on the status of several European regional marine ecosystems. It is therefore likely that changes in the North East Atlantic circulation driven in part by global climate change are likely to have a strong and direct impact on the climate and biology of European regional seas. These include the effects of wind on the transport and mixing of water, and the circulation systems generated by freshwater input and Thermohaline Circulation (THC)[19]. A key issue is the extent to which each of these processes contributes to driving the inflow of Atlantic water to the Arctic. Models have shown that the heat transported by this inflow in some areas elevates the sea surface temperature to a

17. See definition in the Use of Terms section, page 10
18. See definition in the Use of Terms section, page 10
19. See definition in the Use of Terms section, page 10

Figure 2.5. The Research Vessel *Jan Mayen* around Svalbard

greater extent than the temperature increase projected for the 21st century.

A weakening of the inflow could, therefore, significantly reduce warming in these areas and might even induce regional cooling.

Such effects would be especially prominent in parts of the Nordic seas, but the weakening would be likely to have consequences for regional ecosystems to the south such as the North Sea and Baltic Sea. Thus, special attention should be paid to the processes that affect the inflow, especially the THC, and then predicting what the impacts of such changes will mean for the sustained delivery of ecosystem good and services.

Summary Box 2 – Critical factors determining ecosystem function and state

4. Factors which directly affect the rate of primary production and the recycling of carbon and nutrients have a critical influence on the functioning of marine ecosystems.
5. The role of microbial loops in regulating the flow of carbon and nutrients in marine systems may be particularly important but has not been routinely evaluated.
6. In addition to the known controlling factors such as water transparency (turbidity), nutrient levels, salinity and temperature, stratification and seasonal fronts play a significant role in regulating primary production.
7. Climate-forcing factors such as global temperature, freshwater inflows from rivers and Arctic ice melt are particularly important in regulating the THC of the North Atlantic. This in turn is shown to have a significant influence on the status and dynamics of many European regional marine ecosystems.

2.1.3 Processes of ecosystem change – when ecological change is large and difficult to reverse

It is the integration of a number of variables from numerous trophic levels and pressures which describes an ecosystem. Reviewing the information available on some of these levels we see that the North Sea ecosystem appears to have experienced a relatively gradual change (punctuated by abrupt variations in some state variables) between 1983 and 2003 (figure 2.6 below). It is obvious that trying to assess and manage such dynamic systems with multiple trophic- level dependencies presents a challenge. The challenges are made greater by the sectoral approaches for regulating human activities, which do not consider the consequences of multiple pressures impacting at the ecosystem level.

Nevertheless, by examining the degree of connection between principal ecosystem components and using all available monitoring data, it is possible to objectively assess the relative significance of multiple pressures acting on LMEs such as the North Sea ecosystem at any one time as depicted in figure 2.7.

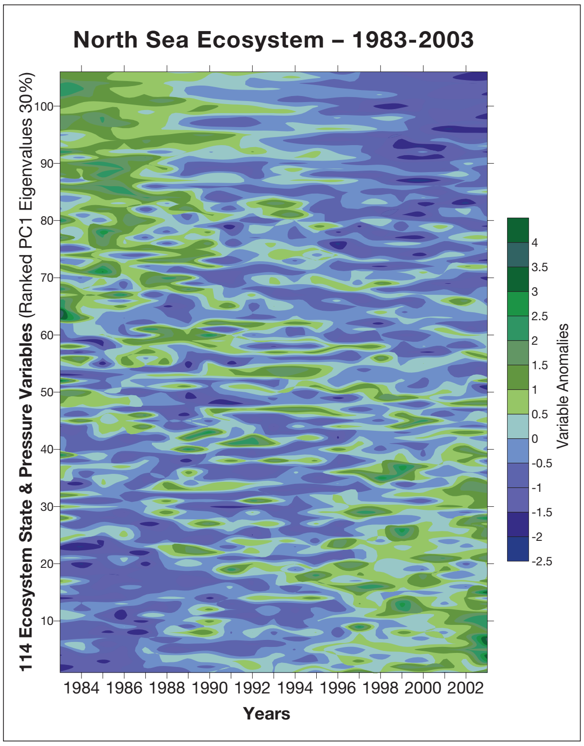


Figure 2.6. A shade plot showing the variation (as anomalies) of all 114 categorised ecosystem variables in rank order according to the Eigen values of the first component axis (PC1) – essentially the same result is obtained by simply ordering the whole matrix by the values in the first year 1983 (Kenny *et al.* 2009).

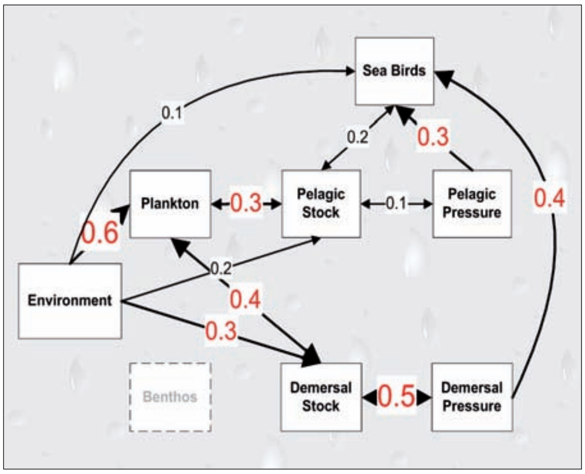


Figure 2.7. The relatedness (or degree of connection) between ecosystem components of the North Sea for the period 1993 to 2003, highlighting a significant bottom-up pressure for the pelagic ecosystem and top-down pressure for the benthic ecosystem. Numbers in red indicate a significant correlation exists between the components based upon the variation over an 11 year sample period (Kenny *et al.*, 2009).

Despite the complexities of all the possible interactions among ecosystem components, and between industry sectors and ecosystem components, there is growing evidence that ecosystem change can have some large scale coherence. Integrated time-series analyses of several LMEs (North Sea: Kenny *et al.* 2009; Nova Scotia Shelf: Choi *et al.* 2005; Baltic Sea: Möllemann *et al.* 2009; and Mediterranean: Molinero *et al.* 2008; Mariotti *et al.* 2002) present new evidence to support the conclusion that large-scale changes in ecological state (or regime shifts as according to Steele, 1998) affecting all components of these ecosystems occurred sometime between 1986 and 1996.

Information Box 3 – Regime shift

A regime shift is defined as a significant change or alteration in the state or properties of an ecosystem. Such changes can occur over varying timescales, but they all tend to be characterized by changes in the same direction such that at some point all the relatively small incremental changes amount to a significant change in state.

These studies also present further insight into how ecosystems change state, which may appear to be a gradual or an abrupt process depending on how many trophic levels are taken into account, which parameters are monitored, and how they actually change.

Recent studies now reveal possible approaches in detecting, predicting and managing regime shifts (Deyoung et al. 2009). Such regime shifts may simply be part of multi-annual or multi-decadal oscillations related to climatic shifts occurring at much larger (hemispherical or global) scales (as discussed in Section 2.1.2). In any one geographical ecosystem, the expression of changes resulting from climatic forcing may take on different patterns reflecting the detailed mechanisms and local processes that are playing roles within the constraints of the larger scale forcing. However, there is growing evidence that although climate forcing appears to be a trigger for many regime shifts in LMEs, those LMEs subject to high levels of human activity such as fishing appear to be at greater risk to regime shift (Vasas *et al.* 2007; Kenny et al. 2009; Kirby *et al.* 2009). In 2007 the Secretary General of the United Nations stated that: *"The facts are clear. The world's seas and oceans are becoming increasingly tainted by untreated waste water, airborne pollution, industrial eff uent and silt from inadequately managed watersheds. Nitrogen overload from fertilizers is creating a growing number of oxygen-starved 'dead zones' in coastal waters across the globe. Moreover, despite the growing reach and intensity of commercial fishing operations, total global fish catch is declining."* Implicit in his statement is that the risks of large and sometimes abrupt changes in marine ecosystems are increasing. To give a European example, in areas of the Mediterranean Sea a combination of climate-induced changes and localized pollution pressure near ports and lagoons has resulted in significant changes in biodiversity resulting directly from the introduction and establishment of exotic species. Nutrient pollution (especially nitrogen and phosphorus) has favoured some of the introduced microscopic marine algae species which are toxic and has thus led to Harmful Algal Blooms (HABs) and associated problems (Koray 2002). In addition, biological invasions are recognized as an important element of global change and the Mediterranean Sea is one of the most impacted seas of the world in terms of biological invasions (Galil 2007).

Alien species like the bivalve *Brachidontes pharaonis* or the jellyfish *Rhopilema nomadica* (see figure 2.8), both belonging to the 100 'worst invasive' species, are environmental threats which could lead to the extinction of numerous native Mediterranean species (Streftaris & Zenetos 2006). A second, well documented and increasing risk in the Mediterranean is that of *"Fishing down the food web"* (Pauly *et al.* 1998). As over-fishing reduces the populations of more valuable larger fish from higher trophic levels, such as piscivores (fish that feed on other fish), the landings of fish lower down the food web, make up a larger proportion of the overall catch. For example, the mean trophic level of catches in Hellenic waters decreased in the late 1990s as shown in figure 2.9.

Figure 2.8. The Jellyfish *Rhopilema nomadica* is an invasive species in the Mediterranean Sea

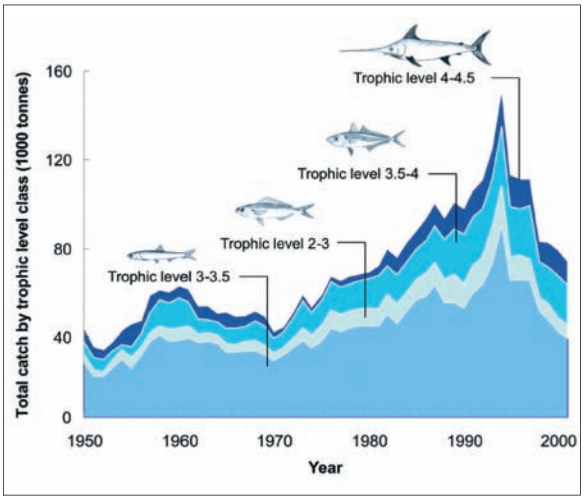


Figure 2.9. Long-term changes in fish catches in Hellenic waters aggregated by four trophic level classes (from Stergiou KI 2005)

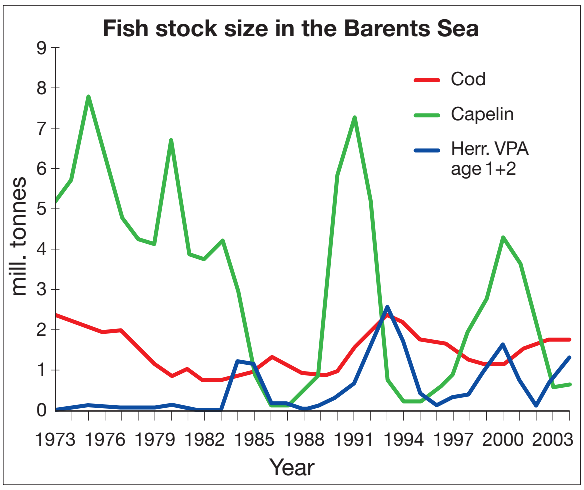


Figure 2.10. Long term trends in the standing stock biomass of cod, capelin and herring of the Barents Sea

Interlinked ecosystem changes are also well documented in the Arctic-boreal Barents Sea ecosystem (see figure 2.10), where the dynamics between three of the most abundant and commercially valuable fish stocks (cod, capelin and herring) are particularly important (Bogstad and Gjøsæter 1994; Gjøsæter and Bogstad 1998; Hamre and Hatlebakk 1998; Hjermann *et al.* 2004). Plankton productivity varies from year to year, with some important oceanographic drivers (ACIA 2005). However, the pathways by which this production variation is transferred through the foodweb are complex. Young herring, growing up in the southern Barents Sea, are efficient plankton feeders, but they also eat fish larvae. Capelin also feed on plankton, but strong year classes of herring tend to keep the capelin recruitment low. By decreasing the capelin stock the herring prevent utilization of plankton production by cod and other fish-eating species in the south (Gjøsæter 1998; Gjøsæter and Bogstad 1998; Hjermann *et al.* 2004). During their spawning migration, capelin also must traverse the area occupied by overwintering immature cod, and throughout the year mature cod also feed on capelin. If the cod stock is large, the feeding pressure on the capelin is high with variable consequences depending on the size of the capelin stock (Dolgov 2002; Yaragina and Marshall 2000). In fact there is evidence of cannibalism when less capelin is available or when juvenile cod are abundant (Bogstad *et al.* 1994; Hjermann *et al.* 2004). Even for these few species, it is clear that interactions can be strong, but their strength may depend on multiple factors, some with more than one connection functioning on different feedback schedules as shown in the figure below. The accumulating evidence from several regional marine ecosystems would allow a more systematic review of regime shift phenomena and a quantification of the relationship between climate forcing and the level of human activities to be undertaken. Such a study could possibly provide a systems level indicator of "regime shift risk" and, therefore, allow politicians and environmental managers to effectively plan, mitigate and adapt to the inevitable ecological regime shifts of the future.

Furthermore, adaptive change of populations and species determines their potential to cope with changing environments. For example, oxygen limitation of thermal tolerance affects the survival of fishes, with sedentary species being particularly vulnerable (Pörtner and Knust 2007). It includes an environmental and a heritable component, which are notoriously difficult to unravel (Endler 1986; Hutchings and Fraser 2008). However, genetic heritability is key to adaptability and the time scale of adaptation may not correspond with the environmental changes and hence jeopardize the organism's survival. As reduced diversity caused by fisheries and pollution will jeopardize the adaptive potential (Ehlers *et al.* 2008), the conservation of global biological biodiversity is key to mitigation. Alternative competition patterns may occur when new species are introduced into the ecosystem or existing species change in abundance as a result of changes to ocean climate. Many specialist fishes have relatively narrow habitat and niche requirements and hence very specific interactions in the ecosystem. Often new taxa tend to be more opportunistic and generalist species. Another key factor that may be affected is the temporal and spatial match between predators and prey, since the timing of reproduction for many species is related to that of their prey. Climate related changes in recruitment success seem to have a strong impact with convincing cases for Western Atlantic cod and lesser sand eel (Frank 2001; van Deurs *et al.* 2008). The relationships and processes described above have to be taken into consideration when a management plan is being agreed.

There is now a growing body of evidence which suggests there are some common features in state changes of many LMEs in response to human and ocean climate forcing. Further comparative analysis of ecosystem dynamics is likely to provide new insights and understanding of how such ecosystems respond to human and natural pressures. This should increase our ability to make accurate predictions about future marine ecosystem change.

Summary Box 3 – Processes of ecosystem change

8. Large-scale changes, which affect all components of the ecosystem, from the bottom to the top of the food web, have been shown to occur periodically in many regional seas throughout the world.
9. A common feature of ecosystems which demonstrate such large scale changes or shifts in ecological regime is the coincidence of a significant ocean climate trigger (such as an abrupt change in ocean circulation or temperature) acting on a system already under considerable pressure exerted by human activities, particularly fishing activity.
10. There is some evidence to suggest that LMEs oscillate in state in relation to large-scale ocean climate forcing such as those driven by the NAO and PDO. Such natural changes and stressors acting on the system will affect its capacity to withstand pressures exerted by human activities.
11. If this is the case then it is reasonable to expect that at some predictable point in time an LME may be more vulnerable to a regime shift for a given level of a human pressure such as fishing activity or due to the introduction of alien species.
12. A review of regime shift phenomena is now possible to quantify the relationship between climate forcing and the level of human activities and to develop an "ecosystem risk indicator".

2.1.4 Interconnected ecosystems and their dynamics: the importance of complexity and diversity in maintaining healthy seas

The fact that many North Atlantic ecosystems (including the Barents Sea, Baltic Sea, Bay of Biscay, North Sea and Mediterranean) have responded to ocean climate events centered around the North East Atlantic (as indicated in Section 2.1.2), demonstrates interconnection between adjacent LMEs. For example, in the Norwegian Sea the inflowing Atlantic water has shown a warming trend and an increase in salinity from the late 1970s to the early 2000s. However, these trends are influenced by pronounced fluctuations related to variations in the NAO index (Mork and Blindheim 2000; Blindheim 2004). The late 1980s and mid 1990s were periods of rapid warming of the inflowing Atlantic waters in the south-eastern Norwegian Sea, corresponding in time to the stepwise changes seen in the North Sea ecosystem. It seems likely that a cascade of interconnected oceanographic processes are at work that influence, to a greater or lesser extent, the climate of all European regional seas. An understanding and quantification of such inter-dependencies is at the heart of being able to predict and, therefore, manage the impacts of human activities which operate across vastly different scales in time and space. As more research is conducted at the scale of LMEs such interdependencies between systems will be defined, allowing adaptive management measures which anticipate ecological state changes to be developed and applied across the range of scales needed.

Summary Box 4 – Interconnected ecosystems

13. Climate in European regional seas is influenced by interconnected oceanographic process. An improved understanding and quantification of the interdependencies between LMEs is needed in order to better predict and manage future foreseeable anthropogenic impacts.

2.1.5 Knowledge gaps and priorities for further research

1. Climate change and ecosystem processes

- The management of regional marine ecosystems needs to strike a balance between anticipating climate impacts, including regime shifts, and regulating localised human activities. At present, most of the management effort is directed at regulating activities and not for the mitigation of or adaptation to, inevitable and largely unmanageable changes in state. Systems which can both observe and predict changes in pressure and state will be needed so that governments and their agencies can realistically achieve the targets being set for Good Environmental Status (GES) under the MSFD.
- A quantification of the relationship between the impacts of climate forcing and those of human activities through a more systematic review of the "regime shift" phenomenon could possibly provide a systems-level indicator of "regime shift risk". Little is known about the response times of species to climate change. For example, the rapid disappearance of sea ice may not allow for adaptive change by many arctic specialists and may result in the disappearance of ice-dependent species. More generally microorganisms, zooplankton, and fish are all expected to exhibit shifts in distribution (ICES 2008) but the rates at which this will occur cannot be predicted at present. Furthermore relatively rapid mean changes in temperature may not allow for adaptive change by many sessile and sedentary organisms which may possibly result in the disappearance of some species.
- New species entering an ecosystem as a result of changes to ocean climate may pose new competitive pressures for the previous community. Many native specialists have relatively narrow habitat and other niche requirements and can therefore be threatened by competition from more opportunistic and generalist invaders.
- Knowledge gap in relation to the match/mismatch between predators and prey is important since the timing of reproduction for many species is related to that of their prey. How the timing and location of the spawning of most species might alter in response to climate change is unclear.
- Ocean acidification is yet another climate-related threat about which much more needs to be known[20].

20. http://www.cbd.int/marine/doc/scientific-synthesis-marine-peerreview-02-en.doc

Figure 2.11.
The American jackknife razor clam, *Ensis directus*, is an edible marine bivalve mollusc, found on the North American Atlantic coast, from Canada to South Carolina. It is now also found in northwestern Europe where it represents a dominant member of some coastal benthic communities.

2. Scale of variation (spatial and temporal)

Understanding which factor or combination of factors has the greatest influence on ecosystem state across a range of spatial & temporal scales is a fundamental requirement for effective EAM. Therefore, there is a need to:

- Develop scaling laws which define such relationships need to be developed and applied in response to regional policy instruments such as the MSFD.
- Explicitly define and quantify the patterns of spatial & temporal variation in ecosystem properties of the European regional seas at a level of resolution appropriate for the management of human activities.
- Develop operational models to predict such patterns of variation to assist in the development of more adaptive management approaches.

3. Complex system dynamics and production

Species, populations and communities are indirectly affected by atmospheric climate through the effects on their surrounding environment and on the food webs in which they are part. While the response of a species to change in one particular variable can often be surmised, although not generally quantified, its response to a collection of direct and indirect effects occurring simultaneously is considerably more difficult to determine. This is further complicated by the non-linearity of many processes and their variation over different scales of time and space. Therefore research which establishes the cause-effect links between multiple pressures (both natural and anthropogenic) and ecosystem component state changes is urgently required. Such research should be fall within the following categories:

- Individuals, populations and communities of organisms have varying thresholds of resistance to perturbations. Although the rates of change are known to vary with the biological resistance and the magnitude of perturbation acting upon the system, such rate changes need to be defined and quantified for a range of habitats and community types.
- In addition, the rates of recovery following perturbation (or the resilience of a system) also vary between habitats and communities, but importantly the pathway of recovery is expected not to be the same as the pathway of initial change. The difference between the impact and response pathways is known as hysteresis and a quantification of this for any given ecosystem is an essential requirement for the management of perturbations in terms of setting tolerances and planning for recovery.
- A closer examination of role of microbial loops in regulating the flow of energy in systems is seen as being particularly important.

2.2 Understanding the dynamics of human interactions with the marine environment

A key pillar of the Ecosystem Approach to Management (EAM) to Biotic Ocean Resources[21] (BORs) is the recognition that people are integral parts of ecosystems, and of the need to better understand the dynamic interactions between changes in ecosystems, changes in human uses of ecosystem services, and human well-being. This has led to the development of a fast growing research community studying the dynamics of coupled social-ecological systems in the oceanic domain, as part of the larger field of multidisciplinary[22] research on sustainable development (see figure 2.12).

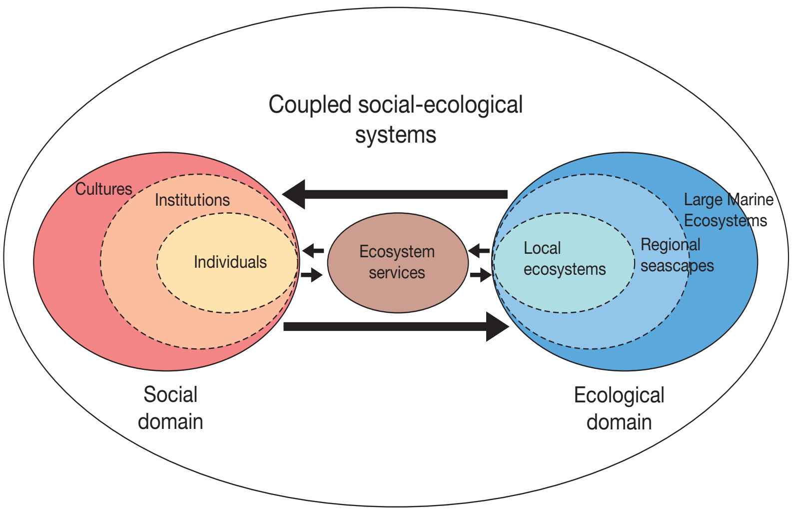
2.2.1 The state of ecosystems and human well-being (this section builds on Levrel, 2007)

Marine and coastal ecosystems have also been included as components of global assessments of the status of ecosystems and human development, such as the Millennium Ecosystem Assessment (MEA 2003).

The MEA was launched in 2001 to improve the understanding of interdependencies between human development and changes in ecosystems at the scale of the planet. The goal of the programme was to inform governments, NGOs, scientists and the general public about ecosystem changes and their interactions with human well-being. This was the first global-scale international programme aimed at integrating economic,

21. See definition in the Use of Terms section, page 9
22. See definition in the Use of Terms section, page 10

Figure 2.12. Dynamic human and ecological systems referred to as "coupled social-ecological systems". Interactions between the social and ecological domains occur over multiple geographic and organizational scales, and understanding connections across scales is critical to the long term success of Ecosystem Approach to Management efforts. While some domains may be relatively smaller in scale, such as individuals and institutions, they are not necessary all nested. For example, cultures occur at geographical scales that are parallel to or larger than institutions. Ecosystem services represent a key connection between the domains, and the flow of services is affected by both social and ecological factors (from "Ecosystem-based management for the oceans" by Karen McLeod and Heater Leslie, 2009).



ecological and social issues associated with the conservation of biodiversity. As stressed in the description of the framework for the MEA, it assumes that changing human conditions both directly and indirectly drives change in ecosystems. Conversely, changes in ecosystems entail changes in human well-being, while many other factors also affect human condition, and many natural forces also influence ecosystems.

To perform this integrated assessment, the MEA analysed developments in ecological services over the past fifty years. According to this analysis, the only services which increased were the "provisioning" services. However, the benefits of this intensified use of resources were distributed very unevenly and were accompanied by a major depletion of 15 out of the 24 services inventoried by the MEA. The 2005 report emphasises that 60% of ecosystem services are being degraded or used unsustainably.

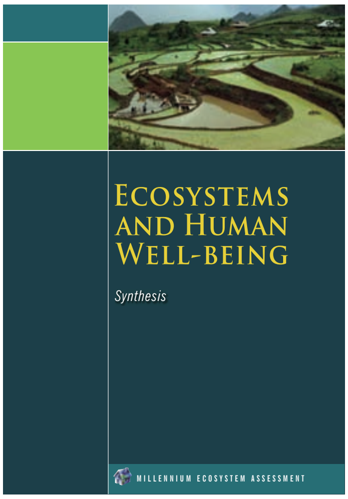


Figure 2.13. The Millenium Ecosystem Assessment: Ecosystems and Human Well-being (general synthesis)

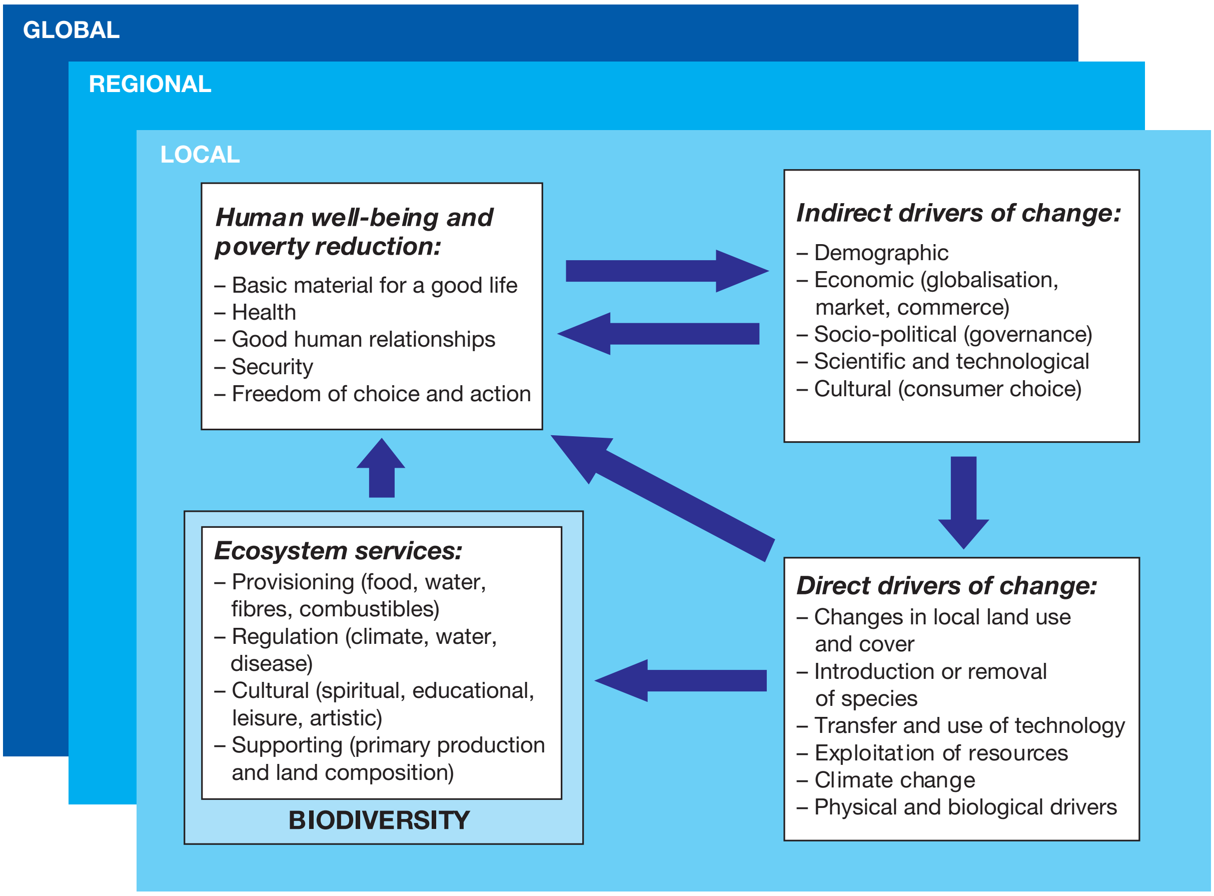


Figure 2.14. Relationships between biodiversity, ecological services, change factors and human well-being (Millennium Ecosystem Assessment, 2005)

Information Box 4 – The ecosystem services approach (Levrel 2007 citing Daily 1997).

"(...) to illustrate the complexity of the ecosystem services approach and to distinguish it from a simplistic understanding of natural capital, Gretchen Daily begins with a story. Let us imagine that there is a breathable atmosphere on the moon and that humans could settle there. Which species should we take with us for food, health care, clothing, etc.? Daily concludes that we would need between 100 and 10,000 species to support human life on the moon (...).*

But then a problem arises: we would also need to bring along the species which support these useful species. While we know quite well which several thousand species are directly useful for us, the same is not true for the species on which these useful species depend, nor for the interactions between them. We would probably be unable therefore to recreate the ecological conditions necessary to our survival on the moon. Consequently, rather than seeking to create artificial ecosystems, it would be better to try to understand how real ones function and how they are interdependent with human well-being. Even if we have plenty of experience of humanitarian crises originating in ecosystem dynamics, we find it extremely difficult to anticipate these crises, even when we ourselves have caused them (...)".

* Professor, Department of Biological Sciences, Woods Institute for the Environment (Stanford University, US)

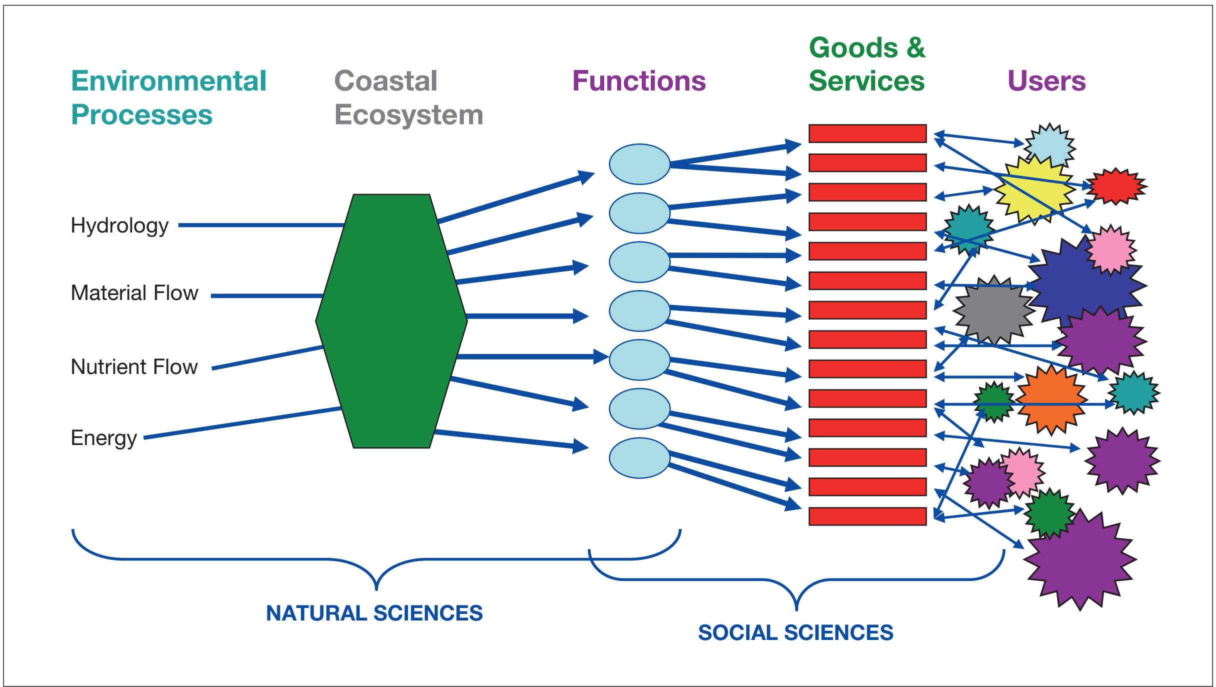


Figure 2.15. Understanding the linkages among coastal and marine ecosystems and human activities.

The MEA approach was applied to marine and coastal systems, leading to a global assessment of the dependence of people on the ocean and coasts and their resources for their survival and well-being. The major drivers of change, degradation, or loss of marine and coastal ecosystem goods and services were assessed, and considered to be mainly anthropogenic. Gaps in knowledge, particularly regarding the definition of ecosystem services provided by marine ecosystems, and consequences of changes in these services for human well-being, were regarded as a key issue by the authors of the assessment. Filling these gaps requires developing both the empirical knowledge of human uses, and understanding ways in which human well-being depends on the goods and services provided by marine ecosystems.

Direct and Indirect Services	Estuaries and Marshes	Mangroves	Lagoons and Salt Ponds	Intertidal	Kelp	Rock and Shell Reefs	Seagrass	Coral Reefs
Food	●	●	•	●	•	●	•	●
Fiber, timber, fuel	●	⬤	●					
Medicines, other	•	•	•		●			•
Biodiversity	●	●	●	⬤	●	⬤	●	⬤
Biological regulation	●	⬤	●	•		•		●
Freshwater storage and retention	•		•					
Biochemical	•	•			•			•
Nutrient cycling and fertility	●	●	●	•	•	•		●
Hydrological	•		•					
Atmospheric and climate regulation	●	●	●	•		•	•	●
Human disease control	●	●	●	●		•	•	•
Waste processing	⬤	⬤	●			•	●	•
Flood/storm protection	●	●	•	•	•	●	●	⬤
Erosion control	●	⬤	•				•	•
Cultural and amenity	⬤	•	●	⬤	•	●	●	⬤
Recreational	⬤	•	•	⬤	•			⬤
Aesthetics	●	•	●	●				⬤

Figure 2.16. List of ecosystem services and their relative importance according to different categories of coastal systems (MEA 2005, p. 527)

Summary Box 5 – Ecosystem goods and services

14. According to the MEA, the major drivers of change, degradation or loss of marine and coastal ecosystem goods and services are anthropogenic in nature.
15. There is a general lack of knowledge regarding the nature and extent of ecosystem services provided by marine ecosystems and the consequences of changes in these services for human well-being.

2.2.2 Understanding the dynamics of social-ecological systems

According to the MEA, human actions play a central role in the evolution of ecosystems, both directly and indirectly. However, in many cases, the fundamental sources of ecosystem degradation cannot be understood and successfully addressed, without understanding the behaviour of individuals and societies that drive these changes (Young 2008).

A key dimension of such behaviour concerns the institutional and economic drivers of ecosystem uses. Most BORs are under appropriation regimes which encourage excessive usage and degradation of the resource base. The diagnosis on the causes of overexploitation in fisheries provides a good illustration of this: excess fish harvesting derives from the common pool nature of marine fish resources which leads to reciprocal negative externalities[23] between operators and to the development of *"race for fish"* phenomena (Gordon 1954).

In practice, these phenomena lead to the use of harvesting capacities exceeding those required for a given sustainable level of fish production. This has resulted in the dissipation of potential wealth within the economy, the increase of conflicts between operators and the development of harvesting levels which exceed the potential for renewal and growth of the exploited species.

23. See definition in the Use of Terms section, page 9

Summary Box 6 – The social and ecological system (1)

16. In many cases, the fundamental causes of ecosystem degradation cannot be understood without improving our understanding of the behavior of individuals and societies that drive these changes.
17. Central to such behavior are the institutional and economic drivers of ecosystem uses. While some of these are well known, others are not, although their role is central.
18. Even when individual, institutional, and economic behaviors are at least partially known, methods to influence those behaviors to improve the likelihood of sustainable choices are often not apparent.

Figure 2.17. Container ship at night

The fisheries experience also illustrates the fact that, even if certain driving factors are well understood, this may not suffice for the problems to be effectively addressed. Indeed, despite this well-established diagnosis and the recurrent crises caused by these dynamics, today's production capacities in fisheries still often exceed requirements. This is largely a consequence of the fact that prevailing management measures, aimed at preserving the productive and reproductive capacity of fish stocks, have been weakened where governance regimes did not effectively regulate access to fish resources (Troadec & Boncoeur 2003). Conservation measures, alone, do not address the social and economic dynamics leading to the development of overcapacity. Once overcapacity exists, it creates additional social pressures which promote the adoption of insufficient conservation norms and inadequate implementation or control of the management recommendations advocated by independent scientific authorities (Hilborn *et al.* 2004). This, in addition to poor implementation, may create a positive feedback for even more over-capacity, until the system is simultaneously in ecological, social, and economic crisis. Understanding the social and economic factors which have prevented the adoption of measures to tackle these fundamental problems is key to the exploration of future scenarios for sustainable fisheries.

Accounting for the multiple uses of BORs leads to the extension of this analysis to a set of potentially more complex processes, in an effort to build an integrated understanding of larger social-ecological systems. Many human activities directly or indirectly impact marine ecosystems (e.g. industries exploiting energy and mineral marine resources, maritime transport, waste production from land-based activities, coastal urbanisation, aquaculture, recreational activities).

In addition to the "common pool" status of most BORs, externalities arise from the existence of interactions between these different uses of ecosystem services, via their impacts on ecological processes (e.g. a negative impact on commercial fish stocks following a loss of habitat resulting from coastal development). The potential benefits to an individual operator of a given use of biotic resources will thus depend not only on the individual's own decisions but also on decisions made by others, potentially elsewhere in space and in time. While such interactions affect commercial uses of BORs, they can also directly or indirectly affect non-market uses including both extractive (e.g. recreational fisheries) and non-extractive (e.g. recreational diving) uses.

In all cases, these interactions entail collective costs and benefits which economic agents are not encouraged to take into account in their decisions regarding the use of ecosystem services. The difficulty arises from the multiple scales at which interactions may occur, and from the uncertainty which may exist regarding key ecological processes at play and their dynamic interactions with human activities. The renewable nature of BORs confers a strong inter-temporal dimension to the problem. A central issue in this context is the inertia of social-ecological systems, which leads to important tradeoffs in the selection of alternative policy objectives, between the amount of change which can be sought, the time in which this change can be achieved, and the associated distribution of costs and benefits across stakeholders[24], and in time (Martinet *et al.* 2007; Hilborn 2007).

Based on this analysis, a central question is how to develop measures of the value of ecosystem services

24. See definition in the Use of Terms section, page 10

that can be included in assessments of trade-offs which underpin both public and private decisions regarding ecosystem uses. This question has two dimensions. Firstly, the methods by which ecosystem services may be evaluated and their value included in impact assessments[25], from the scale of economies to the scale of individual development projects, are still far from stabilized, despite numerous efforts to improve existing systems. This is an active and important area of research, which has not yet produced stable operational approaches in the context of marine ecosystems. To be successful, methodologies for evaluating marine ecosystem goods and services will need to have high credibility across the full spectrum of interested parties from economists to conservation biologists, and be considered useful by decision-makers. Secondly, there is a growing body of work focusing on the role of economic incentives in the design of policies targeted at improving the sustainability of ecosystem uses. Debates are ongoing on the possibilities and limitations of tradable rights systems for BORs, the implementation of green taxes, or the use of liability rules in the environmental domain. In all cases, the main objective is to allow a negative ecological impact of ecosystem use to be "costed" to the responsible agents. Key issues here relate to the relative efficiency of alternative approaches, but also to the problems of social acceptability and equity which such measures imply.

A further consideration is a parallel with material in 2.1.3 on ecosystem regime shifts. As research has called attention to the importance non-linearities and "tipping-points" in ecosystem dynamics, knowledge of which ecological risks to approach with precaution and how to manage those risks has improved. Social and economic systems also have strong non-linearities, and may also have "tipping points"; a domain where change can be accommodated relatively readily, bounded by a point beyond which further change may cause large and fairly abrupt alterations in social or economic systems. Exploring if such non-linearities characterise ocean-focused social and economic systems, and so, where the tipping points may be located, will be essential for developing policies that are effective and well-supported.

25. See definition in the Use of Terms section, page 9

Summary Box 7 – The social and ecological system (2)

19. Accounting for the multiple uses of BORs leads to extending analysis to a set of potentially more complex processes, involving many direct and indirect interactions between activities.
20. The difficulty arises from the multiple scales at which interactions may occur, and from the uncertainty which may exist regarding key ecological processes at play and their dynamic interactions with human activities. The renewable nature of BORs confers a strong inter-temporal dimension to the problem.
21. Operational measures of the value of ecosystem services need to be established, that can be taken into account by both public and private stakeholders in their choices regarding ecosystem uses.
22. Knowing if and how non-linearities are expressed in social and economic dynamics of marine industries and communities is necessary to develop effective policies and strategies for sustainability.

2.2.3 Knowledge gaps and priorities for further research regarding the dynamics of ecosystem uses

1. Understanding the demographic, economic, institutional and technological drivers of human behaviors that lead to increased perturbations of marine ecosystems

While some empirical knowledge is available, there is a general lack of empirical data concerning both the current uses of marine ecosystem services and the trends observed in these uses, across different spatial and temporal scales. It is thus often difficult to provide empirical descriptions of the changes in uses of BORs, although this seems fundamental to any efforts in analysing changes and understanding the drivers of those changes. Even when some uses of BORs, such as fisheries, have been documented better than others, basic data regarding the economic and social dimensions of these uses is still lacking in many places. Better monitoring of these uses would therefore appear to be essential to improving our understanding of the dynamics of these uses and their interactions with ecological change. Empirical research, both quantitative and qualitative, is also required to assess the relative contributions of the different drivers of change (demographic, economic, institutional and technological) to the variability of uses observed across space and time.

Figure 2.18. Newly landed fish at a local port in the Costa Brava (Spain)

2. Understanding possible human responses, at individual and collective levels, to changes in marine ecosystems

A second key research area concerns the specific evaluation of consequences of ecosystem changes for economies and more generally for societies, and the analysis of adaptation/mitigation options. This area of research flows directly from the first key area in so far as it requires an understanding of the dynamics of human uses, and of the drivers of these dynamics. It involves identifying changes in the availability of goods and services derived from marine ecosystems and measuring changes in market and non-market values associated to alternative ecosystem states. A central dimension in this domain is to better understand perceptions by stakeholders of the status and trends in marine ecosystems, impacts of human uses on these ecosystems, and effects of policies regulating these uses. Studies aimed at valuing the economic consequences of changes in ecosystem quality are an important area where further research is required. Another important research area involves assessing the vulnerability[26], resilience and adaptation of economies and societies to ecological changes. Yet another important area of research involves the study of how ecological valuation results have been used in governance processes and decision-making. Important lessons can be learned from the study of both successful examples of use of ecological valuation to improve sustainability of real-world decision-making, and from cases where either decision-making did not benefit from the valuation result or where the uptake of results was poor. All of these areas of research require a multidisciplinary approach in the social sciences.

3. Understanding the dynamics of coupled social-ecological systems

The third key area of research involves developing multidisciplinary research programs involving knowledge of both ecological and social systems to foster understanding of the dynamic interactions between these systems. This includes, for example, the development of joint ecological-economic assessments of marine resource systems based on empirical data and the development of multidisciplinary dashboards[27] (D. Pelletier *et al.* 2005) to assess the health of these systems. To some extent, particularly for complex systems, such research programmes may be based on adaptive-management policies, where stakeholders and scientists define regulatory programmes as real-life experiments involving a monitoring and analysis component, with regular re-assessment and revision as learning occurs. With the development of information technologies, such research may also be based on the development of integrated social-ecological models of ecosystems and their uses. These models may help to test alternative assumptions about some of the key drivers of change in social-ecological systems. They may also be used to assess alternative scenarios regarding economic, ecological or institutional drivers. To account for the real-life complexities of EAM, such approaches require both multi-criteria and dynamic representations of alternative scenarios.

2.3 Analyzing the functioning and effectiveness of management and governance systems

2.3.1 Definitions and rationale

2.3.1.1 Why are we including these systems in the SEAMBOR evaluation?

As noted in Chapter 1, implementing the Marine Strategic Framework Directive (MSFD) within an Ecosystem Approach (EA) involves setting societal objectives for the uses of marine ecosystems, and application of adaptive management in pursuing achievement of those objectives. Both the setting of objectives and

26. See definition in the Use of Terms section, page 10

27. See definition in the Use of Terms section, page 9

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Figure 2.19. The Helford river estuary (Cornwall, England)

adaptive management are social processes played out in the established governance mechanisms, which can be informed by both natural and social scientists. Implementing the decisions and making progress toward achievement of the objectives requires efficient and effective management systems. The ambitiousness of this initiative should not be underestimated.

Countries like Australia and Canada have found integration of management and governance across ocean industry sectors and diverse stakeholders challenging, even when there is a single national authority and clear legislation (e.g. Australian Oceans Act). The challenges are much larger given the complex European governance model. As a union of sovereign Member States, Europe must deliver coherent ocean management through legal instruments which, in some cases, are guiding Member States in exercising their legal competence (e.g. the MSFD) and in others have exclusive competence with the Community (e.g. the Common Fisheries Policy – CFP). Furthermore, the EU Treaties do not provide any formal basis for executive bodies at the level of marine ecosystems. Even if regional bodies were to be considered a valuable governance structure, there is no legal basis to empower them to act, beyond serving as fora for consultation. Actions must be either on the Community level or Member State level. These are very fundamental governance issues which must be addressed before any functioning marine governance in the EU can be contemplated.

The MSFD aims notably to frame several existing sectoral instruments: the Common Fisheries Policy, in particular, but also instruments from the European environmental policy (e.g. Water Framework Directive – WFD, Birds and Habitats Directive – BHD) which already integrate in their remit the EA. This, in turn, requires that these different institutional strata articulate between themselves and, at a more pragmatic level, their policies and instruments must interact effectively. The MSFD only fixes a common frame and guidelines to promote, in all sectoral maritime policies, the integration of environmental activities. As such, it complements but does not replace the fields of action/competence of pre-existing instruments and does not interfere in their applications. Nonetheless questions are likely to arise in association with all the policies to be integrated, such as:

– With the CFP, the first issue is how to set appropriate objectives consistent with the MSFD.
– With the WFD, areas such as the definition of the "field of application" (notably geographically) in the perspective of setting-up effective policies.
– With the BHD, we must aim for synergistic outputs that link the more general protection of the marine environment to the use of spatial management tools such as Marine Protected Areas (MPAs) networks primarily used for the preservation of marine biodiversity.
– For all of these policies, how to link the scales of action considered most effective ecologically and economically with the mixture of legal competences of Member States and the EC, when the competencies and best scales of action do not match.

In addition, there will be numerous other constraints on fisheries, following both from adoption of an EA (see section 2.1 and 2.3.2.1) and from variable "external" constraints, generally arising from legal regulation instruments in the realm of environmental policy. The regulation of fisheries activities will increasingly be dealt with either directly through marine protection measures (e.g. marine biodiversity protection under the Habitats Directive) or indirectly by requiring fisheries management measures administered by fisheries agencies to be validated against a wider range of policies including these Directives. The need for all these sectoral policies to function in a coordinated manner poses many challenges to expand and adapt the governance process as that interpret and apply the Policies. There are corresponding research needs to support governance as a coordinating process, respecting competencies but delivering necessary outcomes over and above the research needed to inform each sector individually.

The previous sections lay out key research needs to ensure that research-based knowledge is available to governance and management mechanisms. The ecological knowledge acquired in the research themes of 2.1 informs the governance processes of the consequences of various candidate objectives and alternative management actions on the ecological dimension of sustainability. It also informs management processes[28] of which measures are likely to facilitate progress towards those objectives and how to measure that progress. The

28. See definition in the Use of Terms section, page 10

research in 2.2 will provide complementary information on how the social and economic objectives associated with benefits from the sea can be achieved, what the major drivers of those uses may be (including changes in the ecosystems being used), and which management measures are likely to succeed in various social and economic contexts.

It is a fundamental tenet of conservation and the sustainable use of ecosystem resources that sustainability has multiple dimensions – ecological, social, economic, and institutional, and the ultimate sustainability solution will involve choice and compromise among those dimensions. How those choices and compromises are made is also an essential component of successful implementation of an Ecosystem Approach to Management (EAM). The fundamentally dynamic nature of the processes at play in the co-evolution of marine ecosystems and human societies entail a need to account for the extended temporal dimension of collective choices regarding the uses of Biotic Ocean Resources (BORs). Along with inter-generational equity issues, this involves accounting for the inertia which may constrain the speed at which adaptation can occur in both ecological and social systems.

Successful implementation requires that governance processes use information as effectively as possible, including information on risks and uncertainties. The processes must also be both credible (experts think the outcomes reflect the information input well) and legitimate (those being affected by the outcomes feel the process leading to the outcomes treated them fairly). Moreover, all sectors of society that feel they are legitimate stakeholders in the outcomes – ocean industries, coastal communities, scientific and technical experts, civil society – will have interests in the short- and long-term consequences of the outcomes of the governance process. Views on outcomes that are considered credible or legitimate may differ greatly among these sectors. How the governance mechanisms take all these perspectives into account when setting objectives and making adaptive management decisions is a complex social process that itself must be subject to research, as it is a key dimension of the EA to BORs management, and one which has received limited research effort over the past decades.

How can governance and advisory mechanisms most effectively achieve credibility and legitimacy to produce objectives and decisions that all sectors of society will support, and that actually lead to sustainable use of goods and services from healthy marine ecosystems?

Research on governance and management needs to be conducted at a variety of scales, because both operate at scales from communities to ocean basins or larger.

Figure 2.20. The German Parliament building in Berlin (Reichstag)

There is much to be learned about how objectives set or decisions made on one scale, guide or constrain choices at other scales.

Both “top-down” (government agencies design the rules and provide the surveillance and enforcement agents) and “bottom-up” (the individuals or industries whose activities are being managed design the rules and develop the mechanisms to achieve compliance) governance and management processes must be considered in interpreting and implementing ocean policies. How these processes interact is complex, poorly understood, and varies with both scale and jurisdiction. Experiences from other jurisdictions should be studied for the lessons they contain, but further research is needed to know how to adapt those lessons to the complex EU governance structure. The examination of case histories of Integrated Management where the sectors being integrated were managed at a variety of scales, and coordination was at larger scales than the competencies of most of the participating agencies, would be of particular value (see some case histories in Annex 2).

Summary Box 8 – Governance and management systems

23. Implementation of a decision-making process towards achievements of societal objectives for the uses of marine ecosystem requires effective and efficient management systems.
24. Successful EAM implementation requires that governance processes use information as effectively as possible, including information on risks and uncertainties.
25. Research is needed to inform the development of governance and advisory mechanisms in order to produce objectives and decisions that all sectors of society will support to sustain use of goods and services from healthy marine environments.
26. Research on governance and management needs to be conducted at a variety of scales.
27. Both top-down and bottom-up governance and management processes should be considered in interpreting/implementing ocean policies; their interaction is complex and poorly understood.
28. Experiences from other jurisdictions should be studied for the lessons they contain, but further research is needed to know how to adapt those lessons to the complex EU governance structure.

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Figure 2.21. "The Ocean of Tomorrow" Information Day Joining research forces to meet the challenges in ocean management. The European Union established in 2007 a new Integrated Maritime Policy, of which the "European Strategy for Marine and Maritime research" is a fundamental part. It highlights the importance of integration between established marine and maritime research disciplines with the objective of reinforcing excellence in science and reconciling the sea-based activities with environmental sustainability. "The ocean of tomorrow" call for proposals is the first concrete example of the cross-thematic approach recommended in this strategy.

2.3.1.2 Current status and necessary transitions

The MSFD is intended to assure that maritime industries contribute to economic prosperity while maintaining or restoring acceptable environmental quality [COM (2006) 275 final, COM (2007) 575 and Plan of Action Annex SEC (2007) 1278/2]. This is to be achieved as much as possible through use of existing sectoral governance and management instruments and tools (Directive 2008/56/CE). Many of these governance and management agencies are already severely challenged to deliver full sustainability in their sectoral operations (e.g. Green Paper for the last revision of the CFP). Some of these challenges may have been the consequence of overly narrow definitions of the management decisions that needed to be made, and will be ameliorated to some extent by adopting the broader EA inherent in the MSFD. However, at least some of the challenges arose from the complexity of decision-making processes even within individual sectors and from difficulties in implementing decisions that lacked support among the participants in the industries being managed. These challenges to sectoral governance and management are made more complex, because expansion of accountabilities and jurisdictional authority of agencies to allow broader consideration of policies mean that each governance and management unit has to accommodate more participants and address more interactions, and each ecosystem component may become directly subjected to decisions by a larger number of agencies.

In dealing with the problems posed by the fragmentation of decision-making across both sectors and ecosystem components (Crowder *et al.* 2006), opinion is converging on the need for a greater emphasis on place-based management as the strategy that most effectively makes the EA and Integrated Management (IM) operational (Young *et al.* 2007). This will require taking governance and management agencies designed to manage a sector or a set of ecosystem components, having them first work individually in new spatial contexts, and then coordinate across agencies and levels of governance. The broadening and coordination need to be done by strengthening the effectiveness of the sectoral agencies rather than weakening them, while creating mechanisms to ensure coordination with other sectors.

Diverse authorities provide principles and frameworks for adaptive governance and management (Constanza *et al.* 1998; UN CBD 2000 & 2003; Olsson *et al.* 2004). Progress is slow but there is wide agreement that mechanisms that feed diverse and reliable information into governance and management processes are essential, as is flexibility in how those institutions operate. These information-providing mechanisms in turn presuppose the existence of appropriate monitoring programmes, including programmes that detect ecosystem and societal changes quickly. They also presuppose periodic Integrated Assessments to examine and interpret the information from monitoring and new research and apply systematic approaches to evaluate the consequences of existing policies and practices. The flexibility of decision-making further presupposes engagement of all the relevant stakeholders and levels of government, using agreed indicators and reference points in ways that inform choices without limiting them.

However, agreement that these mechanisms and degree of flexibility are essential is important but does not constitute guidance on how they can be achieved. That guidance can only come from directed research on the processes themselves.

Summary Box 9 – Frameworks for future governance/management systems

29. To operationalise EAM and Integrated Management, a place-based management strategy is needed to best address the fragmentation of decision-making processes across both sectors and ecosystem components.
30. Adaptive and flexible governance and management systems require suitable and effective information-providing mechanisms.
31. The reliability/relevance of such mechanisms relies on appropriate/adequate monitoring programs and Integrated Assessments.
32. All relevant stakeholders and levels of government should be engaged in the decision-making process.

2.3.2 Research themes in governance and management processes

Major EU environmental policies and frameworks have already been implemented to promote conservation and sustainable use of fisheries, water quality, and habitats in Europe. Experience with the CFP, the WFD and the BHD, summarised in Annex 2, provides an insight into the research needs for governance processes and management to successfully pursue implementation of these policies and directives, and the MSFD.

2.3.2.1 Governance systems

Information Box 5 – What are governance systems?

Governance has been defined as *"the interactions among structures, processes and traditions that determine how power and responsibility are exercised, how decisions are taken, and how citizens or other stakeholders have their say. Many agents can be involved in governance, such as the citizens, the government, the private sector, the civil society"* (Graham *et al.* 2003). The main components of governance systems are the fora and mechanisms by which:

- Component 1: the technical information, including risks and uncertainties needed to inform a decision are made available.
- Component 2: the views of all stakeholders are sought.
- Component 3: the options for suites of objectives and the associated management actions available are identified.
- Component 4: the information and views are associated with the options that are available.
- Component 5: the choices among options are made.

All five of these components require the types of scientific information described in 2.1-2.3, but also can be the subject of research themselves.

In EAM, the science needs are particularly important because the scope of information relevant to a decision is defined broadly. That scope includes the ecosystem components affected indirectly as well as directly by each managed human activity in the sea, the interactions among the human activities, and their cumulative effects on the ecosystems in which they occur. Many of the research questions in 2.1 and 2.2 address pieces of this broad scope, but there are research needs at the scale of the processes themselves.

Research on communication including dissemination strategies and mechanisms is important in components such as 1 and 2. Social dynamics research contributes importantly to ensuring components such as 2 and 5 are both credible and legitimate. Research associated with engineering and business practices, including decision theory, can contribute to making components such as 3, 4, and 5 more effective, as can research on how societies adapt to change and stress. Research on governance components is complex, as the components must promote creativity in finding options that may not be initially obvious. Such research must accommodate formal, structured approaches to decision-making that are transparent and perceived as just by all participants, that are accountable for both inputs and outputs to the governance system, and that function within the legal competencies of EU Member States and the European Commission.

2.3.2.2 Management systems

Information Box 6 – What are management systems?

Management systems are the collection of processes and procedures by which decisions are implemented. Variants must accommodate the characteristics of different social and cultural contexts, and the opportunities and challenges of different human activities. They can be strongly "top-down" (driven by institutions, agencies and their policies) or "bottom-up" (driven by social processes and community dynamics). Most management systems fall somewhere between these two extremes, with characteristics of each. Whatever the balance, equal access by all parties to data and information is essential for credible and legitimate management.

The main components of a management system include the processes and procedures for:
- Component 1: conveying the suite of objectives and management options to the management system;
- Component 2: designing an implementation (management) plan for the management options;
- Component 3: assigning roles and responsibilities for implementing the plan;
- Component 4: ensuring compliance with the provisions of the implementation plan;
- Component 5: periodically evaluating the effectiveness of the implementation plan in achieving the suite of objectives for which it was designed;
- Component 6: conveying the results of the evaluations back to the governance process, to trigger reconsideration of decisions of objectives and/or management options, as needed.

There are many research questions associated with designing and improving management systems, particularly in the context of EAM and Integrated Management. A strong social science foundation is needed to document the capabilities of stakeholder groups and communities to assume responsibility for various steps in the process, particularly components 2, 3, 4, and 5, and their willingness to accept top-down input from government agencies.

Research on improved communication strategies and tools is important to all components, but particularly to 1 and 6. In fact, an effective communication loop from 6 back to 1 for another cycle of management actions provides a strong basis for adaptive management. Economic research can have an important role in evaluating the cost-effectiveness of alternative management strategies and tactics. Political science also has a crucial role in ensuring that governments discharge their legal obligations in a fair and just manner, and that the requirements of all appropriate legislation are met throughout the management processes.

Performance evaluation is crucial in components 5 and 6, and requires significant science support both in its establishment and ongoing operation. Evaluation standards must be set, often as indicators and reference positions for each of the suite of objectives. Science needs to document the reliability of the selected indicators; their specificity, sensitivity, legitimacy, and other relevant performance characteristics. Science is also needed to update the indicators on appropriate time and space scales and conduct the re-evaluations of the effectiveness the choices that have been made. These evaluations need strong science content to determine whether any failures were in implementation, in choice of management tactics, in selection of incompatible or otherwise inappropriate objectives, or due to changes in ecological or societal circumstances that require reconsideration of past choices.

Summary Box 10 – Designing and improving management systems

33. A strong social science foundation is needed to document the capabilities of stakeholder groups and communities to assume responsibility for various steps in the process and their willingness to accept top down input from government agencies;
34. Research on improved communication strategies and tools is important to ensure an adaptive management;
35. Economic research and political science have crucial roles throughout the management process;
36. Research is needed to support and implement adaptive performance evaluation tools (standards, indicators) in order to monitor the effectiveness of a management system.

2.3.3 Knowledge gaps and priorities for further research

2.3.3.1 Research priorities for evaluating governance processes

Four considerations (inclusiveness, transparency, timeliness, and review/evaluation) are essential to the evaluation of the effectiveness and efficiency of governance processes. Each of these considerations has some relevant science aspects. These aspects comprise an important part of the science needed for implementation of an EAM.

1. Inclusiveness

- Which stakeholders have what roles in the process? Are the roles appropriate given the spatial or socio-economic scale of the issue, the legal context, and the consequences of the policies and decisions being considered? How can the geographic scales of sectoral competencies be reconciled with the roles and scales most effective for participatory governance? Does each group have the capacity to fill their proper role, and access to the necessary information?
- What provisions are made for science experts to participate directly in governance processes and to provide science information to other stakeholder groups? Do these roles for the science experts conflict, or are they perceived to conflict, by parts of the stakeholder community?
- Reciprocally, how do different participants in the governance process gain access to the scientific and technical information they need to participate effectively in governance, and to test the reliability of the information provided to them and used by other participants in the process?

2. Transparency

- Are the provisions for inclusion of stakeholders sufficient, such that all consider the outcomes of the processes legitimate? If not, what parts of the process are considered insufficiently transparent and what can be done to improve the transparency of those parts?
- Are the bases for decisions documented and available? Do all parties have equal access to the science advice going into the system, and explanations of the role/impact of science considerations in the decisions?

3. Timeliness

- How long does it take for decisions to come out of processes? Are the "transaction costs"[29] of the governance processes so high that the processes cannot react swiftly, even when there is urgent need for a decision?
- Is the science advice available in usable forms? Is the science advice adequately integrated across the ecosystem components, industry sectors, and social, economic, and ecological dimensions of the decisions to be made, or is the governance process required to do the integration after the expert processes are completed?
- Is the science advice available at the proper time for the governance process to use it effectively? If not, is the problem with the overall timetable for the governance process, or issues of scheduling that are more readily changed?
- For both the form and the timeliness of advice, can existing expert advisory processes be adapted to address problems that are identified, or are modifications to the advisory processes required?

4. Review and Evaluation

- Does the governance process include reviews of its own performance?
- Are such performance evaluations structured into the system, or must they be demanded by society?
- Are the performance evaluations done with sufficient independence and transparency to be legitimate and credible?

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Figure 2.22. The European Commission in Brussels, Belgium

29. See definition in the Use of Terms section, page 10

All of those questions have science implications on two levels. Each question has an operational aspect, as the governance process does its job in setting objectives and evaluating and choosing management strategies. Science will have a central role in ensuring each governance process can work efficiently and effectively. Science also has a further role in studying how the governance processes work as they address their issues. In this role science can identify, if not "best practices", at least better and worse practices for being effective, efficient, legitimate and credible, and provide guidance on how the governance processes themselves can improve their performance.

2.3.3.2 Research priorities for evaluating management systems

When research is being done on how effective and efficient a management system is, several questions are fundamental.

These include at the strategic level:
- Are there explicit management objectives (ecological, economic and social)?
- Are they being expressed in ways that guide management in the intended direction?
- Are the objectives consistent with science knowledge/understanding of the ecosystem and impacts of the activity being managed?
- Are the ecological, economic, and social objectives inter-compatible, such that management could achieve them all?
- When management decisions are made, what was the relative role of science advice and other pressures on the advice? Could those "other pressures" have been reduced and had the science advice included social and economic considerations central to the decision?

And at the technical level:
- Are the available management tools sufficient to allow achievement of the objectives? If not, what are their shortcomings and what can be done to improve them?
- Is implementation of the management tools successful? If not, what are the impediments to implementation and what can be done to overcome them?
- Is management being conducted efficiently? Is the science advice/knowledge guiding management to the most cost-effective options? If not, what is not being considered that should be?
- Are the outcomes of management efforts moving the system in the direction consistent with the objectives? If not, what is the source of the failures and how might they be addressed?
- Does the science advice and knowledge provided to the decision-making processes include evaluations of the management measures being applied, so poor ones can be weeded out?

These fundamental questions underscore that some questions can be posed reflexively regarding the science that is provided to management systems, and to management systems themselves and how they are functioning:
- If science advice is not having a substantial impact on management decisions, is the problem with ineffective communication of the science, such that the advice is not being understood?
- Is the problem with incorrect focus of the science, such that the advice is understood but not considered sufficiently relevant or complete enough to inform the decision-making?
- Are the dominant factors in a decision not the ones for which scientific input is being sought (for example, social consequences of alternatives may dominate a policy choice, whereas the information being sought is about the ecological status of a resources) such that the science input is communicated clearly, considered to be relevant to at least some parts of the decision, but appears to be ignored in the final decision?
- Are individual parts of the science input sound, understood and relevant, but the decision-making process fails to integrate the independent science input into an integrated understanding of the risks and opportunities associated with each option?
- Would the management systems be more effective if their decisions were more consistent with science advice?
- Would the management system be more effective if the science advice was more complete or reliable?

2.3.4 Conclusions

The European science community has some components that pre-position it to contribute to the science needed for supporting the governance and management changes needed to implement the MSFD effectively. There are strong capabilities in all the relevant disciplines of ecological, economic, and social sciences. All these scientific communities have accepted the EA and Integrated Assessments (IAs) as cornerstones of truly sustainable uses of marine ecosystems and the viability of marine industries and coastal communities. Therefore, the necessary scientific capacities and the conceptual framework both already exist, providing great promise for the research community to contribute to making governance and management more effective, more efficient and more credible.

Realisation of this promise is not guaranteed, however. As in many other parts of the world, these separate disciplines lack a history of working together, particularly ecological and social sciences. There are some outstanding exceptions to this generalisation, but they are few in number. Not only is there little history of collaborative work among the social, ecological, and to some extent economic sciences, as discussed in section 3, but there are institutional challenges to be overcome in building these collaborations. Some of these institutional challenges are rooted in the complex legal structure of the EU, and may prove both difficult to avoid and difficult to change.

All these are tractable issues if the institutions providing the funding and employing the researchers simply broaden their concepts for what types of research deserve priority, and what types of activities should be rewarded in career progression reviews. These are small changes in the "governance and management" of the scientific capacity of Europe, compared to the changes in governance and management of industry sectors and society that have been discussed in this section, as necessary for successful implementation of the MSFD. This Directive cannot be implemented without true implementation of an Ecosystem Approach and Integrated Management. That implementation, in turn, requires research on governance and management that can only be done when social, ecological, and economic sciences are working together effectively.

2.4 Assessments to support the Integrated Maritime Policy

2.4.1 Integrated Assessments: rationale and approaches

The overarching purpose of assessments is to inform policy and management decisions. Therefore, it is of the utmost importance that assessments are reliable, based upon existing scientific knowledge and used in the best possible way. Measures to maintain or restore Good Environmental Status (GES) may have large socio-economic consequences, but be necessary to secure long-term benefits for society. Assessments form the basis for evaluation of the effectiveness of existing measures and considerations of whether changes in policies and measures are required and so, what their consequences might be. Policies and measures may be regarded differently at European, national, and subnational levels, reflecting different scales and perspectives, and requiring flexibility in approaches to assessments. Assessments also have a valuable role to play in assisting the design of monitoring programmes.

Building upon a review of the Integrated Assessments (IAs) literature, knowledge of existing IA activities, and our understanding of how monitoring and assessment programmes are delivered by EU Member States, it is possible to consider the development of realistic and workable plans for implementation of Ecosystem Approach to Management (EAM). These plans have a central role for assessments.

There are two basic requirements for assessment:
- Identify all relevant components of Integrated Assessments (IAs) and demonstrate how all elements relate to one another; and
- Describe and quantify the status and trends in all relevant ecosystem components over varying spatial and temporal scales.

There are three types of IAs, namely:
- Integrating all ecosystem components, including human activities, socio-economic factors and environmental state variables;
- Sectoral assessments[30] of specific human activities such as fisheries, shipping, dredging etc., which assess the impacts of the activity on all relevant ecosystem components (for example all the pink cells in the figure below form a sectoral assessment of dredging); and
- Thematic assessments[31] of specific ecosystem components which consider its status in relation to all the other components it interacts with (for example all the blue cells form a thematic assessment of the status and dynamics of marine plankton).

The first types of assessments are fully IAs when they integrate across all human activities (sectors).

There are no current examples of fully IAs to deliver the EAM. Two major impediments are that a single unifying framework does not exist to deliver such assessments, and to this point, no agency has had the mandate to call for (and support) a fully IA. The individual parts are more or less in place, but there is a need to bring them together for their evaluation in a logical and workable way. This may appear to be an ambitious task, but actually it is already happening in an *ad hoc* way through the work of several groups (nationally and internationally), such that different approaches have been, or are in the process of being developed. Through their application it will become evident that some approaches will work, whereas others will not, although learning would be faster if there were a systematic evaluation of experiences with the various approaches that are being explored.

Initial findings highlight the importance of matrices in helping to understand the complexity of interactions between human activities (pressures) and ecosystem

30. See definition in the Use of Terms section, page 9
31. See definition in the Use of Terms section, page 9

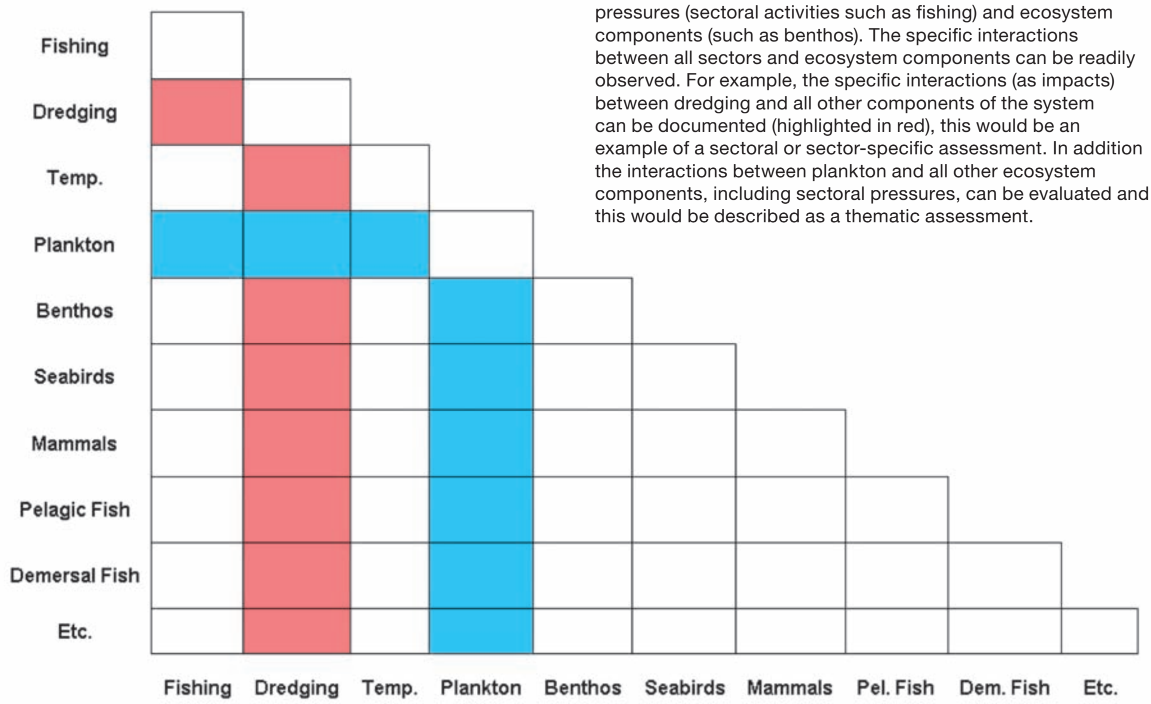

Figure 2.23. Example of a matrix approach used to describe the relationship or degree of interconnection between human pressures (sectoral activities such as fishing) and ecosystem components (such as benthos). The specific interactions between all sectors and ecosystem components can be readily observed. For example, the specific interactions (as impacts) between dredging and all other components of the system can be documented (highlighted in red), this would be an example of a sectoral or sector-specific assessment. In addition the interactions between plankton and all other ecosystem components, including sectoral pressures, can be evaluated and this would be described as a thematic assessment.

state (state changes) and to identify appropriate levels of monitoring. This is an approach being considered for example by OSPAR (Johnson 2008). Using such matrices to identify significant interactions between human activities (pressures) and ecosystem components is important and valuable particularly in relation to identifying appropriate levels of monitoring, but this is not widely appreciated. Although the approach is useful and significant, it is important to ensure that all the interactions between relevant ecosystem components are considered and examined and therefore the use of a triangular matrix is preferred. Such a matrix allows both thematic and sectoral assessments to be undertaken.

It is also worth noting that an assessment is both a process and its product (OSPAR 2006; Assessment of Assessments 2009). As a process, a marine environmental assessment is a procedure by which information is collected, evaluated, integrated, and interpreted. How the process is conducted can affect an assessment's credibility to experts, legitimacy to civil society and the private sector, and relevance to policy-making and management. Assessment products generally feature an assessment report, which is a document synthesising, and interpreting the information, and presenting the findings, the data bases and knowledge sources behind the report. Depending on the mandate of the group conducting the assessment, an assessment may simply describe a current situation, evaluate consequences of potential management options, and/or evaluate effectiveness of past policies and management actions. Assessment products generally include recommendations for action for future work to improve the next cycle of assessment and advice to policy and management.

The product can either be a thematic assessment dealing with one aspect of the marine environment, a sectoral assessment dealing with the effects of a single industry or human activity, or be integrated to varying degrees across sectors, ecosystem components, and environmental, economic, and social factors. Thematic assessments often deal with the status of particular species or habitats, such as assessments of Threatened and Declining Species, or the status of the physical environment, such as the Annual ICES Report on Ocean Climate[32]. Sectoral assessments can deal with separate issues such as eutrophication, environmental impacts of fishing, effects of shipping, etc.

32. http://www.ices.dk/marineworld/oceanclimate.asp

Figure 2.24. Stock assessment training course organized by ICES in February 2010

A general assessment addresses the pressures of all human activities and the resulting overall state or quality of the environment. In the OSPAR system, these reports of more IAs have been called Quality Status Reports (QSRs). Similar assessment reports are produced in the HELCOM system for the Baltic Sea (see Annex 3).

An equally significant aspect of EAM is how it relates to the more operational steps or stages of delivering effective monitoring and assessment programmes. For example, the figure below highlights a matrix which shows the relationship between different sectors (human sectoral activities) and the associated steps in their specific monitoring and assessment programmes. The cells of this matrix identify what monitoring, reporting/analysis

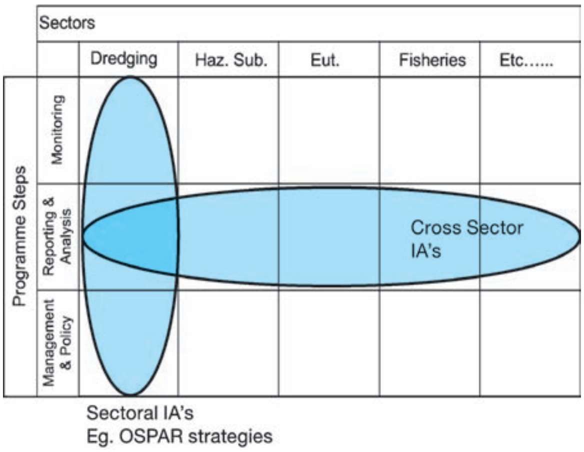

Figure 2.25. An operational matrix approach which relates human pressures (which are subject to management & regulation) to the steps associated with their respective monitoring and assessment programmes. Integration horizontally across columns (sectoral human activities) will ensure that the key steps of their respective monitoring and assessment programmes are integrated across sectors and allow the monitored ecosystem components to be thematically assessed, whereas integration vertically across rows (programme steps) will ensure/allow sectoral assessments to be integrated and inform evaluation of, for example, management strategies. Again, integration into the plan will place those thematic assessments into the sustainable use framework, and make the assessments more fully integrated (IAs).

and management advice is being generated for each of the managed sectors. Clearly integration across all programme steps for a given sector gives rise to a partial IAs (OSPAR approach) which can inform the selection and implementation of effective management and control measures for that sector (this is a programme step integration). However, the value of such a partial IA will be affected by how strongly other industry sectors and natural forcers affect the ecosystem properties encompassed by the "theme".

In addition, a further level of integration can be undertaken by integrating across sectors (horizontal sector integration). A current limitation of sector integration is that most examples to date are programme step-specific, for example the integration of monitoring programmes (EFARO), programme results (OSPAR QSR & EEA), or management advice (ICES). We are not aware of any European examples which fully integrate across all sectors and programme steps in a logical and workable way. Efforts under the UNEP Regional seas programme and Transboundary Diagnostic Assessments (TDAs) strive to do this, but in contexts that are information-poor compared to the European seas[33]. Hence they are at best a partial model for fully IAs in support of EAM in European seas.

To undertake fully IAs, there must also be integration across environmental, economic and social dimensions. The matrix approach outlined above can be used to assess all three dimensions, the only difference being in the type of information used to quantify and describe the interactions between components. For example, the cells in the matrix can represent either the economic, social or ecological significance of their interactions. Clearly not all of the interactions between components will be relevant or significant and indeed some of the interactions may not have any direct social or economic value. Nevertheless, using a single comprehensive documentation of ecosystem components to identify all relevant social, economic and environmental variables will help to ensure that consistent and unbiased assessments are undertaken.

Many of the assessment approaches used in Europe by the science advisory bodies to OSPAR, HELCOM, GFCM, Fisheries Management bodies, etc. feature indicators and reference points. These, in turn, are selected to evaluate status and progress relative to specified objectives (Section 1). In light of the substantive natural variation and incomplete resilience in natural systems (Section 2.1) the use of objectives and targets should be closely associated with environmental assessments. This linkage allows the current situation to be interpreted

33. www.lme.noaa.gov

in relation to trends and changes from past situations. The concepts of ecological quality, as used in OSPAR, and of environmental status, as used by the European Commission (Article 1 of the MSFD), use some different wordings but are otherwise similar and have the same origin. Therefore, the experiences gained in OSPAR and its science advisory bodies in developing EcoQOs and assessing status relative to them are sound building blocks for the work required for all European marine areas when implementing the MSFD.

Likewise the extensive experience with environmental indicators provides another sound building block for the necessary assessments. Indicators simplify the complexity of environmental issues and situations from a multitude of variables to a few, but thereby carry the danger of oversimplification and inappropriate basis for decisions. Substantial guidance exists on best practices for selection of indicators (Rochet and Trenkel 2003; Rice and Rochet 2005; Rochet and Rice 2005). These practices can be supported by causal chain analyses to relate possible indicators to measures to mitigate unfavourable environmental conditions. However, causal chains in ecosystems are not straightforward and the effectiveness of mitigation measures depends on social and economic factors as well as ecological ones. Therefore, selection of both indicators and of management measures requires comprehensive and IAs, even if indicators are being used for regular updating of environmental status.

As summarized above, there are many building blocks for assessments in support of EA and Integrated Management (IM), and implementation of the MSFD. However, more effort is needed to pull the pieces together into more fully IAs with practical utility. Pressures can have impacts well beyond their point of application. For example, transport of nutrients input to one coastal area may lead to eutrophication effects and degradation of habitat quality in other areas. Similarly, overfishing of a fish population in one sea area may result in fewer young fish in subsequent years, affecting the feeding conditions of seabirds in adjacent coastal areas. The interconnectedness of ecosystem components in food chains and food webs, and their dependence on habitats, also requires assessments integrated across all ecosystem features and habitats as highlighted in Chapter 2.1.

Finally, for policy and management to achieve their objectives, efforts to regulate the impacts of different human activities on marine ecosystems have to work coherently. It is an ambitious goal to have the strategies and tools for management of the impacts of one industry on the marine environment, all compatible with the strategies and tools for managing other industries, but even that is not enough. The social and economic consequences of the policies and management measures have to be coherent as well for society at large and particularly coastal communities, to enjoy the many benefits provided from the seas and oceans. Hence, only when the building blocks are combined into fully IAs will the full basis be available for an EAM, and for full implementation of the MSFD.

Assessments play a central role in the EA in general and specifically in the MSFD. Because assessments have to evaluate as well as inform policy and management, it is important that they are decoupled from direct political influence, both as process and products. Assessments are scientific in nature, and scientific objectivity and independence must be secured. This requires clear delegation of tasks and responsibilities to scientific institutions with independent roles but secured funding to carry out their scientific advisory tasks within the institutional framework of EAM.

The situation today is one with many national agencies and institutions, often with a lack of national coordination, and competing for funds. Within countries, there is a need for streamlining the national and subnational tasks of monitoring and assessing the environmental status, including living marine resources. This should be done as part of an international co-ordination where increased cost-efficiencies could be achieved by countries working together in the shared LMEs.

Delivery of the expanded and new science programmes discussed in this report, and obtaining the necessary benefits from that science through connecting the products to governments, the private sector, and civil society, will require a high degree of coordination. The three partners involved in preparing this report are well positioned to play key roles in that coordination. ICES has a history of over a century of bringing scientists together to plan, conduct, review, and apply marine biological and ecological science. It has a strong infrastructure for coordinating the efforts of scientists across North-western Europe, and is increasing connections with researchers in southern Europe as well. It has an equally well-developed infrastructure for peer-review of science results and their application to address advisory question for the EU, fisheries and environmental agencies with marine interests, and Member States. Both aspects of ICES are designed to ensure the integrity of the science, protected from policy biases, and that quality assurance is kept a priority. ICES has striven throughout the past two decades to improve the integration of diverse science disciplines, with a number of successes and a number of lingering challenges. One of the most persistent challenges has been the lack of effective linkages between the natural sciences, which are the strength of ICES, and the social sciences, which link to ICES in only a small number of Expert Groups, and not at all in advisory processes. Another limitation of ICES is that it does not actually have its own funding to support the science, instead providing advice to those who pay for this service. Rather it relies on the research institutions of Europe (and the US and Canada) to make expertise available for ICES initiatives. As a result, the ICES pool of expertise is strongly oriented towards researchers in national laboratories. Academic scientists do participate in ICES, but the connections are not nearly as complete or as strong. For both reasons, ICES should be expected to remain in a planning and coordination role for the performance of science, and the role of national institutions and universities will require additional coordination.

EFARO is well-placed to actually coordinate institutional actions, complementing the strength of ICES in bringing the scientific community together. As leaders of the European research institutions for fisheries and aquaculture, the EFARO delegates have management authority over staffs, facilities, and budgets, and links to national governments to provide the people, instruments, and platforms needed to get work done, whether coming from the ICES science and advisory processes, national priorities, or other sources. The focus of EFARO, however, is on fisheries and aquaculture only, and not the full spectrum of ocean uses and sciences. Moreover, the academic community is not tightly linked to EFARO. Like ICES, their social science resources are few and linkages to that community are highly variable among members.

The Marine Board-ESF (despite lacking a substantial link to the social scientific community), can therefore play a major role in bringing together the full range of science experts needed to deliver the science requirement for implementation of the MSFD. Furthermore, and acting as the pan-European platform for organisations which support and carry on marine science, the Marine Board-ESF is ideally placed to define and promote specific research agendas and priority needs in relation to the EAM implementation at the decision-making level. Its strategic focus and strong linkages to the priority setting aspects of funding for science can be important for both EFARO and ICES members.

On the assumption that several national policies within Europe could be harmonised and strategically aligned on future EAM management and governance processes, the Marine Board-ESF would be in a position, in co-operation with ICES and EFARO, to effectively convey a strong and unified impetus to policy and decision makers to greatly impact on EAM implementation both at a pan-European and regional/LMEs level.

Summary Box 11 – Assessments to support the Integrated Maritime Policy

37. Assessments form the basis for evaluations of the effectiveness of existing measures and considerations of whether changes in policies and measures are required and if so, what their consequences might be. They have also a valuable role to play in assisting the design of monitoring programmes. An assessment is both a process and a product (e.g. thematic/sectoral/integrated report).
38. Fully Integrated Assessments (IAs) integrate all ecosystem components, including human activities, socioeconomic factors and environmental state variables. A matrix approach can be used to assess all three dimensions.
39. Selection of both indicators and of management measures requires comprehensive and IAs.
40. There are many building blocks for assessment in support of EAM, Integrated Management and the implementation of the MSFD. However, more effort is needed to pull the separate pieces together through the development of frameworks which enable multiple types of information and evidence to be integrated into management advice.
41. There is a need for streamlining the national tasks of monitoring and assessing environmental status as part of an international coordination programme, based on a regional approach.
42. The organisations participating in this Working Group have a major role to play in coordinating the marine research and in communicating and delivering a unified message to the policy and decision makers with regards to EAM implementation.

2.4.2 Knowledge gaps and priorities for further research

There are still numerous knowledge gaps which need to be addressed before fully IAs will become a reality. Research in support of this goal must focus on the following priority areas:

- Preparation of best practice guidance on how to undertake integrated assessments;
- Preparation of best practice guidance on how to disseminate the results of Integrated Assessments to different stakeholder groups;
- Objective methods which explore, quantify, describe and weight the connectivity and interactions between ecosystem components are required;
- Objective methods which explore, quantify, describe and weight the status and trends of ecosystem components are required;
- A review of methods most suited for dissemination and communication of results to different end-users;
- An evaluation of the sensitivity of integrated assessment methods to changes in scale, both temporal and spatial;
- The development of systems which can predict and forecast changes in the interactions and status of ecosystem components against different scenarios;
- Well-tested guidelines for selection of indicators and development of scenarios already exist, but systematic usage is not well established. Hence merely higher standards for practice in these, and many other assessment-related tasks, are necessary.

2.5 Developing tools for knowledge transfer

2.5.1 The challenge of knowledge transfer

Knowledge transfer refers to the process which facilitates the dissemination of research-based knowledge, expertise and skills between research organisations and society. As part of progress towards a European Research Area (ERA), increasing access to research results and improving knowledge transfer between researchers and decision makers, stakeholders, and industry are very important. However, researchers, decision-makers and stakeholders lack a consistent history of engagement, so avenues for knowledge transfer cannot be assumed to exist. Moreover, effective knowledge transfer requires a set of tools that facilitate communication between the complex network of participants in governance, including experts, decision-makers, and stakeholders, and in at least some cases, such tools are lacking. Consequently, improved knowledge transfer will require research on both processes and tools.

The general view of ecosystems functioning in terms of interplay between biotic and abiotic components, and human uses of these components, as well as the need to manage associated human impacts on ecosystems, are actually widely accepted by the general public and the main stakeholders of the oceans. For example, TV documentaries and movies have played a major role in spreading this view in society during the last 10 years. However, these communication efforts have not made clear the role of an Ecosystem Approach (EA) and Integrated Management in managing those human impacts. There is neither consensus on the most appropriate roles of all societal players, nor on the best processes to ensure those players have the information necessary to fulfill their roles. Research to support building greater consensus on those roles is discussed in 2.3, but research on improving the tools for knowledge transfer should be pursued at the same time.

The research community must increase the priority given to transfer of knowledge from research to better inform decision-making and policy development. Innovations are needed to improve knowledge transfer and bridge the gap between those who produce research-based knowledge and those who are in a position to use it. In addition, however, there is inadequate understanding in society of how individual choices influence the status of ecosystems. Knowledge transfer needs to help citizens to see how their choices as consumers and producers may play an impact upon marine ecosystems. Consequently improved knowledge transfer must address public misconceptions about the true limits to the availability of ecological goods and services, the role of biodiversity, and generally increase knowledge regarding marine ecosystems. Thus, improved tools for communication between scientists and society are essential.

A set of tools have been developed to communicate research-based knowledge to different players: workshops, meetings, conferences, TV documentaries, videos, video games, magazines, newsletters, news articles, websites, reports, scientific publications, demonstrations, rallies, and many others. A major gap in our current knowledge is an evaluation of what are the most effective tools for transferring various types of knowledge to different audiences. Also lacking is an evaluation of how effectively different tools support the practices of the different users of knowledge in governance.

2.5.2 The context for knowledge transfer

We identify three domains or pathways for knowledge transfer:

- Spreading scientific knowledge among scientists and applied technicians (higher education and research and technical training);
- Communication of scientific knowledge to participants in governance processes; and
- Outreach of scientific knowledge for the general public and society.

The science being done has at least four different foundations:

- Scientific process driven Research & Development;
- Mandatory monitoring and assessment programmes;
- Management action; and
- Strategic policy development.

Strategic policy development and effective implementation depends on the effective flow of information among these different activities. This flow of information is complex both because the information itself is complex in each activity, and because each activity involves different role-players. The tools to achieve the effective flow of information need to recognise these different activities and the needs, interests, and capacities of the key players in each one.

Consequently the science needed to address the development of tools for knowledge transfer must include:

- Clear identification of players and their roles in each component, and an understanding of their cultures and customs;
- Clear identification of the inputs required by each component; and
- Clear identification of the products produced by each component.

Research on governance processes in Section 2.3 will contribute to the first, and research on ecosystems themselves (2.1), including the human component (Sections 2.2) will contribute to the second. However, research on tools to fill the gaps highlighted in Chapter 3 is needed in its own right. Even after all the linkages among participants in each component have been identified, tools must ensure effective "translation" of products from the culture of the producer to the culture of those who will use those products.

Between 2007 and 2009, the Group of Experts for the IOC/UNEP-coordinated Assessment of Assessments to develop a "Regular Process" for policy-relevant regional and global marine assessments, reviewed practices and products of over 400 different types of assessments previously implemented to inform marine policy and management. Their report identifies best practices for

Figure 2.26. Group of Experts for the IOC/UNEP coordinated Assessment of Assessments

many aspects of the complex social processes for marine policy development and implementation, including:

- Objectives, scope and conceptual framework;
- Data and information;
- Science/policy relationship;
- Nomination and selection of experts for conducting assessments;
- Treatment of lack of consensus among experts;
- Peer review;
- Cyclic review and evaluation of advice; and
- Communication.

Many of the best practices identified in that report help to clarify the context for knowledge transfer within and among the domains and pathways identified above. For example, in the conceptual framework for policy relevant assessments, best practices involve examination of impacts on human well-being in addition to status, causes and impacts in the marine environment, including the costs and benefits of changes in ecosystem goods and services and the identification of groups and areas most vulnerable to changes in environmental goods and services. Experts conducting such examinations of impacts and identifying such groups need to communicate their findings clearly to those bearing the impacts and those most at risk. Failing to communicate this knowledge effectively to those groups does not prepare those groups to participate effectively in choosing and implementing measures to address the risks to which they are exposed. If the risks are potentially serious, ineffective communication may unintentionally create a public opinion environment fostering unnecessary alarm and calls for precipitous, poorly-considered measures to mitigate the risks.

2.5.3 Potential approaches for knowledge transfer

The best practices for communication from the Group of Experts report provides a starting point for identifying the work needed to develop tools for knowledge transfer.

These practices include:
- For regular progress reports during the assessment, identify target audiences and a means for review and comment of draft documents by a broad audience (distinguishing peer review from broader external review);
- In the early stages of an assessment, develop a communication strategy for disseminating assessment results, bearing in mind, and in consultation with, each target audience;
- Ensure that targeted policy-maker audiences receive special attention in the communications strategy;
- Differentiate outputs so that more detailed, technical material is pitched for management officials or the industry sectors, with a precise summary for high-level officials, etc;
- Use charts, graphics and indicators judiciously for different audiences to capture the attention of important but less specialized constituencies while avoiding over-simplification for knowledgeable policy-makers, managers and users;
- Use maps and spatial data to present information, both for public and specialized audiences;
- Make a special effort to reach some identified target audiences;
- Target society at large as a consumer and work with industry to promote sustainable and environmentally friendly products; and
- Use a talented science writer to develop scientifically-accurate products to reach a wider public audience and/or high-level officials.

However, the Group of Experts report does not include guidance on the best ways to discharge each of these communications tasks. That guidance needs to come from focused study of which tools and processes are most effective for the various tasks, the degree to which the best tools and processes need to be adapted to various players in the overall process, and the different domains of knowledge transfer in 2.5.2.

Figure 2.27.
An Assessment of Assessments © IOC/UNEP

Summary Box 12 – Developing tools for knowledge transfer

43. The research community must increase the priority given to transfer of knowledge from research to better inform decision-making and policy development;
44. An improved knowledge transfer will require research on both processes and tools to facilitate the communication between all stakeholders, from those who produce the research-based knowledge and those who are in a position to use it.

2.5.4 Knowledge gaps and priorities for further research

In light of 2.5.3, the knowledge gaps and research priorities for developing tools for knowledge transfer may be listed as:
- Understanding, improving and facilitating research based knowledge transfer between researchers and decision makers or the policy community;
- Understanding, improving and facilitating research based knowledge transfer between researchers and users;
- Understanding, improving and facilitating research based knowledge transfer between researchers and society; and
- Understanding, improving and facilitating knowledge transfer between decision-makers back to researchers, users and the society.

3. Developing strategies and technologies to inform the implementation of the Marine Strategy Framework Directive

3.1 Introduction

Europe's deep-ocean margin stretches over a distance of 15,000km along the Atlantic Ocean from the Arctic to the Iberian margin and from western to eastern Mediterranean, through to the Black Sea. The margins extends from the shelf edge at about 200m depth until around 4000m depth where the abyssal plain or oceanic basins begin, and covers 3 million km^2, an area about one third of that covered by Europe's landmass. Most of this deep-ocean frontier lies within Europe's Exclusive Economic Zone (EEZ) and is therefore of direct interest for the exploitation of biological, energy and mineral resources. A major aim of European policy is to develop these resources in a sustainable manner. This requires knowledge of ocean margin ecosystem structure and dynamics considering the variety and complexity of the continental margin environments, which hold many specialized species and ecosystems, including deep sea corals, chemosynthetic life, and canyon communities (HERMES, 2005).

Such knowledge must be generated in an integrated way that ties research on biodiversity and biological processes intimately with the physical factors controlling ecosystems (geology, sedimentology, physical oceanography, and biogeochemistry). In addition, it is important to set present-day ecosystems in an historical framework by studying the sediment record to determine long-term environmental changes and the potential response of ecosystems to global change over decadal to millennial scales. Changes due to large-scale natural forcing (e.g. climate oscillations, sea level change) or to more local human effects (e.g. resource exploitation, inputs of pollutants and nutrients) must be distinguished from each other before man's activities make this distinction impossible. In some areas, notably deep-water coral colonies, man's impact on the environment has already been considerable (Weaver *et al*. 2004). Tolerances of these often poorly-studied ecosystems to perturbations must be understood so that the sustainability of commercial initiatives in the deep sea can be evaluated (HERMES 2005).

The potentially vast renewable and non-renewable seafloor resources present in Europe's offshore and in international waters have received renewed attention in the past decade. Established industries such as fisheries and hydrocarbon extraction are moving rapidly and steadily down-slope as shallower and more accessible resources become depleted. Deep-sea fisheries and oil and gas exploration now occur in depths of more than 1500m and 2000m respectively, while emerging industries such as blue biotechnology – obtaining useful products through the exploitation of deep-sea biodiversity – are not depth limited (Grehan *et al.* 2007).

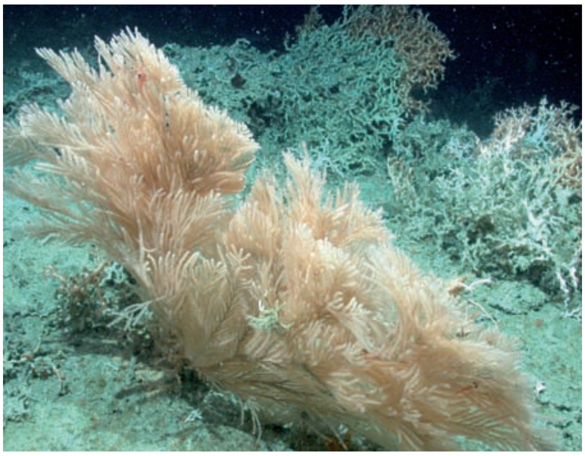

Figure 3.1. High resolution images taken with the IFREMER Remotely Operated Vehicle 'VICTOR' during surveys of Irish cold-water coral sites between 600 to 1000m water depth

The Marine Strategy Framework Directive (MSFD) recognizes that the health of the marine environment is declining and that many human activities are not sustainable. Among its many provisions is a call for *"a new approach to marine monitoring and assessment and the use of scientific information"*. Hence, in addition to the research needs discussed in chapter 2 to increase our knowledge of the natural, social, and governance systems, there are specific operational science needs under the Directive regarding monitoring 'Good Environmental Status' (GES) that have yet to be teased out. Monitoring under the MSFD should be broad enough to allow an improved assessment of ocean resource status and trends.

3.2 Status and trends of Biotic Ocean Resources

3.2.1 Status

• Preparation of marine resource inventory atlases in Geographic Information Systems (GIS)

A number of European countries, for example, Ireland, have in recent years begun systematic seafloor mapping programmes using multi-beam acoustics. These swath systems allow full coverage mapping even in very deep waters. Backscatter generated by the acoustic signals provides an indication of the substrate type, particularly when used in less than 400m water depth. Other techniques such as side-scan sonar can generate data that can improve interpretation of multi-beam generated maps. These data can provide the basis for the location and quantification of seafloor sedimentary resources and efforts to extend such maps to all European waters should be increased. Geographic Information Systems (GIS) provide an efficient way of displaying geomorphology and habitat overlays for use by planners and policymakers (Wright and Heyman 2008). A major challenge thus remains, to provide information about the distribution of biotic resources in the deep-sea to add to the information obtained from remote sensing acoustic surveys. One promising area of research in this regard is the application of habitat suitability modelling to predict the likely occurrence of biotic resources based on a thorough knowledge of habitat preference (Clark *et al.* 2006; Wilson *et al.* 2007; Davies *et al.* 2008; Tittensor *et al.* 2009; Guinan *et al.* 2009).

• Physical characterisation of ocean processes underlying ecosystem dynamics, at scales relevant for human exploitation of Biotic Ocean Resources (BORs)

Understanding physical and trophodynamic ocean processes is key to prediction of habitat suitability for targeted BORs. Climate change effects will most easily be registered at larger scales while un derstanding local environmental forcing conditions will provide the basis for distinguishing optimal from sub-optimal habitat. The development of nested three-dimensional oceanographic models may be important in this regard.

• Assessment of goods and services provided by BORs

Deep-sea ecosystem goods and services provide provisioning services (food, raw material, fuel etc.), regulating services (climate regulation, disease regulation etc.), cultural services (recreational, aesthetic, spiritual etc.), and supporting services (photosynthesis, nutrient cycling, primary production) (UNEP 2007). 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 (both qualitatively and quantitatively) could result in their being assumed to have zero value and not factored into decision making (Grehan *et al.* 2009). However, valuation studies of these resources are, as yet, practically non-existent and appropriate methodologies are in early stages of development.

• Preparation of an inventory of economic activities and their impacts

An accurate picture of current economic activities is required so that impacts/threats to BORs can be quantified. Human activities having a direct or indirect impact on marine biodiversity, in particular, in sensitive habitats such as deep-water corals, seamounts, hydrothermal vents or cold seeps, need to be catalogued and their impacts quantified (UNEP 2007). There is a lack of information about the nature, scope and range of actors

Figure 3.2. A dredger at work

and a context for such activities, their environmental impact, and conflicts arising in areas where these activities co-exist. Although attempts are being made to improve the situation, access to data about the extent of much offshore economic activity (e.g. fishing) is fragmented or non-existent.

Consequently, accurate quantification of the impact of economic activity is currently very difficult. A major effort is thus required by Member States in conjunction with the European Commission to ensure that relevant datasets are made available to scientists working in authorized research projects either at national or European level.

• Economic valuation of the potential of BORs

Much of the use value connected to biotic resources is found in their option and quasi-option (potential future use) values rather than in the direct or indirect use values as they exist today. Socio-economic valuations (including for non-market and non-use values and restoration) are also necessary to facilitate accounting for non-market and non-use values in decision-making and management. Cost-benefit analysis will be required, including the issue of discounting (long-term benefits vs. short term costs). The loss of value due to biodiversity loss needs to be assessed and multi-criteria analysis for conservation and sustainable use of deep-sea biodiversity performed (UNEP 2007).

• Socio-economic studies of multiple ocean uses and their interactions (including conflicts)

While Strategic Environmental Assessments (SEAs) attempt to determine the likely accumulative impact of multiple projects and plans, very few actual studies have been conducted on the interaction between different ocean use activities. The implementation of an integrated ocean management strategy predicated on EAM will require the implementation of Marine Spatial Planing (MSP), a tool for improved decision-making. It 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 (Grehan *et al.* 2009).

3.2.2 Trends

• Establishment of monitoring and evaluation programmes including operational oceanography/ observatories

The MSFD has acknowledged the need to integrate existing but fragmented initiatives in order to facilitate access to primary data for public authorities, maritime services, related industries and researchers. The Commission has, therefore, undertaken to set up a European Marine Observation and Data Network (EMODNET) to open up opportunities for high technology commercial companies in the maritime sector, improve the efficiency of activities such as marine observation, management of marine resources and marine research in European laboratories. A number of initiatives are ongoing to pave the way for a network of European ocean observatories, including the ESONET and EMSO projects, co-funded by the European Commission through FP6 and FP7 respectively. It is increasingly apparent that successful monitoring requires the establishment of baselines against which reference points can be set and compared. This will enable the tracking or mapping of biotic ocean resources trajectories in time. The separation of local from regional effects requires the establishment of a well chosen network of monitoring sites and a commitment to provide long-term operational funding for ongoing monitoring. This should be addressed by Member States as part of their response to the implementation of the MSFD.

• Good Environmental Status (GES) Descriptors

To comply with the MSFD objective of clean, healthy and productive oceans and seas, a number of qualitative descriptors are listed in Annex 1 that should be monitored to ensure GES. However, the Directive does not provide criteria or methodological standards or compliance thresholds for these descriptors. Scientific guidance on these monitoring and evaluating these descriptors is being developed by ICES and JRC. However, even when that guidance is available, much work will be required by the Member States to produce operational monitoring protocols with which to establish appropriate baselines against which GES can be assessed.

• Implementation of Marine Spatial Planning strategies

Increased activity within Europe's marine waters has led inevitably to growing competition for finite maritime

Figure 3.3. French Atlantic coast (Charente Maritime)

space. Competing claims from a range of activities, including fisheries, navigation, oil and gas extraction, and wind and wave energy generation are accompanied by increased pressure on vital marine ecosystems and habitats. These various activities are regulated on a sectoral basis by different agencies and according to different pieces of legislation. Without the means to coordinate a common approach to the allocation of maritime space among different sectors the problems of overlap and conflict between sectors and individual stakeholders is evident. There are also cross-border issues as developments in the maritime area of one country may well have impacts for another. The relatively new notion of Marine Spatial Planning (MSP) has emerged as a means of resolving inter-sectoral and cross-border conflicts over maritime space. The recent EC Communication on Marine Spatial Planning [COM 2008 (791)] lays out some guiding principals, notably that the sustainable management of marine regions depends on the condition of the respective ecosystem and therefore an ecosystem management approach is an overarching principle for MSP. Although activities on land may have a direct impact on sea regions, MSP manages only maritime activities and activities in coastal and oceanic waters. The scope of MSP in terms of geographical coverage will differ according to regional conditions. Development of MSP must take into consideration, and where appropriate contribute to, the implementation of several international and EU instruments of relevance.

Implementation of the MSFD will require:
– Using MSP according to area and type of activity;
– Defining objectives to guide MSP;
– Developing MSP in a transparent manner;
– Stakeholder participation;
– Coordination within Member States – simplifying decision processes;
– Ensuring the legal effect of national MSP;
– Cross-border cooperation and consultation;
– Incorporating monitoring and evaluation in the planning process;
– Achieving coherence between terrestrial and MSP, e.g. through Integrated Coastal Zone Management (ICZM); and
– A strong data and knowledge base.

• Data management information systems

The large-scale and multidisciplinary research required to underpin any Integrated Maritime Policy (IMP) will generate large amounts of data. The European INSPIRE Directive (EC 2007/2) has, as a practical goal, the collection of data only once, whether by independent research, government agency or by industry. A European wide system for archival of data and infrastructure to facilitate ease of re-use is not yet a reality despite many years of effort.

A service-oriented federated system is needed to improve and integrate all facilities in Europe handling oceanographic or related data (Pfannkuche *et al.* 2009). Open access to, and sharing of data not only helps to maximize the research potential of new observational technologies and networks, but provides greater returns from public and industry investment in research and monitoring. In recent years, a number of initiatives and projects have addressed the implementation of common policies and infrastructures:

– The OECD Principles and Guidelines for Access to Research Data from Public Funding (OECD 2007) provide broad policy recommendations for national science policy and funding bodies;

– The INSPIRE Directive obliges Member States to make available catalogues of all data holdings;

– The Global Earth Observation System of Systems (GEOSS) coordinates capacities worldwide and the implementation of a global network of observing systems based on common standards;

– The Global Monitoring for Environment and Security (GMES) promotes, at EU level, the establishment of European capacity in Earth Observation including the oceanographic field – the latter supported by a number of EU projects (ESONET/EMSO, MERSEA, EUR-OCEANS, CARBOOCEAN, MarBEF, SPICOSA, ECORD-net) will ultimately pave the way for EMODNET;

– The Intergovernmental Ocean Committee (IOC) network of National Oceanographic Data Centers (NODC, International Oceanographic Data Exchange, coordinated on the European side by SeaDataNet) and the International Council for Science (ICSU)/World Data System (WDS, represented in Europe by WDC-MARE), are also important building blocks for the EMODNET which should be operational by 2014/15 (Marine Board-ESF 2008). Close consultation will be required with scientists and other stakeholders to ensure usable infrastructures are put in place.

• Development of (timely) adaptive management capabilities

With an aim to reduce uncertainty over time (mostly based on monitoring feedback), a holistic and integrated EAM to BORs will require a structured and iterative decision-making. In this way, decision-making will simultaneously maximize one or more resource objectives and, either passively or actively, accrue information needed to improve future management. Aspects of the governance processes needed for adaptive management are discussed in Section 2.3, in addition to the methodological decision-support developments discussed below.

• Development of a management paradigm able to cope with scientifically irreducible uncertainty

This will support decision-making and the governance of BORs (see Section 2.3) that in turn will require:
– New policy options for an Ecosystem Approach to Integrated Management of BORs;
– A review of existing legal frameworks and identification of gaps leading to possible development of new ocean laws;
– Formal Member State adoption of polices, goals and measures;
– Implementation of an integrated EA (including funding, staffing and organizational changes).

3.2.3 Knowledge gaps and priorities for further research

1. Status, structure and functioning of BORs

There is a need:
– For a comprehensive European high resolution (multi-beam) bathymetry and inferred substrate basemap;
– For an inventory/map of European BORs at regional scale;
– To better model hydrographic and environmental

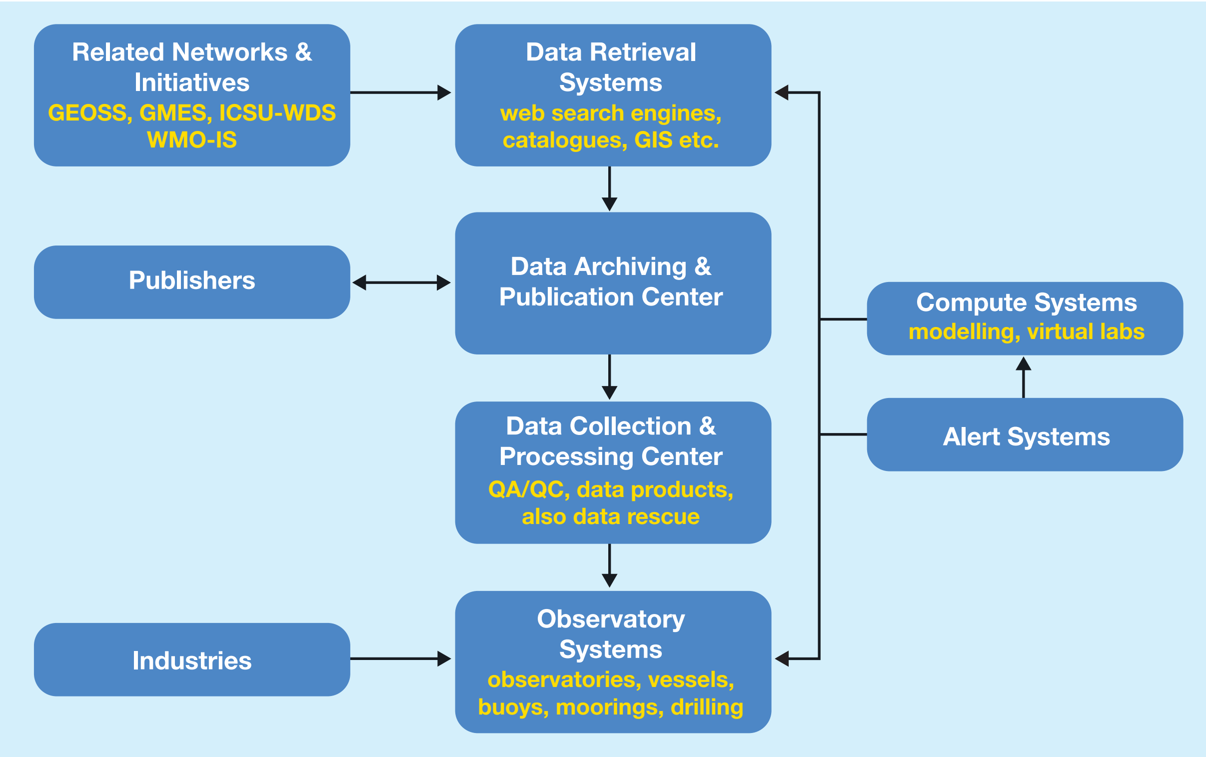

Figure 3.4. Data Information System. Crucial in a federated system is the division of labour according to the capabilities of participating facilities. Essential functions (roles) comprise data production, collection, processing, archiving, publication, and dissemination. In addition, brokers are needed for linkage to related networks (incl. libraries), compute facilities, publishers (journals), and industries. Adoption of globally accepted standards (essentially OGC and ISO family of standards) compensates for the heterogeneity and dynamics of requirements and developments. (from the document: The Deep-Sea Frontier (2007): Sustainable use of Europe´s deep-sea resources Scientific needs and strategies)

forcing at habitat relevant scales including sediment dynamics and organic material supply;
- To improve coupled hydrographic/ecosystem models;
- To carry out monetary and non-monetary economic valuations of ecosystem goods and services;
- To conduct monitoring in a spatially comprehensive manner and to include the timing and amount of primary and secondary production, larval fish community composition, and reproductive success in marine mammals and seabirds. Key ecosystem components, including non-commercial species, must be included;
- To evaluate spatial and temporal effectiveness of existing monitoring programmes by analysis and modelling;
- To undertake field studies to quantify climate-related processes, giving particular attention to:
  - Open-ocean and shelf convection;
  - Physical and biological processes related to oceanic fronts;
  - Sequestration of carbon in the ocean, including a quantification of air-ice-ocean exchange;
  - Long-term effects of UV-B radiation on biota; and,
  - Interactions between benthic and pelagic fauna.
- To strengthen biophysical modelling of the ocean with increased emphasis on coupling biological models with physical models in order to improve predictive capabilities.

2. Status and environmental footprint of economic activities (assess the economic potential of ocean resources)

There is a need:
- For comprehensive information about the nature and value of marine economic activities (e.g. wealth and employment created);
- To provide economic activity data for the development of economic modelling to support management scenario testing;
- To quantify the footprint of economic activities including the extent of downstream effects.

3. Status of human impacts

There is a need:

- To map and monitor threats to the sustainability of BORs in European waters;
- To determine, map and monitor the level of existing anthropogenic stress on BORs as part of a comprehensive integrated assessment;
- To determine the likely impact on BORs of new activities and assess exploitation trends;
- To assess the relative roles of natural variability and human-induced changes;
- To understand ecosystem responses to anthropogenic impacts in terms of sensitivity, resilience and potential for recovery;
- To determine the spatial and temporal scales of impact and recovery.

4. Management information needs

There is a need:

- To understand how different sectors will use MSP tools;
- To develop mitigation strategies to reverse negative (or undesired) trends and to minimize impacts;
- For economic valuation of the consequences of ecosystem perturbation/destruction;
- For consistent monitoring of biological and economic descriptors to ensure maintenance of ecosystem integrity and the provision of goods and services both locally and in the broader regional/European monitoring context;
- To establish the data requirements and rules for conflict analysis.

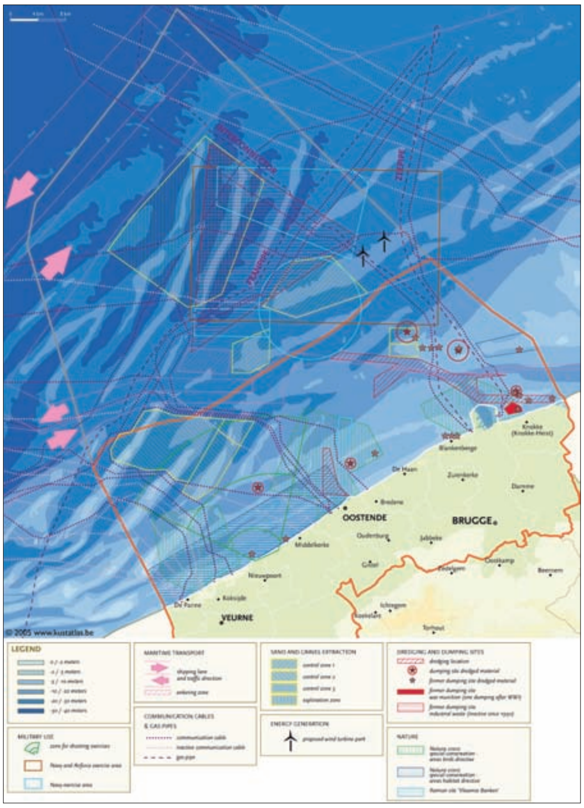

Figure 3.5. A Map of human activities in Belgian inshore waters

4. Impediments to the implementation of an Ecosystem Approach to Management of Biotic Ocean Resources

Implementing the Marine Strategy Framework Directive (MSFD) requires Integrated Management incorporating an Ecosystem Approach (EA). These requirements pose many challenges for implementation. Some of the challenges arise from the breadth and complexity of the Ecosystem Approach and Integrated Management. The corresponding large demands for knowledge and information alone are enough to make implementation difficult for institutions, expert advisors, and participants in governance and management activities. These difficulties are increased, however, because there are actual structural impediments to progress. Reviewing these impediments will help identify where the science community can help to overcome or avoid them, and allow those responsible for implementation to plan realistically.

4.1 Impediments

4.1.1 Scope, cooperation, accountabilities

Policy and management agencies are established to fulfill particular roles. For several reasons, the scope of these roles is often explicitly constrained:

1. Legal frameworks, particularly in the complex European setting of Member States and the Commission, may have been carefully negotiated compromises of many competing interests;
2. To avoid potential redundancies of responsibilities and conflicts among agencies;
3. To allocate and manage budgets in line with public policy objectives;
4. To ensure that all the tasks necessary for maintaining an orderly society are dealt with; and
5. To allow accountability of agencies to elected representatives.

The first of these constraints may be particularly important in the marine context, as many of the relationships between Member States and the European Commission (EC) were negotiated without substantial consideration of ecological aspects and marine ecosystem dynamics. The partitioning of many jurisdictional authorities does not transfer readily to the regional dynamics of marine ecosystems, particularly in the context of an EA. As a result, even where the need is acknowledged and the will exists, agencies may be prevented from broadening their ranges of actions to address ecosystem issues or from pooling their responsibilities and adapting their policies and management actions to integrate with those of other agencies.

Cooperative actions can require agencies to move outside their primary responsibilities to improve integration of management actions or to broaden the ecosystem context of policies. Those who approve agency work plans and budgets may not oppose such extra-agency action or inter-agency collaboration but may require that it be supported by funding and manpower supplied from external sources and time. Mandate-based impediments also may arise when the integration of actions across agencies make it efficient for one agency to take on additional tasks at possibly a small incremental cost to provide a significant incremental benefit to another agency. Such impediments can be overcome through cooperative planning and agreements on cost-sharing, but the extra effort of such planning may discourage already overworked agencies from even initiating the dialogue that leads to such planning and agreements. This can be the case, for example, when information is needed by a user agency on different space and time scales than the needs of the agency with the mandate for collecting the information.

Progress on implementing the EA may also be impeded when an agency's mandate does not make it responsible for the ecosystem impacts of the industries/activities which are regulated by that agency. Even if an agency has the will to implement an EA, it may lack the resources to monitor such ecosystem effects or the authority to set and enforce regulations outside its core mandate. Commonly the mandates for monitoring and reporting on the status of environmental drivers and ecosystem components impacted by an industry sector may be given to agencies with few linkages to those managing or regulating the sector causing more impacts. Sometimes these may be allocated to agencies which have competencies at very different scales, making it even more complex to coordinate monitoring and reporting on impacts, and coordinating appropriate responses. Each agency may adopt policies and measures appropriate for their respective mandates, but some may function at cross-purposes to the policies and measures of the other agency. Mutual planning and accountabilities can sometimes be established among agencies where there is a will to collaborate and plan interactively. However, in some cases, the legal structure of the EU may prevent the establishment of bodies with effective powers at the scale of marine ecosystems, even when the need is widely acknowledged. In addition, for coordinated actions at regional marine ecosystem scales to succeed, all relevant Member States must at least accept the actions. The necessary EU-wide negotiation to multiparty consensus can be much more complex than bilateral agreements. Moreover, tight agency mandates impede the necessary flexibility in work planning and budgeting.

Accountabilities can also impede progress simply by consuming large amounts of limited science capacity, for example, when the delivery of products designed to

4. Impediments to the implementation of an Ecosystem Approach to Management of Biotic Ocean Resources

© EC

Figure 4.1. Fishing net inspection

ensure accountability requires significant effort but adds little value to the decision process.

For example, assessments have to be done annually for many fish stocks as a basis for updating single species quotas. These quotas may actually be of limited value in ensuring sustainable harvesting for several reasons, including:

– The quotas by single species may not take into account the patterns of fishing in space, and sometimes not even to the species harvested;
– Fisheries are often multi-species, and un-integrated stock-by-stock advice does not resolve the overarching multi-species questions;
– The scientific advice on appropriate harvest level is often superseded by “social or economic considerations” that are applied subjectively.

Such challenges are in themselves subject to research, such as integrating the ecological, social and economic aspects of the decisions or integrating harvest controls in multi-species fisheries (see Section 2). However the drain on fisheries science expertise to support the monitoring, analyses, modelling, and meetings just to provide the single-species quota advice slows progress on answering the higher level questions that could lead to greater efficiencies and greater effectiveness in science support to fisheries policy and management.

4.1.2 Protecting existing mandates and funding

The EA requires proper implementation of information on both drivers and impacts, whilst implementation of Integrated Management means adjusting an agency’s approaches to its tasks to work in closer harmony with the approaches of other agencies, and possibly taking on and sharing new duties. Consequently, progress requires agencies and institutions to do more things and/or do things differently. If the agencies give more priority to protecting their existing mandates and funding than to adapting their activities to do more things or different things, the necessary institutional flexibility will be hard to achieve. Even if an institution does have the flexibility, the additional things to do or different methods for doing them may be opposed by another agency that claims the new or different activities impinge on their mandates, and create bureaucratic roadblocks to change.

This lack of flexibility, which can result from a need to protect mandates and funding sources, is not restricted to policy and regulatory agencies. Science institutions are also created with core mandates, and funded to deliver them. If the science institution is progressive, it may accept the need to broaden the scope of its activities and even may be supported financially to do so. However, the changes may be perceived as moving into the mandate and scope of activities of other research centres, or may lead to costly duplication of infrastructure. Again, actions to protect mandates and funding sources from incursions by other science institutions become impediments to integrating the types of expertise needed to provide the knowledge basis for progress. The complex network of European science organisations, with international, national, regional and private institutions and networks means that resolving conflicts will be complicated and challenging. Moreover, if science organisations feel their funding basis may be at risk, outcomes satisfactory to all research centres may be hard to find.

4.1.3 Science-policy mismatches in timing

Generally policy is slow to develop, and moves in large steps whereas scientific information and understanding accumulates more incrementally. At the same time, policy objectives generally have short-time horizons, particularly with regard to social and economic goals, where ecosystem processes and responses often unfold over much longer time scales. These mismatches in the scale and timing present several impediments to progress on Ecosystem Approach and Integrated Management.

There are two general mechanisms by which policy gaps become apparent: failures of existing policies and the programs built on them to achieve their objectives, or emergence of new societal problems stemming from changing environmental, social or economic conditions. Both types of policy gaps emerge slowly. Not all consequences of an ineffective policy appear at once and they may manifest themselves more readily in some settings than others. For example, failure of a fisheries management decision may appear sooner to those monitoring the resource than those harvesting it, and at different rates to different fleets. Changes in the ecological or societal context of a policy also accumulate gradually, especially at the early stages of the new trend when adaptation would be easiest. For well-established policies, the associated monitoring and evaluation systems may test the validity of key assumptions about the background context made at the time they are established, but not re-test their validity until the context has changed to the point where the policies are already failing. Episodes of crisis of a more or less profound nature reflect the existence of these policy gaps. They often lead to short-term political responses, the succession of which can progressively increase the policy gaps (Mesnil 2008).

Development of major new environment-related policies commonly takes time (Mee *et al.* 2007) and requires input from expert advisors in social, economic, and ecological sciences and one or more cycles of public consultation and adaptation of options and preferences. The science information needed for action on the aspects of an issue that emerged earliest may be ready well in advance of the complete support needed for a major policy change. If the expert advisors are astute and the consultation process broadly inclusive, inter-related aspects may emerge for which quantitative science advice is not expected to be available for some years. Consequently, a major policy innovation is likely to address the potential as well as the demonstrated aspects of a complex problem, challenging the capacity of science, to assist collective choice processes relevant to the EA. Because the support for some aspects of new policies may be incomplete, the policy as a whole may be stalled. Moreover, explicit short-term social and economic policy goals will often have more complete and convincing supporting evidence than the longer term considerations. Science support is therefore necessary to address the potential longer-term consequences of policy choices, taking into account greater complexity (more linkages and more feedbacks), longer response times, and more uncertainty.

Hence, the mismatch in scope and timing of changes in policy and changes in scientific information can be an impediment to progress from two directions. In the early stages of emergence of a major new policy issue, policy-makers are slow to change because the governance processes take time, and the science case is incomplete and easily challenged. Once policy makes a major change, science may become the impediment because it is unprepared to advise on how to implement important but complex aspects of the new policy. This inability to advise on implementation is often more serious for the long-term environmental costs and benefits than the short-term social and economic aspects of a policy, creating a bias towards actions that effectively address the latter while potentially increasing risk to the former.

4.1.4 Lack of overarching objectives

Explicit policy and management objectives have long been a cornerstone of the Ecosystem Approach and Integrated Management (NSC 2002; FAO 2003). Sustainable use requires such objectives for the ecological, social, and economic basis of a decision. One of the consequences of the historical sectoral approach to policy and management was that specific objectives were established within each sector. Failure to set objectives on all three dimensions and integrate decisions across the multiple objectives, contributed to failures to achieve any of the objectives in the medium or longer-term (ICES 1999, 2007).

Adopting an EA makes a given sector accountable not just for ecological objectives with regard to the components of the ecosystem that it uses directly, but all the components of the ecosystem affected directly or indirectly by its activities. For example, fisheries need to achieve not only objectives for status and yield for target species, but also for status of habitats and bycatch species impacted by the fishery.

The EA adds this increased complexity of objective-setting without providing any special new strategy for identifying the joint set of ecological, social, and economic objectives to be pursued. This in itself can be an impediment to progress on implementation of an EA.

Making policy and management integrated across sectors adds a further level of difficulty to setting objectives.

Figure 4.2. Prawn trawl bycatch makes up between 2 and 10 times the weight of the retained catch

Within Integrated Management, sectoral objectives cannot be established independently of objectives established for other sectors. Thus Integrated Management creates the need for a hierarchical development of policy and management objectives. Overarching societal objectives are necessary from a process superimposed above the sectoral objective-setting processes, and operating in advance of them. This process will be even more complex than the sectoral processes, as all the issues relevant to each sectoral objective-setting process are potentially relevant to this higher-level process.

Ecosystem Approach and Integrated Management simplify none of the challenges of objective setting, either with regard to the knowledge needed or the processes that are applied. Rather, the challenges may be harder as the integrated objective-setting process requires:

- Substantially more knowledge of sector impacts and sector interactions on ecological, social and economic dimensions;
- Engagement of a much wider range of stakeholders than for single-sector processes;
- Responsibility for allocation of "rights to impact" ecosystems components, such that the combined impact of all the sectors does not place the over-arching ecological objectives at risk; and
- Sufficient credibility and legitimacy to constrain the flexibility in setting and pursuing economic, social, and ecological objectives at the sectoral level.

Individually, each of these challenges is more complex than dealing with single-sector planning and management. Collectively they are a significant impediment to progress of Ecosystem Approach and Integrated Management, and place major demands on science for enhanced and adapted support.

4.1.5 Difficulties to agree on the distributional implications of Ecosystem Approach and Integrated Management policies

Both the Ecosystem Approach and Integrated Management involve redefining rights and responsibilities with respect to the impacts of human activities on ecosystems, and the interactions between uses. Consensus must develop on how to allocate the impacts of different industries relative to the achievement of over-arching policy objectives. If several different industry sectors create pressures that impede achievement of a common over-arching objective, the first thing that policy and management must integrate is how much impact each sector is allowed to have without the aggregate impact placing the achievement of the overarching objective at risk. The allocation of access to a shared resource (e.g. in fisheries) is one of the most challenging aspects of policy and management within single sectors. There is no reason to expect the allocation of impacts among different sectors to be any easier, and the processes necessary to address this will be complex. Opposition often arises from the distributional implications of such processes, in contexts where rights and responsibilities are still evolving and unclear. This opposition may lead decision-makers to reject the results of scientific studies on non-scientific grounds because the implications would necessitate the confrontation of issues that the processes were not prepared to handle. There could even be a lack of support for studies which would make tradeoffs more explicit if the governance system felt that it would lose flexibility to accommodate difficult parties.

4.1.6 Appeal and conflict resolution

Agents subject to government decisions want to have very clear rules and appeal processes. Once rules have been established in a given sector, both agencies and their clients are reluctant to see any changes that may be perceived as weakening their opportunities or giving greater power to other groups. The appeal and conflict resolution process, therefore, often promotes an entrenching of sectoral interests.

When appeal and conflict resolution processes are imbedded in legal frameworks, the governance agencies will wish to minimise the opportunities for agents to register an appeal to an action or a policy. Thus they become tied up in ensuring processes operate in the required ways, rather that ensuring that their outcomes are sustainable. That risk aversion and adherence to specified processes can inhibit innovations to broaden the ecosystem context of decisions or to integrate decision-making with other sectors. The existence of appeal and conflict resolution procedures also may empower diverse stakeholder groups with the ability to stall and delay actions by governments and tie up experts in responding to the demands of the appeal on conflict resolution process rather than implementing improvements to policy and management.

4.1.7 Research – sharing of power and scale

Research should increase knowledge and, therefore, be a constructive factor in the implementation of Ecosystem Approach and Integrated Management. However the benefits of research are only realised fully if scientific information is recognized as legitimate and credible by civil society and the private sector, and the scale of feasible scientific research can be matched to the scale of management and policy decision-making.

Knowledge produced by scientific experts and knowledge gained through "real life" experience can be compatible but is often quite different. This can be a strength when the EA leads to a pooling of knowledge gained by both scientific research and extracting livelihoods or cultural benefits from the sea (Gray 2006). This potential is not always realised, however, if any one group denies the legitimacy of the knowledge provided by another group (Cash *et al.* 2003; Eckley 2001; van de Kerkhof and Wieczorek 2005). Until recently, the formal scientific advisory processes (provided by organisations such as ICES), have focused almost exclusively on scientific knowledge produced by experts in government or academic laboratories. This segregation of scientific expert knowledge from other types of knowledge has contributed to strong opposition to at least some science advice and delayed policy and management actions. For implementation of the Ecosystem Approach and Integrated Management to proceed smoothly, it will be necessary to ensure advisory processes which are guided by advice from the full range of actors and knowledge sources that are relevant.

For practical reasons much scientific research is conducted on a scale that is relatively small in either or both space and time (see 2.1). Policy and management commonly have to be developed on much larger spatial scales, which may be continental or global. Likewise, policies must, where possible, place current conditions in an historical context by making comparisons with past conclusions. Questions frequently arise about whether the scientific information is truly representative of the whole area that will be subjected to policy and management actions, and if the conditions during the period of research are representative of the conditions against which the policies and management actions will be applied. Little beyond general, common sense guidance exists on the conditions under which research outputs and findings can be generalised or extrapolated to unstudied places and times.

With respect to either inclusiveness or scale, arguments about the relevance of scientific information to a policy issue can drag out inconclusively for long periods. While the debate proceeds, the science can divide opinion and impede action, rather than provide a common foundation for policy and management (Rice 2006). Thus the science process itself can impede progress on the implementation of an Ecosystem Approach and Integrated Management.

Summary Box 13 – Review of institutional impediments to the implementation of the EAM of BORs

45. Partitioning of jurisdictional authorities may impede addressing "broad and integrated" ecosystem issues and adapting/integrating policies and management actions.
46. Tight agency mandates and resources (protection of funding and reluctance to change tools they use); agencies with competencies at different scales.
47. Complex EU wide negotiation to multipartite consensus.
48. Agency accountability can consume science capacity and add little value to the decision process.
49. Science/policy mismatches in timing, scope and scale.
50. Setting EA objectives without a targeted overarching strategy.
51. Difficulties in agreeing on the distributional implications of Ecosystem Approach and Integrated Management policies.
52. Appeal and conflict resolution processes promote an entrenching of sectoral interests.
53. Research: sharing of power (segregation of scientific expertise and knowledge) and scale.

4.2 Reluctance to change tools

4.2.1 The challenge

Section 4.1 describes a number of institutional impediments to progress on an Ecosystem Approach to Integrated Management. A common way that such institutional impediments are frequently expressed is through the reluctance of agencies to change the tools they use. Sometimes this reluctance may be rooted in legal requirements to protect confidentiality of personal or commercially valuable information. However, even without a legislative basis for this reluctance, operational procedures and standards may have been the product of extensive and difficult consultations and negotiations. Changes may reopen a sensitive agreement with no assurance that a new compromise is possible, or industries may argue that they have designed processes to comply with the agreed standards, and changes would be burdensome. Examples of such agreements are the sharing agreements of fisheries quotas among countries, and the procedures and standards for indicators under the Water Framework Directive (see Annex 2).

Information Box 7 – Sharing agreement on fisheries quotas

A specific example of these problems is found in the implementation of gear modifications to improve the selectivity of fishing. Many restrictions have been introduced through legislation, and some devices are being used on a voluntary basis. Quite often, the fishing industry has been sceptical about the effectiveness of these restrictions, because the science behind the initiatives is perceived as theoretical and out of touch with the realities of commercial fishing (Suuronen and Sarda 2007). As an example, the mesh size increase, legislated in the late 1980s, was gradually negated in the UK North Sea fishery by cod-end design features that reduced the selectivity (Ferro and Graham 2000). Moreover, discarding in the North Sea is recognized as having negative ecological and economic impacts. However, industry resisted implementation of discard reduction measures, giving high importance to the expected immediate losses and expressing low confidence in projected medium and long-term gains (Catchpole *et al.* 2005).

Managers and industries may prefer tools that are flawed in various ways, but ones where the flaws are known and methods to accommodate them available. More innovative approaches, which have the potential to overcome flaws in the current approaches, can be revised because of fears that they contain new flaws, which are harder to detect and quantify.

4.2.2 How can research help overcome opposition to new tools?

Whether the adherence to flawed tools is a result of legal impediments, concerns over social or economic transitions, fear of the unknown or simple inertia, several types of research can help to facilitate the implementation of new tools.

4.2.2.1 Fuller quantification of the effects of adjustments of standards and benchmarks

When the changes in tools are adjustments to existing standards, the adjustments are often based on new scientific results, and the expected consequences are known. For example, the proposal to change the tolerance for tributyltin (TBT) as a threat to human and ecosystem health was based on further study of the effects of the contaminant being regulated (Birchenough *et al.* 2002). The increase in mesh size proposed for the North Sea roundfish fisheries were intended reduced wastage due to discarding of small fish and increase yield in the medium term (e.g. ICES 1988 ACFM advice). Ongoing research on DNA barcoding and other genomic tools also is expected to facilitate better tracing of seafood from source to market (Baker 2008).

Opposition to such adjustments can be rooted in a lack of belief that the problem to be corrected is serious, or because the social and economic transition costs are considered too high. Both of these classes of concerns are open to direct research. For example, if a mesh change were necessary to reduce discarding, scientific advice could document not just the amount by which the capture of small fish would be reduced, but the contribution those fish would make to future status of the stock and future yields. Moreover the expected economic returns to the fishery, given the catch composition expected with the new gear, and the market value of that catch, would inform the harvesters of short-term and medium-term economic consequences of the gear change.

Another cause for resistance to change may be that this change brings about a shift in the distribution of costs and benefits associated to the use of marine ecosystem goods and services. It is often not sufficient that the overall benefits of a change exceed overall costs for this change to be adopted. A key question here is whether systems exist which allow compensation of those who will lose, or gain less, and who may, therefore, be expected to oppose change. In terms of research, this implies that policy assessments, including ecological-economic analyses of alternative management scenarios, should include a detailed evaluation of the distributional impacts of these scenarios, and possible compensation measures.

In these cases, advisory practice does not consistently consider the full range of analyses relevant to quantifying the social, economic, and ecological consequences of the regulatory changes, even though the methods and data to do so are available. Changes to decision-making (2.3) and assessment and advice (2.4) could address this problem.

4.2.2.2 Research to better understand the performance of various tools

Sometimes opposition to changing management strategies and tools is rooted in a lack of evidence that current practices are actually failing, or that new strategies or tools would actually perform any better. This poses more demanding challenges to researchers to provide the missing evidence. However, research methods for assessing the performance of management strategies and tools have been developed and are increasingly being applied.

Information Box 8 – The Management Strategy Evaluations (MSEs)

In fisheries, Management Strategy Evaluations (MSEs) are now common in many jurisdictions (Punt *et al.* 2001; Smith *et al.* 1999). MSEs use computer simulations of both the dynamics of the ecosystem and the fishery to explore how robust different management options are to uncertainties about ecosystem processes, resource status, and fleet operations, including compliance with the regulations. It is becoming possible to explore scenarios in interactive workshop settings with various interest groups, including policy makers, managers, and stakeholders. In such cases not only can the understanding of the likely performance of new management tools be increased, but the various participants in governance may develop greater confidence in the science advice. Such approaches are currently being extended to other areas of environmental and resource policy, such as water management.

Significant scientific resources need to be invested when these simulation-based robustness tests of management options are implemented. When historic series of the values of indicators used to support decision-making are available, however, less demanding approaches for retrospective testing of performance of various decision rules can be applied to explore the consequences of management options reflecting the different risk tolerances that various groups (Rice and Rochet 2005; Piet and Rice 2006; Rochet and Rice 2005, 2009). The application of these decision-support tools requires commitment of substantial time and effort from experts in natural, social, and economic sciences working in integrated teams, and the availability of appropriate information from a number of disciplines. Moreover, the process of developing such comprehensive models for evaluating management strategies often identifies the need for new monitoring data or a better understanding of additional crucial ecosystem processes or industry operations.

The complexity of issues to tackle in the EA may in some cases be too high for the latter decision-support approaches to be feasible, as too any uncertainties may exist to successfully build anticipations of the impacts of management scenarios. In such contexts, a third approach in developing decision-support tools involves the application of the adaptive management approach (Walters 1986). The principle of this approach is to develop management scenarios and assessment programmes which are closely linked. This will allow management decisions to serve as real-life experiments from which it is possible to learn about the dynamic response of social-ecological systems. For the adaptive management approach to succeed, close partnerships between administrations, the sectors affected by the policy and the scientists are necessary. Furthermore, a new category of research projects is necessary, which could be supported by both science and policy funding schemes. An example of such applications could be the design and implementation of Marine Protected Areas (MPAs) as experiments in which certain uses of Biotic Ocean Resources (BORs) are restricted while others are encouraged, and where monitoring schemes are designed to assess the ecological and economic responses of the systems impacted.

4.2.2.3 Research and actions to support new approaches to more Integrated Management

Uptake of Integrated Management requires adapting approaches to sectoral management in some fundamental ways, including setting of explicit environmental, social, and economic objectives and fuller quantification of the impacts of each sector on the ecosystem. Both of

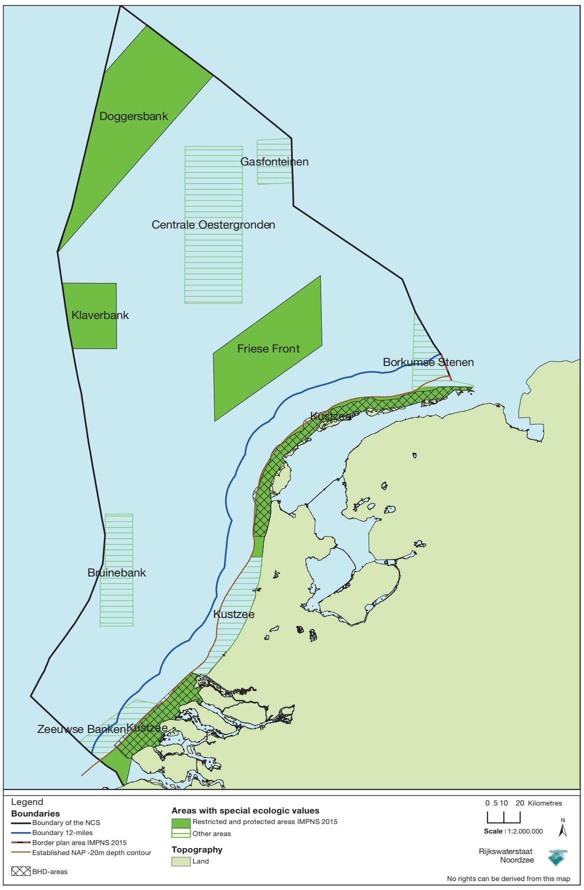

Figure 4.3. North Sea Areas with special ecological value

these changes are necessary so the goals of Integrated Management are clear and accepted by all participants in governance and the combined ecosystem impacts of all the activities being managed in an integrated manner are sustainable (see 2.3). It will also require MSP, and managing where an activity occurs as well as how much of the activity may be permitted[34].

Reasons for resistance to clear specification of objectives, full quantification of impacts of an industry, implementation of new management approaches such as spatial management have already been discussed (2.3, 2.4, 2.5). They can include a lack of appropriate governance structures, a lack of information, and a lack of belief that problems are serious, or inability to develop options that are considered equitable to all participants, Again, research can address all of the impediments to implementing ecosystem management. Social science research on governance can help clarify objectives of stakeholders and reconcile objectives across groups with diverse interests (2.2, 2.3, and Chapter 3). Natural and social science in Chapter 2 can expand the knowledge base for all aspects of Integrated Management, including understanding of how space-based tools work in practice. Also, to facilitate more Integrated Management expanded research needs to be accompanied by expanded and Integrated Assessments (IAs). They tie together the knowledge gained through all the various science activities and apply that knowledge directly to the management questions of greatest relevance for integrating planning and management of impacts across sectors.

A good example is the decade-long but unresolved debate over the role of MPAs in fisheries management, despite growing evidence that when properly designed and implemented, MPAs and exclusion zones can be an effective conservation tools (Garcia-Charton *et al.* 2008; Charles and Wilson 2009). The fact that many MPAs have not been designed and implemented well allows advocates of many perspectives to selectively choose cases that fit their pre-selected point of view. Such debates can only be resolved by well designed research combining natural and social sciences and effective monitoring of ecosystems and ecosystem uses. In considering the diverse impediments to Integrated Management, it is clear that not only is research needed, but that research partnerships are needed. These partnerships must include both natural and social science research experts and the stakeholders affected by the more Integrated Management. Strategic assessments provide a particularly promising approach for both developing the partnerships and ensuring that the results of their efforts are used effectively.

34. See examples: www.searchmesh.net; www.imr.no/english/activities/mareano; www.balance-eu.org

4.2.2.4 Improve communication with stakeholders

Regardless of the extent of scientific and technical information underlying a policy or management decision, there may be opposition to that decision if the information is not widely available to stakeholders, and properly understood by them (see 2.5). However, not only must effective tools be identified, the governance processes need to be designed so that those tools can be applied appropriately. Many of the partnerships described in 4.2.2.3 can facilitate the use of good communication tools, if governance processes provide the time and resources to accommodate them.

Good communications tools need to be accompanied by a good communications plan, ensuring timely delivery and regular updates of clear and consistent messages to all the necessary audiences (2.5). Good knowledge, poorly communicated, can be an impediment to changing management practices. Good communication tools are essential to ensure that all participants in the governance process at least start with the same factual information in their deliberations, even if their different goals and risk tolerances mean that they may use the information in different ways.

Summary Box 14 – Reluctance to change tools

54. Policy-makers, managers, and stakeholders can all be reluctant to change the tools used in management, even when better ones have become available. Reasons for the reluctance include:
    - Legal constraints on changing measures;
    - Difficulties in negotiating new standards and benchmarks;
    - Actual knowledge gaps about the consequences of changing tools;
    - Fear of trading known problems for unknown ones.
55. Better quantification of the consequences of a change can help overcome that reluctance by allowing:
    - More effective interaction between science advisors and policy makers;
    - Better integration of research between different scientific disciplines, particularly the social and natural sciences;
    - Collection of a broader range of data on the performance of the tools.
56. Performance evaluations can help overcome that reluctance by providing a better understanding of how effective a new tool must be. Such evaluations require:
    - A commitment of expert time and effort, often using extensive simulations, retrospective

performance evaluations and adaptive management;
– New monitoring data and understanding of additional crucial ecosystem processes or industry operations;
– Greater collaboration between natural scientists and social scientists and greater engagement of experts with stakeholders and managers.

57. Integrated Management will require more effective spatial management tools and support from fully Integrated Assessments (IAs). Good knowledge must be supported by good and timely communication tools so that all participants in the governance process start with the same factual information in their deliberations.

Figure 4.4. Stock assessment in the Celtic Sea

4.3 Lack of clarity of research priorities

4.3.1 Doing the right science and doing the science right

Relevance and quality are two main criteria used when evaluating research proposals. They are sometimes seen in opposition to each other, in the sense that dealing with known opportunities or problems that are seen as highly relevant today may draw attention away questions that may provide new opportunities for tomorrow. This continuum from applied to basic or pure science, and the competition between applied institutes (e.g. of national agencies) and academic universities is an old and lasting phenomenon. Such competition is unhelpful as there is a need for both the problem-directed and freely exploratory research types and for broad collaboration across scientific disciplines. Human and economic activities in the marine environment have in general terms been unsustainable (MEA 2005). There is an urgency to the present situation, and current trends should be reversed as rapidly as possible. This calls for prioritisation of research that helps us to achieve sustainability.

Studying and understanding complex ecosystems requires cutting-edge science and can contribute to wise management and the application of the EA. Therefore, studies at this level of organization of nature see no clear distinction between basic and applied research. The best basic research that provides insight into the structure and function of marine ecosystems is at the same time the best basis for expressing and examining their state and considering measures to restrain or mitigate the effects of adverse impacts.

Marine ecosystems are complex systems with a diversity of spatial habitats, organisms and physical and ecological dynamics and variability (Section 2.1). Humans are part of the natural ecosystems and form complex systems with their own diversity, dynamics and variability (Section 2.2). To improve sustainability we must improve our understanding and management of the interactions between complex and overlapping or intertwined human systems and marine ecosystems. This requires an integrated and systems approach to science with much more coordinated research involving many scientific disciplines in broad collaborative efforts.

While marine ecosystems are complex in their many details and dynamics, they have broad features and principles underlying their structure and functioning. A systems approach to studying and managing them begins by identifying these broad features and principles, and adding details as needed. This provides a logical sequence to research tasks. Initially, knowledge of the broad features and principles of ecosystems will provide some basis for supporting policy and management towards greater sustainability. We also have a widely applicable structure into which many of the details of specific systems will fit.

Each ecosystem has its specific characteristics in terms of topography, hydrography, habitats and communities. However, they all share some common principles underlying how habitats are used, how food webs are structured and function, etc. To understand the dynamics of any system, these features should be studied in the context of that system. Multitudes of disparate studies of different ecological components and processes carried out in different places and different scales need to be organized around such principles before knowledge gained from these individual studies may to some extent be extrapolated to other ecosystems to help us understand how they function.

Beyond the study of marine ecosystems are structure and function, and how human activities interact with ecosystems, research is needed on those complex human systems with their own diversity, dynamics and variability. Few of the many failures to achieve sustainability of marine ecosystems reported in the Millennium Ecosystem Assessment (2005) were due to policies and management that were fundamentally striving to achieve wrong ecological goals. Rather, the failures commonly came from an inability to match policies and management measures to the actual social and economic contexts in which the activities were occurring. It is therefore necessary to understand better the social and economic contexts for human uses of marine ecosystems and social science research of this nature is increasing throughout Europe. The missing priority is to integrate that knowledge with our growing knowledge of the dynamics of these ecosystems. We cannot expect research to guide policy and management to truly sustainable outcomes until the research is conducted by effective teams of natural, social, and economic researchers working together. Therefore, not only do fish population biologists, oceanographers and ecosystem modellers need to work together, but all of them need also to work with economists, sociologists, and anthropologists. Only then will we have the integrated knowledge, and Integrated Assessments (IAs) needed to support policies and management measures that can promote real sustainable use.

4.3.2 Identification of gaps in knowledge

As Integrated Assessments (IAs) are completed by competent experts (Section 2.4), it becomes clear what knowledge is available and where there are gaps in knowledge. Thus the Integrated Assessments (IAs) offer a mechanism for identifying and prioritising research tasks. This mechanism should be systematically utilized for all the European seas, including their coastal areas. These research priorities would initially be at the scale of the assessments, and should form the basis for ecosystem-specific research agendas at those scales.

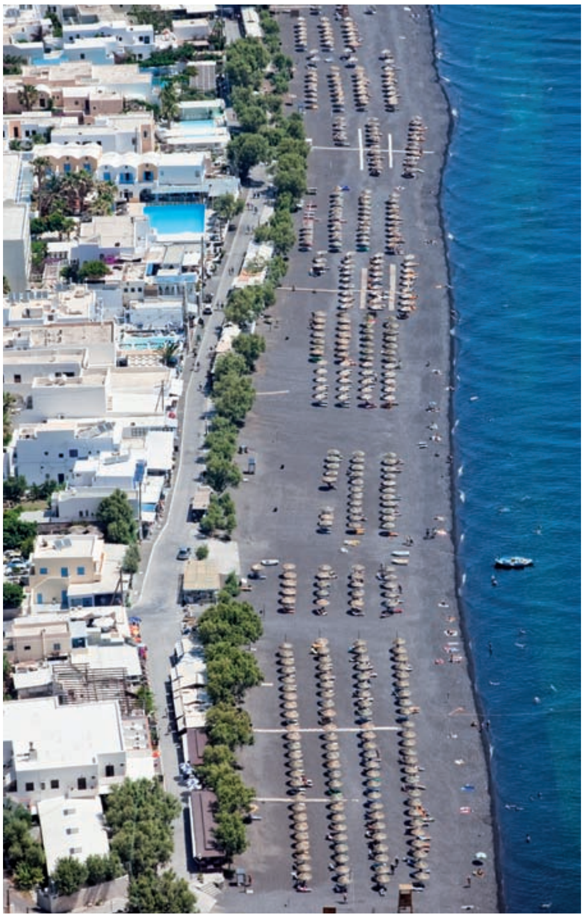

Figure 4.5. Tourism infrastructure on Santorini Island, Greece. Managing human activities on the coast is a major challenge

However, in preparing these research agendas, both larger and finer scales should be considered. Research priorities occurring across many assessments emerge as candidates for truly coordinated research efforts at the EU scale.

At the same time, the need for knowledge at finer spatial scale in the coastal zone related to Integrated Coastal Zone Management (ICZM) should also be incorporated. By linking these research agendas to the Integrated Assessments (IAs) of the Marine Strategic Framework Directive (MSFD) and to assessments done as part of ICZM, it may be possible to achieve the dual objectives of environmental sustainability and economic development (figure 4.6).

Before the ecosystem-specific research agendas are finalised as a basis for research prioritisation, there could be regional research conferences with broad participation of scientists from government agencies and univer-

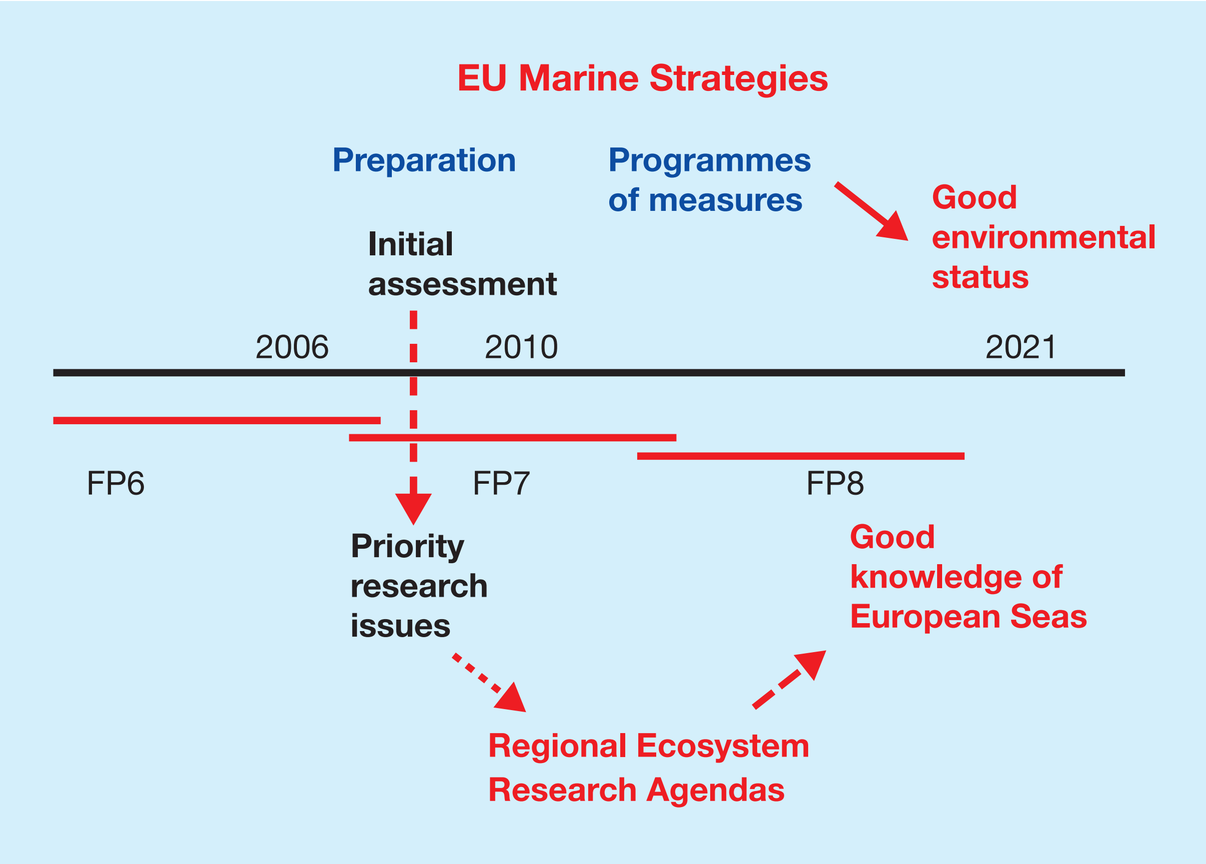

Figure 4.6. Relationship between implementation of the proposed EU Marine Strategic Framework Directive and the development of regional ecosystem research agendas. Building on existing assessments and the initial assessments which are to be carried out for each of the regions/subregions of the European seas, priority research issues should be identified. These should be incorporated into research agendas for each ecosystem (= ecosystem-specific research agendas), implemented with support from FP7 and FP8. The aim should be to do better assessments and to achieve good knowledge of the European seas in parallel with achieving Good Environmental Status.

sities, managers at EU, national and subnational levels, and other relevant stakeholders. The aim would be to agree and set research priorities. A similar workshop at the EU-wide scale could serve a similar function for the research priorities occurring in several of the regional assessments.

5. Workplan that could lead to an improved science base for the implementation of an Ecosystem Approach to Management of Biotic Ocean Resources

Section 2 laid out the key research challenges that must be met, if the natural and social science support needed by the Marine Strategic Framework Directive (MSFD), and more generally by taking an Ecosystem Approach (EA) to Integrated Management, is to be available. The research needs spread through many science disciplines – physics, chemistry, biology, mathematics and statistics, political science, sociology, anthropology, economics, communications, and more. There are many calls for new work within traditional disciplines, but greater stress is placed on new teams of researchers, bringing diverse sciences together for integrated approaches to doing the research – not just managing the human activities. Section 3 followed with operational needs for new or expanded monitoring, assessments, and similar activities that have to become on-going science activities if the MSFD is to receive the ongoing science support needed for implementation.

Such an extensive list of research needs and ongoing commitments can overwhelm science planners and funders, unless it is organized and prioritized enough for major themes to emerge.

Figure 5.1. Piecing it together

This final section sketches out a general workplan for attacking the challenges in Chapters 2 "Science dimensions" and 3 "Implementation of the MSFD", taking due note of the potential impediments in Chapter 4. For efficiency's sake we do not provide a rationale for each step in the workplan. These rationales have already been developed in the preceding material, to which we point as appropriate. We simply bring coherence to the rich array of ideas and concerns that have emerged through those Chapters. **All the activities are of high priority. However some are particularly urgent if progress is to be made on all the others, and on rapid implementation of the MSFD. These are in BLUE with an asterisk***.

5.1 Workplan for research related to the status and uses of Biotic Ocean Resources

1. To provide the knowledge on resources necessary for managing extractive uses of marine resources (particularly living ones) and the impacts of industry sectors on those resources in ways that ensure Good Environmental Status (GES), and for planning for sustainability of uses in a changing and uncertain future, it is necessary to:
- Evaluate the role of lower trophic levels (nutrients, phytoplankton, and zooplankton);
- Develop strategies and tools for partitioning natural variability and human-induced variability (e.g. eutrophication and pollution; climate change)***;**
- Improve quantitative resource assessment techniques;
- Improve methods for data-poor situations (e.g. Bayesian statistics; Bayesian networks; Expert Systems).

2. To provide better tools for understanding and quantifying the important interactions in these ecological systems, the impacts of human activities on them, and their variation on many time and space scales in assessments, planning, and management, there is a need to:
- Improve modelling and assessment methods for situations of uncertainty and/or data limitation both for biological and economic systems;
- Test and further develop trophodynamic and web modelling;
- Put in place a framework for effectively dealing with reducible uncertainty and, on the other hand, coping with irreducible uncertainty*;
- Develop "rapid assessment" integrated tools of cumulative impact and new analytical frameworks;
- Develop/improve methodologies and provide guidance for integrated assessments, which partition the

effects of the diverse natural and human-induced sources of variability*;
- Expand research on stochastic modelling techniques to model coupled socio-ecological systems;
- Develop tools for integrated policy evaluation taking into account (i) multiple objectives, (ii) collective choice dimension of management, (iii) dynamics/inertia, (iv) distributional issues and (v) uncertainty/risk analysis;
- Develop/improve methodologies for ecological risk assessments;
- Develop/improve methodologies to carry out conflict analysis;
- Develop/improve models for policy/decision support.

3. To have improved ability to plan for levels of human activities and ocean industries which deliver economic and social objectives sustainably, it is necessary to:
- Prepare an inventory of economic activities;
- Evaluate the economic potential of Biotic Ocean Resources (BORs);
- Conduct socio-economic studies of multiple ocean uses and their interactions;
- Evaluate, and to the extent possible quantify, current fisheries exploitation capacity, and current capacities of other ocean industries;
- Improve assessments of the cost of management (e.g. some management strategies based on co-management or self-management may be relatively cheap);
- Improve the scientific basis for cost-benefit analysis, across social, economic, and ecological dimensions of sustainability, including non-monetary values*.

4. To have improved ability to connect human activities to the resources they require or impact, and to plan for levels of those activities which deliver both prosperity and GES, there is a need to:
- Improve the knowledge of how ecological support systems (food webs, physical-biological coupling, etc.) are linked to the provision of goods and services actually used as BORs;
- Map and monitor threats to sustainability of BORs in European waters*;
- Identify and quantify direct and indirect impacts/threats to BORs and higher trophic level organisms (such as mammals, seabirds, etc.)*;
- Maintain inventories of significant impacts, such as pollution, eutrophication, habitat modification, invasive species, fisheries overexploitation, climate change, etc. on appropriate scales;
- Support empirical and model-based research on drivers of change in human uses at various scales (empirical and model-based);
- Apply concepts and analytical tools of systems analysis to better understand the coupled dynamics of socio-ecological systems (both empirical and modelling approaches and research tools and approaches for adaptive management).

5.2 Workplan for research and science activities related to the management of human activities and conservation of Biotic Ocean Resources

1. To have a better knowledge of the full range of impacts and risks associated with specific human activities, there is a need to conduct focused research on:
- Detrimental impacts of various fishing gears and practices;
- Adapt land-use and watershed planning tools for ocean management;
- Development of expert systems for the evaluation of risks and impacts in information-limited or capacity-limited situations;
- Assessments of consequences of ecosystem changes for economies/societies, and analysis of adaptation/

Figure 5.2. Offshore production platform with jackup drilling rig in background

mitigation possibilities, addressing marine goods and services identification, economic valuation, assessment of dependence of economies/societies to marine ecological goods and services, assessment of adaptive capacity.

2. To avoid or mitigate undesirable impacts of ocean industries where there is unacceptable risk, it is of importance to:
- Assess the ecological, social and economic consequences of Marine Protected Areas (MPAs);
- Develop activity specific mitigation strategies to reverse negative (or undesired) trends and minimize impacts*;
- Develop low-impact techniques for the extraction of BORs;
- Develop improved enforcement/compliance technologies (e.g. VMS);
- Establish social, biological and economic GOIS indicators (Goals, Objectives, Indices and threSholds) to ensure maintenance of ecosystem integrity while providing goods and services*;
- Develop and operate institutions for conflict analysis and conflict resolution;
- Evaluate the advantages and limitations of alternative approaches to ecosystem conservation policies, including the use of economic incentives.

3. To improve the ability of the complex EU governance structure to function effectively at regional marine ecosystem scales, there is a need for:
- A thorough review of what opportunities the EU legal frameworks provide to create and empower bodies with decision-making and regulatory (including enforcement) authority at the regional scales that are central to implementation of the MSFD.

5.3 Workplan for the operational use of tools and provision of ongoing support for the implementation of the Marine Strategy Framework Directive or the Ecosystem Approach generally

1. Take measures to improve data management and inter-operability of data sources and analytical methods, including:
- Update/improve resource inventories and statistics*;
- Maintain and analyse databases on economic activity (value/jobs and footprint (nature and extent of impact on the ecosystem)*;
- Initiate new data collection protocols and stabilize monitoring programs for key socio-economic variables;
- Inventory/consolidate/strengthen existing data collection protocols on human uses of marine ecosystems;
- Facilitate/Improve access to databases, at least to scientists;
- Improve quality and relevance of data;
- Create settings that promote methodological innovation/transfer: survey methods, statistical approaches, meta-analysis, natural experiments, modelling and simulation.

2. Require and provide science support for:
- Industrial operations risk assessment;
- MSP implementation strategies;
- Strategic (regional) environmental assessments;
- Linking the above assessments to socio-economic studies.

3. Develop and apply adaptive management capacities*.

4. Assess current status and trends in exploitation of BORs. Establish target and limit reference points where appropriate.

5. Establish monitoring and evaluation programmes for exploited resources, where they do not exist.

6. Establish regular assessments of marine environmental status including oceanography, where they do not exist.

7. Establish social, biological and economic GOIS indicators (Goals, Objectives, Indices and threSholds) to ensure maintenance of ecosystem integrity while providing goods and services*.

8. Develop a Strategy for translating these conceptual objectives into operational objectives. Operational objectives should be ranked and defined against a time frame*.

9. Improve planning and management practices and institutions by including social sciences component in regional ecosystem assessments*.

5.4 Main science impediments

The main science impediments to progress on this workplan require actions at national and institutional levels to:
- Expand funding for people, tools, and platforms, and undertake targeted capacity development.
- Support for training of marine scientists in social sciences including marine governance and the role of knowledge in policy, and of social scientists with expertise in marine research*.
- Support the development of a European research community in social sciences applied to marine eco-

systems uses and their regulation and its integration in the international community on human dimensions of global change.

- Strengthen the interaction between social and natural science communities (e.g. oceanography, living resources)*.
- Provide access to critical non-public domain datasets. Such access is critical in regular monitoring and useful to gain new insights.
- Codify and where necessary improve data sharing policies and protocols.
- Address the professional reward structure both in government and academic agencies so experts are rewarded and motivated to work on applications of knowledge, not just acquisition of knowledge.
- Increase research and capacity for modelling and assessment in situations of uncertainty and/or data limitation both for biological and economic systems.

These changes will not happen unless a **Strategy is developed for translating these conceptual goals for better research and science in support of the MSFD into operational objectives.** These operational objectives should be ranked and defined against the knowledge gaps highlighted through this report, set within specified timelines, and subjected to periodic review and reporting on progress.

WG SEAMBOR proposed actions/recommendations to ensure progress on EAM and MSFD implementation

The SEAMBOR Working Group finally recommends to the European Commission and National funding agencies a range of urgent actions which will be necessary to ensure progress on important EAM initiatives and rapid implementation of the MSFD:

- Develop strategies and tools for partitioning natural variability and human-induced variability (e.g. eutrophication and pollution; climate change);
- Put in place a framework for effectively dealing with reducible uncertainty and, on the other hand, coping with irreducible uncertainty;
- Develop/improve methodologies and provide guidance for integrated assessments, which partition the effects of the diverse natural and human-induced sources of variability;
- Improve the scientific basis for cost-benefit analysis, across social, economic, and ecological dimensions of sustainability, including non-monetary values;
- Map and monitor threats to sustainability of BORs in European waters;
- Identify and quantify direct and indirect impacts/ threats to BORs and higher trophic level organisms (such as mammals, seabirds, etc.);
- Develop activity specific mitigation strategies to reverse negative (or undesired) trends and minimize impacts;
- Establish social, biological and economic GOIS indicators (Goals, Objectives, Indices and thresholds) to ensure maintenance of ecosystem integrity while providing goods and services;
- Update/improve resource inventories and statistics;
- Maintain and analyse databases on economic activity (value/jobs and footprint (nature and extent of impact on the ecosystem));
- Develop and apply adaptive management capacities;
- Develop a Strategy for translating these conceptual objectives into operational objectives. Operational objectives should be ranked and defined against a time frame;
- Improve planning and management practices and institutions by including social sciences component in regional ecosystem assessments;
- Support the training of marine scientists in social sciences including marine governance and the role of knowledge in policy, and of social scientists with expertise in marine research (such as mammals, seabirds, etc.); and
- Strenghten the interaction between social and natural science communities (e.g. oceanography, living resources).

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Annex 1. The Marine Strategy Framework Directive: qualitative descriptors for determining Good Environmental Status [Referred to in Articles 3(5), 9(1), 9(3) and 24)]

(1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.

(2) Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.

(3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.

(4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.

(5) Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.

(6) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

(7) Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.

(8) Concentrations of contaminants are at levels not giving rise to pollution effects.

(9) Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.

(10) Properties and quantities of marine litter do not cause harm to the coastal and marine environment.

(11) Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

To determine the characteristics of GES in a marine region or subregion as provided for in Article 9(1), Member States shall consider each of the qualitative descriptors listed in this Annex in order to identify those descriptors which are to be used to determine GES for that marine region or subregion. When a Member State considers that it is not appropriate to use one or more of those descriptors, it shall provide the Commission with a justification in the framework of the notification made pursuant to Article 9(2).

Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive).

Annex 2. Case histories: governance, challenges and research needs

This Annex reviews four of the major pieces of EU legislation that affect conservation and sustainable use of European marine ecosystems. They have been in force for different amounts of time (from the early 1990s to very recent), and address difference ecosystem components and uses (exploitable resources, water quality, habitats, and integrated approaches to all). Research needs that have emerged from experience with implementation of the longer-standing policies and directives are summarized with corresponding rationales. These are lessons which help shape the conclusions in this report on the research needs to support implementation of the Marine Strategy Framework Directive (MSFD), the most recent of the policies considered in the Annex.

2.1 Fisheries policy and management

The Common Fisheries Policy formed the foundation of managing fisheries in the EU through most of the past two decades. It was designed with the intention of striking practical balances on two different aspects of fisheries, one a balance between providing fullest possible harvesting opportunities and sustaining the exploited stocks, and the other equity among EU member States who had different histories of participating in fisheries in different parts of the EU waters. The former goal was to be achieved by setting quotas based on scientific advice usually from ICES and social and economic inputs from the Scientific Technical and Economics Committee for Fisheries (STECF) of EU Directorate General for Fisheries, (https://stecf.jrc.ec.europa.eu/) and the latter was to be achieved by applying carefully negotiated sharing percentages among States to the quotas. In practice, after months of work by ICES, STECF and DG Fish, the actual process of setting the annual quotas required agreement by Fisheries Ministers.

Such a process began with a complex governance structure – dynamics between science and technical advisory bodies and their administrative clients; dynamics between the EU bureaucracy and States, and dynamics among States with competing interests. The governance became more complex over the past couple of decades for several reasons. Some were biological, as status and productivities of various stocks altered in ways that made the carefully negotiated sharing formulae less and less satisfactory for either States or the objective of sustainable use of the stocks. Multispecies fisheries were the norm, and there was no balance among fleets that ensured the fully available yield was taken from the healthiest stocks without overfishing stocks already depressed. Other reasons were political, as the make-up of the EU changed, bringing new players to the table seeking equitable treatment, and different EU states pursued fleet management – particularly decommissioning of surplus capacity, at different rates. As a result States frequently agreed to quotas above the recommendations from science, in order to resolve political impasses, and where restrictive quotas were implemented, compliance by the industry was often poor. Despite multiple reviews and adaptations of the Common Fishery Policy, many European fisheries persisted in crises economically, socially, ecologically, or all three. These governance challenges became even more complex in the 2000s, as the Ecosystem Approach to fisheries management became accepted. Participatory governance, already being implemented to bring the fishing industry into the governance system to improve compliance, had to accommodate conservation interests as well. More countries have joined the EU, requiring amalgamation of previously independent fisheries agencies. The MSFD brings an overarching requirement to integrate fisheries management with management of other industry sectors in the sea. Fisheries managers are also being held accountable for a wider range of ecosystem effects of the fisheries they manage.

The EU is showing significant flexibility in governance, illustrated by the establishment of Regional Advisory Committees (RACs), and the creation of DG MARE to replace DG Fish, among other agencies. However, these changes are in early stages of implementation, and significant refinement is needed for them to function effectively. There is ample scope and an urgent need for research on how these new governance processes are working, in terms of outcomes (How should European fisheries change to become truly sustainable socially, economically, and ecologically? Are States and communities satisfied with their opportunities to participate in fisheries? Are wealth and secure employment being created?) and processes (Are transaction costs for decision-making kept to efficient levels? Are all stakeholders satisfied with their roles in the decision-making processes? Are the decisions considered credible and legitimate by those who must comply with them?). Will adherence to the Principles in 2.3.1.2 ensure better outcomes and better processes? Answers to all of these questions are essential for successful and IM of European fisheries in an ecosystem context. All require significant research by well-integrated teams of social and natural scientists.

2.2 Governance and implementation of the Water Framework Directive (WFD)

The Water Framework Directive (WFD), a framework for community action in the field of water policy, entered into force on December 2000. It is operated through a Common Implementation Strategy to direct and provide guidance in relation to water related challenges and needs. The WFD covers different water masses, superficial waters, transitional waters (estuaries) and coastal waters, which may result in overlaps with other policies. One of the greatest challenges for the new MSFD will be to carefully consider WFD fields of application/competence as WFD covers the water element, and the MSFD the marine environment composed of several elements including water. Particular attention will have to lay out on the harmonisation of different policies mandates and tools in order to facilitate the convergence of common objectives in the marine environment. Several questions will have to be addressed by appropriate international/ national/ regional bodies to i) ensure compatibility and ii) to implement the two directives. How to implement a compatible space and management unit between the two instruments (marine regions/subregions Vs hydrographic districts)? How to promote and foster their complementarity rather than integration to effectively achieve "the Good Ecological Status of the marine environment"? How to ensure cross-fertilization and transfer of skills and best practices between the two initiatives?

2.3 Governance and implementation of the Birds and Habitats Directive (BHD)

Although the Birds and Habitats Directive (BHD) has been in force for over a decade, governance challenges remain with regard to its implementing in marine environments. Although the Texel – Faial criteria were adopted in 2003 to guide a consistent process for identifying species and habitats that would warrant protection under the directive, there is no uniform and consistent science advisory process by which the criteria are applied to the available information on marine species and habitats. Although OSPAR coordinates an overall process for the NE Atlantic, input comes from a variety of sources, including EU Member States, contractors, and special interest groups. Independent peer review by bodies such as the International Council for the Exploration of the Seas (ICES) of the information and its uses occurs in some cases and not in others. Stakeholders whose opportunities to pursue social and economic endeavours would be constrained by species or habitats listed under the respective Directives do not have clear and well-defined roles or sometimes even opportunities to input in the process of listing species and habitats. Research on the governance processes could clearly help in many aspects of application of the Habitats Directives. What is the most effective process for establishing an objective, credible, and legitimate scientific basis for listing species and habitat types under the Directive, and identifying specific sites thereafter? At what scale should this process operate? How is traditional knowledge brought into the process, and uncertainty quantified and taken into account? What are the most appropriate roles for affected stakeholders that ensure their subsequent support for the decisions and management actions while protecting the integrity of the science inputs to the process? What are best practices for developing management plans for the species and sites, once identified?

2.4 The Marine Strategy Framework Directive (MSFD)

The MSFD acknowledges the deteriorating state of Europe's marine environment, the inadequacy of the present institutional framework for the management of the seas and the insufficiency of the knowledge base. It stresses that *"a new approach to marine monitoring and assessment and the use of scientific information is required across the different levels of governance which should identify and fill knowledge gaps, reduce duplicated data collection and research, and promote the harmonisation, broad dissemination and use of marine science and data"*. This is particularly important in the deep-sea which due to its inaccessibility and hazardous nature make research and governance highly expensive. One way of advancing MSFD may be to select a pilot region where most of the elements of Integrated Management described above can be put in place and management scenarios tested.

The MSFD also applies to Europe's overseas territories and in the high seas in that "while the Strategy is primarily focused on the protection of the regional seas bordered by EU countries, it also takes into account the international dimension in recognition of the importance of reducing the EU's footprint in marine areas in other parts of the world, including the high seas'". In addition to fishing in international waters, it is likely that a number of EC Member States will become increasingly involved in deep-sea mineral mining and bio-prospecting. The move away from traditional sectoral approaches towards a more holistic, integrated EA to biotic resource management will involve a paradigm shift requiring a much better understanding of: the functioning of ocean ecosystems, their carrying capacity in terms of exploited biota (to better estimate the role of habitat loss as a factor in the decline of exploited marine species) and their resilience in the face of perturbation due to human activity and on a larger scale, climate change. Simultaneously, an operational roadmap for the implementation of the MSFD and obtainment of Good Environmental Status must be put in place that will provide a new framework for decision predicated on an integrated natural and social scientific evidence base.

Annex 3. Assessments to support the Integrated Maritime Policy: examples of Integrated Assessments

3.1 Oslo-Paris Convention (OSPAR)

OSPAR produced together with ICES a Quality Status Report (QSR) for the North Sea in 1993. Subsequently, OSPAR in 2000 produced QSRs for 5 regions of the Northeast Atlantic: i) the Arctic region (North of 62°N including the Barents, Icelandic and Norwegian Seas), ii) the Greater North Sea, iii) the Celtic Seas, iv) the Bay of Biscay and Iberian Coast, and v) the Wider Atlantic. Building upon these regional QSRs, a holistic QSR for the whole OSPAR area in the Northeast Atlantic was also produced. Subsequently, OSPAR has been working according to a schedule within its Joint Assessment and Monitoring Programme (JAMP), with several thematic and sectoral assessments on selected topics before the next general assessment planned for 2010.

3.2 Helsinki Commission (HELCOM)

HELCOM has produced similar assessment reports for the Baltic Sea. The Fourth Periodic Assessment was published in 2001 based on observations from the period 1994-1998. Subsequently HELCOM has produced thematic assessment reports on selected pollution issues.

3.3 European Environment Agency (EEA)

The European Environment Agency (EEA) has developed an indicator based reporting system for environmental conditions in Europe including coastal and marine environments. The report "Europe's Environment – The Dobris Assessment" was published in 1995, followed by "Europe's Environment – The Second Assessment" in 1998, and "Europe's Environment – The Third Assessment" in 2003, "Europe's Environment – The Fourth Assessment" in 2007. The EEA has also published a report comprising assessments on priority issues in the Mediterranean environment in 2006 Moreover in 2007 in the latter region, the UNEP MED POL working group (the marine pollution assessment and control component of the Mediterranean Action Plan) has provided a report on marine pollution indicators, and the EU Data Collection Regulation MEDITS (international bottom-trawl survey in the Mediterranean) working group has presented assessments on fishery related indicators; currently there is an effort on developing and quantifying indicators for the implementation of the EA by the Mediterranean Action Plan system (Regional Activity Centres for the Blue Plan and for Specially Protected Areas).

Annex 4. List of acronyms

ACFM: Advisory Committee on Fishery Management

BHD: Birds and Habitats Directive
BORs: Biotic Ocean Resources

CARBOOCEAN: Marine carbon sources and sinks assessment
CBD: Convention on Biological Diversity
CFP: Common Fisheries Policy

DNA: Deoxyribonucleic acid
DG MARE: Directorate General for Maritime Affairs and Fisheries

EA: Ecosystem Approach
EAM: Ecosystem Approach to Management
EC: European Commission
ECoQOs: ECological Quality elements with Objectives
ECORD: European Consortium for Ocean Research Drilling
EEA: European Environment Agency
EEZ: Exclusive Economic Zone
EFARO: European Fisheries and Aquaculture Research Organisation
EMMRS: European Marine and Maritime Research Strategy
EMODNET: European Marine Observation and Data Network
EMSO: European Multi-disciplinary Seafloor Observatory
ESF: European Science Foundation
ESONET: European Seas for Observatories NETwork
EU: European Union
EUR-OCEANS: EURopean network of excellence for OCean Ecosystems Analysis

FAO: Fisheries and Agricultural Organisation
FP: Framework Program

GES: Good Environmental Status
GEOSS: Global Earth Observation System of Systems
GFCM: General Fisheries Commission for the Mediterranean
GIS: Geographic Information System
GMES: Global Monitoring for Environment and Security

HAB: Harmful Algal Bloom
HELCOM: Baltic Marine Environment Protection Commission – also known as the Helsinki Commission
HERMES: Hotspot Ecosystems Research on the Margins of European Seas

IA: Integrated Assessment
ICES: International Council for the Exploration of the Sea
ICSU: International Council for Science
ICZM: Integrated Coastal Zone Management
IM: Integrated Management
IMP: Integrated Maritime policy
INSPIRE: Directive establishing an infrastructure for spatial information
IOC: Intergovernmental Oceanographic Commission
IODE: International Oceanographic Data and Information Exchange
ISO: International Organization for Standardization

JAMP: Joint Assessment and Monitoring Programme
JMM: Joint Ministerial Meeting
JRC: Joint Research Council

LME: Large Marine Ecosystem

MarBEF: Network of Excellence on Marine Biodiversity and Ecosystem Functioning
MB-ESF: Marine Board – European Science Foundation
MEA: Millennium Ecosystem Assessment
MEDITS: International Bottom Trawl Survey in the Mediterranean
MERSEA: Marine Environment and Security for the European Area (Integrated Project)
MPA: Marine Protected Area
MSFD: Marine Strategy Framework Directive
MSP: Marine Spatial Planning

NAO: North Atlantic Oscillation
NoE: Networks of Excellence
NGO: Non-Governmental Organisation
NODC: National Oceanographic Data Center
NSC: North Sea Conference

OECD: Organisation for Economic Co-operation and Development
OGC: Open Geospatial Consortium
OSPAR: Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo-Paris)

PDO: Pacific Decadal Oscillation
PP: Preparatory Phase

QSRs: Quality Status Reports
RAC: Regional Advisory Committee

SBCI: South Biscay Climate Index
SEAs: Strategic Environmental Assessments
SeaDataNet: Pan-European infrastructure for Ocean and Marine Data management for online integrated data access
SPICOSA: Science and Policy Integration for Coastal System Assessment
STECF: Scientific Technical and Economics Committee for Fisheries

TBT: Tributyltin
TDAs: Transboundary Diagnostic Assessments
THC: THermohaline Circulation

UN: United Nations
UNEP: United Nations Environment Programme
UV-B: Ultraviolet-B radiation

WFD: Water Framework Directive
WDC: World Data Center for Marine Environmental Sciences
WDS: World Data System

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Printing: IREG Strasbourg
May 2010
ISBN: 978-2-918428-10-7

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Print run: 1500 – May 2010