EMaPS Position Paper 2

A European science plan on marine biodiversity

European Marine and Polar Science (EMaPS)

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Membership is open to organisations which are based in Europe and are either ESF member organisations, major national marine or polar scientific institutions, or groups of national relevant scientific institutions which combine to form a single membership to the Boards.

Cover picture: Coralligène at Banyuls-sur-mer, approximately 30m depth. Accumulation of calcareous algal thalli (Corallinales) constituting a reef whose hard structure is very heterogeneous. This formation creates a structural diversification of the ecosystem and supports a very great specific richness (more than 500 recorded species).
Photo © Jean Lecomte/CNRS -O.O.Banyuls

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Foreword

One of the main objectives of the European Boards for Marine and Polar Science, created in October 1995, is to develop strategies that will help its member organisations to make more effective use of their research capacity and collaborate on long-term scientific issues which are beyond the financial reach of individual nations in Europe.

Marine biodiversity is an important case in point for which the EMaPS Marine Board has decided to take the initiative in establishing a Feasibility Study Group (FSG) for the preparation of a well-focused Science Plan. To achieve this objective, the FSG met in Yerseke (The Netherlands) on 16-18 December 1997 to identify areas in which research is required in order to be able to design scientifically-sound management practices concerning marine biodiversity and to develop strategies of European relevance. Special emphasis has been placed on research that can lead to the development of management tools and on the added value of the European dimension.

This ESF-EMaPS Science Plan on marine biodiversity should be an important contribution towards the implementation of well-coordinated research projects at the European level on marine biodiversity, in particular within the EC Fifth Framework Programme for RTD.

Daniel Cadet
Chairman, Marine Board

Executive summary

- Marine organisms play crucial roles in many biogeochemical processes that sustain the biosphere, and provide a variety of products (goods) and functions (services) which are essential to mankind's well-being, including the production of food and natural substances, the assimilation of waste and regulation of the world's climate.

- The rate and efficiency of any of the processes that marine organisms mediate, as well as the range of goods and services that they provide, are determined by interactions between organisms, and interactions between organisms and their environment, and therefore by biodiversity. These relationships have not yet been quantified, and we are at present unable to predict the consequences of loss of biodiversity resulting from environmental change in ecological, economic or social terms.

- Marine biodiversity does not necessarily comply with terrestrial paradigms, and our understanding of its role and regulation lags far behind that of terrestrial biodiversity, to such an extent that we do not have enough scientific information to underpin management issues such as conservation and the sustainable use of marine resources.

- The scale of the research efforts needed to remedy this situation demands European-scale collaboration.

- The overall objective of this Science Plan is to develop, through a directed and concerted effort on the European scale, the scientific basis necessary to support the management for sustainable use of the diversity present in the marine environment, for the benefit of present and future generations, and to inform the public about the issues at stake. The three sub-objectives are:

(i) To describe and characterise marine biodiversity in Europe and to quantify its role in providing goods and services in relatively pristine, as contrasted to impacted, environments, as a baseline for evaluating human impact. This should involve a nested approach to address patterns at a range of temporal and spatial scales.

(ii) To determine the effects of changes in biodiversity, both natural and man-made, on the goods and services marine ecosystems provide. This should involve long-term and large-scale studies, as well as experimental work.

(iii) To provide the scientific concepts and tools for the management of marine resources, living and non-living, including modelling frameworks and rapid assessment protocols.

Specificity and role of marine biodiversity

The European marine environment has been experiencing rapid and accelerating changes, largely derived from human activity, whether stemming from local pressure or from the more diffuse effects of global change. Widespread realisation that marine biodiversity is strongly influenced by these changes, as recognised by numerous legally-binding conventions (Box 1), has fostered plans to conserve and protect marine biodiversity throughout Europe. The equally important realisation that adequate functioning of marine systems depends, in turn, on biodiversity and the fact that protected areas and species can only cover, at best, a small part of the European marine waters and species, clearly shows the need for a broader strategy for the management of biodiversity than conservation alone.

Box 1. Obligations of European states concerning management of biodiversity

Conventions	Year	Geographic range	Activity
Ramsar	1971	Global	Protection of wetlands
Helsinki (HELCOM)	1974/1992	Baltic Sea	Protection of the marine environment
Oslo/Paris (OSPARCOM)	1972/74/92	NE Atlantic	Protection of the marine environment
Barcelona	1976/1995	Mediterranean	Protection against pollution
Bonn	1979	Global	Conservation of migratory species
Bern	1979	Europe	Conservation of species and natural habitats
Warsaw	1982	Baltic and Belts	Fishing and conservation of living resources
Bonn	1983	North Sea	Pollution by oil and other harmful substances
Washington (CITES)	1984	Global	International trade in endangered species
Lisbon	1990	NE Atlantic	Protection of the coasts and waters against accident pollution
Rio (UNCED)	1992	Global	Conservation and sustainable use of biodiversity
EU Directives			
Birds	1988	EU	Special protection areas
Habitat and species directive	1992	EU	Special areas of conservation, Natura 2000

Such a broader management strategy will inevitably require the quantification of the value and benefits of biodiversity. There has recently been major progress in evaluating the goods and services provided by ecosystems through the quantification of the value-added benefits derived from ecosystem functioning (Box 2). The value of marine ecosystems, excluding climate regulation and genetic-resource-based services, has, in this way, been conservatively estimated at $18{,}800 \times 10^9$ ECU per year for the global ocean ecosystem[1], similar to the global gross national product. Biodiversity strongly modulates the services marine ecosystems provide (Box 3), but the relationships between marine biodiversity and ecosystems functions are still unquantified. We are, therefore, unable to predict the consequences of loss of biodiversity in ecological, economic or social terms. The definition and modelling of the relationship between marine biodiversity and ecosystem services and goods will allow the incorporation of marine biodiversity into integrated management schemes and lead, therefore, to more effective management of marine ecosystems and the biodiversity they contain.

Box 2. Examples of goods and services provided by marine ecosystems

- food (fisheries, aquaculture) for man and domestic animals
- a natural treatment system for human waste
- a sink for pollutants from air and land
- a physical and chemical buffering system for global climate change
- an educational amenity
- ingredients for biotechnology (bioactive chemicals, substances for food and medicine)
- oil, gas, gravel, sand, maerl, and other mineral resources
- transport
- cooling water for power-generation plants and industry
- recreational facilities (e.g. water sports, sport fishing, wildlife observation, tourism)

The elucidation of the relationship between marine biodiversity and ecosystem services requires research initiatives at a scale that cannot be encompassed by any single country or loose consortium of countries. Therefore, this task must be tackled at the European level, addressing the mosaic of regional diversity patterns within larger latitudinal and longitudinal gradients that compose the European marine environment. Hitherto, research under national programmes has focused mainly on organismal diversity at small spatial and short temporal scales. Whereas efforts at the national scale can reasonably address, after proper standardisation of protocols, other points in the international agenda for research on marine biodiversity (cf. Diversitas Operational Plan, Communication of the

[1] Costanza et al. (1997) Nature 387:253-260

Commission on the European Community Biodiversity Strategy), the elucidation of the link between marine biodiversity and ecosystem function and services has proved to be an elusive goal, requiring a large-scale, coherent programme on the European and even global scale. European-wide collaboration will allow us to effectively address the effects of global change on biodiversity over a nested array of relevant scales, both in terms of spatial (local to regional) and of biological (molecular to ecosystem) levels of organisation. A European dimension is even more imperative because of the contiguous and open nature of our seas, the dangers of transfer and introduction of exotic species via shipping and mariculture and the poor understanding of the dispersal of marine organisms, and would also allow us to capitalise on the efficient use of large scale experimental facilities such as mesocosms and flumes, and expensive large scale field experiments. The co-ordination of this research effort requires a European Science Plan for which we have tried to lay the foundation in this Position Paper.

Box 3. The role of marine biodiversity in sustaining ecosystem functions, goods and services

Ecosystem functions	Role of marine biodiversity
Primary production	High
Carbon storage	Low
Carbon flow to higher trophic levels	High
Nutrient cycling	High
Ecosystem services	
Gas and climate regulation	Low / Medium
Disturbance regulation	High
Erosion and sedimentation control	Medium / High
Remineralisation	High
Waste treatment and disposal	High
Biological control of nuisance species	High
Monitoring of global change & bio-indication of ecosystem health	High
Recreation, tourism and education	High
Ecosystem goods	
Habitat and refugia	High
Food resources	High
Raw materials	High
Genetic resources	High
Natural heritage	High

Past attempts to elucidate the role of marine biodiversity as a control on ecosystem functions and the services they deliver have failed for a number of reasons:

- Paradigms concerning the patterns of biodiversity on both global and regional scales, the mechanisms that determine them, and the consequences of biodiversity loss, are largely borrowed from the terrestrial realm. Many of them may not be applicable to the marine situation because of differences between these ecosystems (Box 4).

Box 4. The distinctive features of marine biodiversity

1. Life has originated in the sea and is much older in the sea than on land. As a consequence, the diversity at higher taxonomic levels is much greater in the sea where there are 14 endemic (unique) animal phyla whereas only 1 phylum is endemic to land. There is also a remarkable diversity of life-history strategies in marine organisms. The sum total of genetic resources in the sea is therefore expected to be much more diverse than on land.

2. A greater variety of species at a higher trophic level is exploited in the sea than on land: man exploits over 400 species as food resources from the marine environment; whereas on land only tens of species are harvested for commercial use. Exploitation of marine biodiversity is also far less managed than on land and amounts to the hunter-gatherers stage that humans abandoned on land over 10,000 years ago, yet exploitation technology is becoming so advanced that many marine species are threatened to extinction. Insufficient consideration has been given to the unexpected and unpredictable long-term effects that such primitive foodgathering practices engender.

3. The physical environment in the oceans and on the continents is totally different. Marine organisms live in water, terrestrial organisms live in air. Environmental change in the sea has a much lower frequency than on land, both in time and in space.

4. Marine systems are more open than terrestrial and dispersal of species may occur over much broader ranges than on land. Although most species in the ocean are benthic and live attached to or buried in a substratum, in coastal seas a very large proportion of them has larvae that remain floating in the water for days to months. These high dispersal capacities are often associated with very high fecundities and this has important consequences for their genetic structure and their evolution

5. The main marine primary producers are very small and often mobile, whereas on land primary producers are large and static. The standing stock of grazers is higher than that of primary producers in the sea, the opposite to the situation on land. Ocean productivity is on average far lower than land productivity. In the largest part of the ocean, beneath the shallow surface layers, no photosynthesis occurs at all.

6. High level carnivores often play key roles in structuring marine biodiversity and yet are exploited heavily with unquantified but cascading effects on biodiversity and on ecosystem functions. This does not occur on land, where the ecosystems are dominated by large herbivores and, of course, increasingly by humans which monopolise about 40 % of the total world primary production.

7. All pollution (air, land and freshwater) ultimately enters the sea. Marine biodiversity is thus most exposed to and critically influences the fate of pollutants in the world. Yet marine species are probably least resistant to toxicants. The spread of pollutants in marine food chains and therefore the quality of marine food is uncontrollable by man.

These paradigms are now appearing in the standard textbooks, although they are still based on highly equivocal evidence. Our understanding of marine biodiversity lags far behind that of terrestrial biodiversity, to such an extent that we do not have enough scientific information to underpin management issues such as conservation and the sustainable use of marine resources. In recent years, marine research has discovered new ecosystems, new phyla and new basic facts on the functioning of the oceanic system (Box 5).

- Biodiversity must be considered at a variety of different scales: biological organisation levels (genetic, organismal, community), spatial scales from single samples to regional and global, and temporal scales of change from short to long. The threats to marine biodiversity and the consequences of biodiversity change operate on all these scales. Results from research conducted at any single level are, therefore, likely to lead to errors and unsupported expectations when extrapolated to other levels.

- The integration of efforts conducted by individual scientists and even by separate national initatives has proved cumbersome. There is an urgent need for widely-adopted standardised protocols for data collection, and for the development of appropriate analytical, statistical and modelling tools allowing the incorporation of marine biodiversity into local and regional models of ecosystem functions and services. Conversely, the study of marine biodiversity could provide a framework for co-operative research mobilising a wide spectrum of scientific and technical resources.

Box 5. Key new findings related to marine biodiversity

- The discovery of two new phyla, endemic to the marine environment, since 1980.
- The discovery of a new ecosystem, deep-sea hot vents, which rely on chemosynthesis for the primary production of organic material.
- The discovery of viable bacterial populations at depths of several hundred metres in marine sediments at high temperatures and pressures.
- The discovery that most marine species occur in poorly known taxonomic groups such that most marine species are not yet known to science:
  - less than 5 % of marine bacteria are known according to estimates based on recently developed molecular biological techniques, indicating that many new biochemical pathways remain to be discovered;
  - species numbers in the deep sea benthos are extremely different from site to site, indicating that perhaps millions of species new to science may yet be discovered.
- The recent discovery of the smallest autotrophs of the planet in the oceanic deserts, and the finding that they are responsible for a substantial proportion (> 20 %) of the primary production over 70 % of the global ocean.

Science plan objectives

Sponges colonising the hard substrate in the Eastern Mediterranean. Sponges provide structure for other marine species, they are a traditional commercial resource while they are recently used as source of several biomedical products. After 1986 a disease affected several Mediterranean species resulting in severe reduction of local populations. Photo © IMBC

This science plan aims to identify (a) the scientific questions that need to be resolved, (b) the actions that require Europe-wide collaboration, and (c) the end products necessary for the scientific support of management for the sustainable use of the goods and services provided by marine ecosystems in Europe.

The objectives of the research required are specified as:

- To characterise marine biodiversity at a range of biological, spatial and temporal scales.
- To quantify the role of marine biodiversity in providing goods and services in both relatively natural and more human-impacted environments.
- To determine the probable effects of natural and man-made changes in biodiversity on ecosystem goods and services.
- To provide a scientific rationale basis and tools for the proper management of living resources in European seas.

A European science agenda

A European-wide programme is needed which should include field surveys, experiments and modelling.

- **The patterns of biodiversity need to be better known** before one can assess the implications of changes in biodiversity on the goods and services provided by biodiversity. Research should begin with characterisation of the biodiversity as far as possible (from genetic to ecosystem level) in selected key (flagship) habitats across the geographical range of Europe (from the Canary Islands to Svalbard and from the Azores to the Eastern Mediterranean). This could be done by compiling comprehensive inventories at a few sites and less comprehensive surveys at a larger number of sites, using standardised methods and protocols.

- **Surveys need to use nested sampling designs** so that scales of diversity can be assessed. Rapid assessment methods will be used in the broader scale surveys. The implementation of such surveys will require a solid and therefore well supported co-ordination of marine laboratories and taxonomy institutes. Existing networks (e.g. MARS Network of European Marine Research Stations) should be broadened with easy access of information to interested persons and organisations. Links with the Coastal Module of EUROGOOS, the North American Network of Marine Laboratories (NAML) and LOICZ may all be worthwhile.

- **The mechanisms for generating and maintaining marine biodiversity** need to be understood. Marine systems are open and the genetic differentiation of populations, therefore, differs significantly from that in terrestrial systems. Life-history traits of marine populations are very diverse and cannot easily be generalised. The reasons for this diversity are not understood, and functional and historical explanations have to be explored. The genetic structure of populations as a function of the different types of dispersal and how genetic differentiation varies with changes in habitats and biodiversity need also to be studied. In this context, the use of molecular markers of functional processes in relation to changes in biodiversity must be explored. Results from these studies can be expected to lead to rationalised and more effective monitoring of change.

- **Biodiversity at the species level** is a function of complex interactions between species (competition, predation, parasitism, commensalism etc.) and between species and their environment (temperature, food supply etc.). Models of marine food webs and interactions between food web structure and

biogeochemical cycles are badly needed, because they will allow for the predictions required to support different management options and strategies. Such models must be supported by adequate data on the characteristics of the different compartments necessary to describe the food web.

- **Quantitative information on dispersal mechanisms of marine species** is required to provide an understanding of the factors controlling biodiversity in the past, present and future. This will facilitate for example (a) prediction of effects of climate change and large scale harvesting of species (e.g. over-fishing) on ecosystem goods and services, (b) the control of diseases in aquaculture, (c) prevention of the spread of invading nuisance species, and (d) the better design of marine conservation areas and species protection plans. The research must include the role of ecological, oceanographic and climatic factors and wide range of spatial and temporal scales.

- **Naturally fragmented species (such as metapopulations) and populations fragmented by human inference** (e.g. through fisheries, collection in intertidal areas) exist in the marine environment and the threats this fragmentation poses to the long-term survival of these species is unknown.

- **The concepts of keystone or engineering species** must be properly understood before they can be adequately used as representing ecological function. The number of species required for optimal functioning of ecosystems in terms of productivity, resilience, stability, potential for exploitation may be determined experimentally (laboratory, in situ, in mesocosms) and by comparison of functioning of different systems, e.g. the very species-poor Baltic Sea with the more diverse Adriatic Sea.

- **Habitat and seascape diversity** is a key issue for coastal zone management and conservation and is also essential for characterisation and discretisation of biological communities. Marine habitats are described in great detail in intertidal zones but quickly lose definition in deeper environments, partly due to inefficient observation and lack of adequate instrumentation.

- **Experimental work of biodiversity in micro- and mesocosms and in the field at appropriate localities** (e.g. lagoons, enclosed embayments) is necessary to test (a) the relationships between biodiversity and ecosystem functions, (b) the importance of keystone genes, species and habitats and of "engineering species" and (c) the link between heterozygosity, biodiversity and functional

Seagrass meadows, such as the Posidonia oceanica meadow shown, provide important services in the ecosystem, such as habitat for fauna and physical protection of the coastal zone.
Photo © C.M. Duarte Quesada

processes. The field experiments carried out at a nested series of scales from metres to 100s of metres and as far as is practical at scaled time intervals because it is important to understand the effects of scaling on biodiversity and functional processes. Other conceivable experiments include manipulation of food web structure to change energy and matter flow patterns, e.g. removal of top predators through fisheries regulation, channelling of primary production through the microbial food web or to higher organisms, the use of man-made large scale impacts such as those due to overfishing, oil spill accidents, very large civil engineering works (harbour extension, wetland reclamation etc.).

- **Modelling must play a major role** at all levels studied. Key models are likely to be (a) linking genetic variation at the population level to dispersal processes,
(b) linking functional processes to the diversity of species assemblages,
(c) scaling of functional processes and biodiversity from local to regional levels, (d) predicting effects of global change on the services and goods provided by biodiversity. Such models must be linked to population dynamics and to hydrodynamic, biogeochemical, speciation and climate models.

- **Through all the above approaches, well-described methods and protocols,** with documented quality control in methods and data management, must be implemented. This would include standard species nomenclatures, minimal and well-defined terminology, and tools for the identification of biodiversity from the molecular to whole organism and community levels. This does not imply expensive and labour intensive methods, but well-defined methods appropriate to the studies undertaken such that the work may be replicated by other researchers. Tools for marine biodiversity research and management should be developed (e.g. new taxonomic guides, new methods for assessing microbial diversity, ecosystem models), and state-of-the-art tools (e.g. molecular) techniques used where appropriate.

- **The European seas influence and are influenced by oceans and climate shared with neighbouring countries and the world.** It is important that a research programme in marine biodiversity actively promotes and facilitates co-ordination and involvement between researchers in and beyond Europe.

Scientific knowledge on the origin, maintenance, distribution and dynamics of biodiversity

This research will provide, for the first time, an inventory of Europe's marine biodiversity in terms of genes, species and habitats at the beginning of the new Millenium. It will contribute to the world-wide efforts in understanding biodiversity as formulated in the Science and Implementation Plans of the DIVERSITAS programme. The Implementation Plan of this Science Plan will produce a modular research programme to be subscribed by individual scientists as well as national and international consortia. It will, therefore, produce a framework for the co-ordination and integration of marine biodiversity research in Europe and world-wide.

An important product of European marine biodiversity research should be the necessary knowledge and tools for adequately managing marine biodiversity in Europe. This includes:

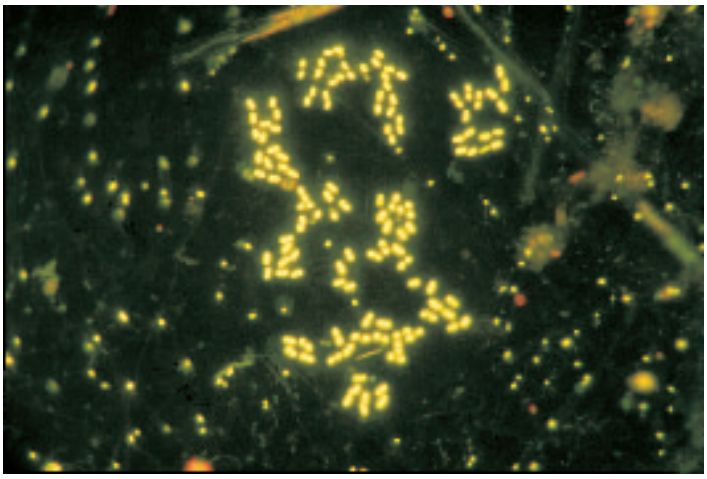
- knowledge on genetic and ecological mechanisms that control biodiversity (gene flow, dispersal, adaptive value of genetic polymorphisms, determination of dispersal and recruitment, species interactions, sediment transport, natural and human-induced catastrophes etc.).
- knowledge on the functional role of biodiversity: what is the variability in genes, species and communities that is required for 'normal' or desirable ecosystem functioning.
- models on dispersal of genes and organisms, species interactions and foodwebs, the interaction between food webs and biogeochemical fluxes, and impact assessment of diffuse and point source pollution, coastal constructions, mass tourism and global change.

Technology and data information systems

The research will require and develop rapid assessment techniques for monitoring of marine biodiversity (genes, species and biotopes), including the use of molecular techniques, rapid identification techniques, assessment of difficult species (microbes, sibling species, multispecies complexes), pictural taxonomic and identification keys accessible on WWW and on CD-ROM, remote sensing techniques (Satellite Imagery, Side Scan Sonar, LIDAR, etc.). It will further provide for the development of data bases and GIS for genes, species and habitats in Europe.

Application in conservation and restoration ecology

The protection of endangered species and habitats is a rapidly growing need in the marine environment. Understanding genetic structure permits the



Cyanobacteria are probably the most abundant primary producers in oceanic environments and dominate especially in oligotrophic waters. Some species are also globally important as nitrogen fixators. Photo © C.M. Duarte Quesada

identification of stocks and the magnitude of gene flow and exchange. Identification of individuals permits the evaluation of dispersal and homing behaviour and genetic origin. By using different genetic markers, differences between individuals can be aged in evolutionary terms, which allows for evaluation of evolutionary versus ecological factors that determine the present status of threatened species.
The criteria for the design of protected areas are largely derived from terrestrial ecological theory, and little scientific basis exists for an integrated policy of conservation in the marine environment that takes into account the particulars of marine life histories.

Application in management of living resources

Fisheries policies at the moment are rapidly moving away from single to multispecies assessments. A number of programmes originated or co-ordinated by ICES (The International Council for the Exploration of the Seas) already implicate global change processes in the study of commercial fish populations (Cod and Climate, GLOBEC). Besides fisheries, marine aquaculture is an important and growing economic activity in countries such as

Marine organisms living in close association one with the other, modifying the texture of the seabed and contributing to the increase in spatial heterogeneity. The nature of these inter-specific interactions is still largely unknown. Photo © IMBC

Ireland, Greece, Italy, Scotland, Spain and Norway, and new problems of controlling biological invasions have become widespread in recent years.

Application in water quality studies

The use of biological communities in monitoring ecosystem quality with biological criteria is now widespread and is legally required in some countries for certain operations (e.g. drilling for oil and gas in Norway). This is, in fact, one of the oldest applications of the diversity concept and a very sophisticated methodology has been developed to make optimal use of the data on abundance and biomass of species to allow description of changes in the marine environment. It allows comparison of the spatial and temporal scales of impact and recovery in relation to different types of anthropogenic impacts, as well as in relation to different combinations of anthropogenic pressures.

Economic valuation of marine biodiversity

Except for the rational management of known living resources (molluscs, crustaceans, fish) with a view to their sustainable exploitation, a number of direct resources from the sea have hardly been explored. These include genetic resources and new biotechnological techniques. Their study requires experimental protocols for regulation and management of genetically transformed biota especially in aquaculture, natural products with applications in food processing and human health, and requirements for legislating patents on organisms and processes.

Rocky shores in north and western Europe harbour with a rich biological community dominated by large seaweeds of the genus Laminaria. Photo © Magda Vincx

Coastal zone management

The different possible uses of the coastal zone and the consequent requirements for planning and management require implication of biodiversity as one of the main assets of ecosystems. As argued, the valuation of marine biodiversity is for the moment impossible because most basic knowledge is missing, but in future it will, without doubt, become a major argument in the designation of areas for nature conservation and protection, sport and commercial fisheries, tourism, waste disposal, for establishing

Box 6. A summary of products, benefits and end-users of marine biodiversity research

	Products and benefits	End users
Research	• genetics controlling biodiversity - intrinsic and extrinsic factors controlling dispersal - gene flow, individual flow - fragmented distribution • functioning of ecosystems - number of species and optimum functioning • models - dispersal of genes and organisms - effects of invaders and impact of removal of barriers to distribution through introductions - functional aspects of biodiversity (interactions between species / food webs and biogeochemical fluxes) - designation of protected areas and natural reserves • impact of fisheries through discarded species and through habitat damage • impact of global change on marine biodiversity	• scientific community • national and international programmes • fisheries • aquaculture
Conserv-ation	• distribution of genes, species, habitats along the coasts of Europe (hot spots: transition zones, barriers) • living resources (stock identification,homing behaviour) • control of alien and transgenic species (prevention of possible negative impact by hybridisation or competition) • protection of endangered species and habitats • scientific bases for policies	• fisheries • aquaculture • management and conserv-ation of living resources and habitats • coastal management • industry • governments • public
Decision-making	• environment quality (water, substrates) • impact of coastal management • impact of industry (oil drilling,mining,dumping) • management of pollutants, ballast water	
Economic valuation	• rational management of coast • rational management of fisheries and aquaculture • promotion of disease resistance and control • genetic and food resources, potential for biotechnologies (natural substances, transgenic plants and animals, including normalised experimental protocol for their regulation and management) • patents on organisms and processes	
Education, training and public awar-eness	• data basing and networking • exchange of information between scientists and between scientists and society • programmes for public information and education training	

shipping routes and procedures for the disposal of ballast water, and for policies involving deliberate introduction of exotic species.

Education, training and awareness

Human perception of biodiversity, attitudes and behaviour directly or indirectly affect the conservation and the sustainable use of biological diversity. Changing these factors requires long term concerted efforts in education and public awareness in general, and some especially well targeted actions towards sectors like sea professions, coastal city and coastal recreation area managers, water management, both at national and European level.

List of the participants in the workshop held in Yerseke (NL) on 16-18 December 1997

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List of acronyms

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
EMaPS	European Marine and Polar Science
ESF	European Science Foundation
EuroGOOS	European Global Ocean Observing System
GIS	Geographic Information System
GLOBEC	Global Ocean Ecosystems Dynamics Research
HELCOM	Helsinki Commission, protection of Baltic marine environment
ICES	International Council of the Exploration of the Seas
LIDAR	Light Detection and Ranging (instrument)
LOICZ	Land-Ocean Interactions in the Coastal Zone
MARPOL	International Convention for the Prevention of Pollution from the Ships
MARS	Network of European Marine Research Stations
NAML	North American Network of Marine Laboratories
OSPARCOM	Oslo and Paris Commission

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