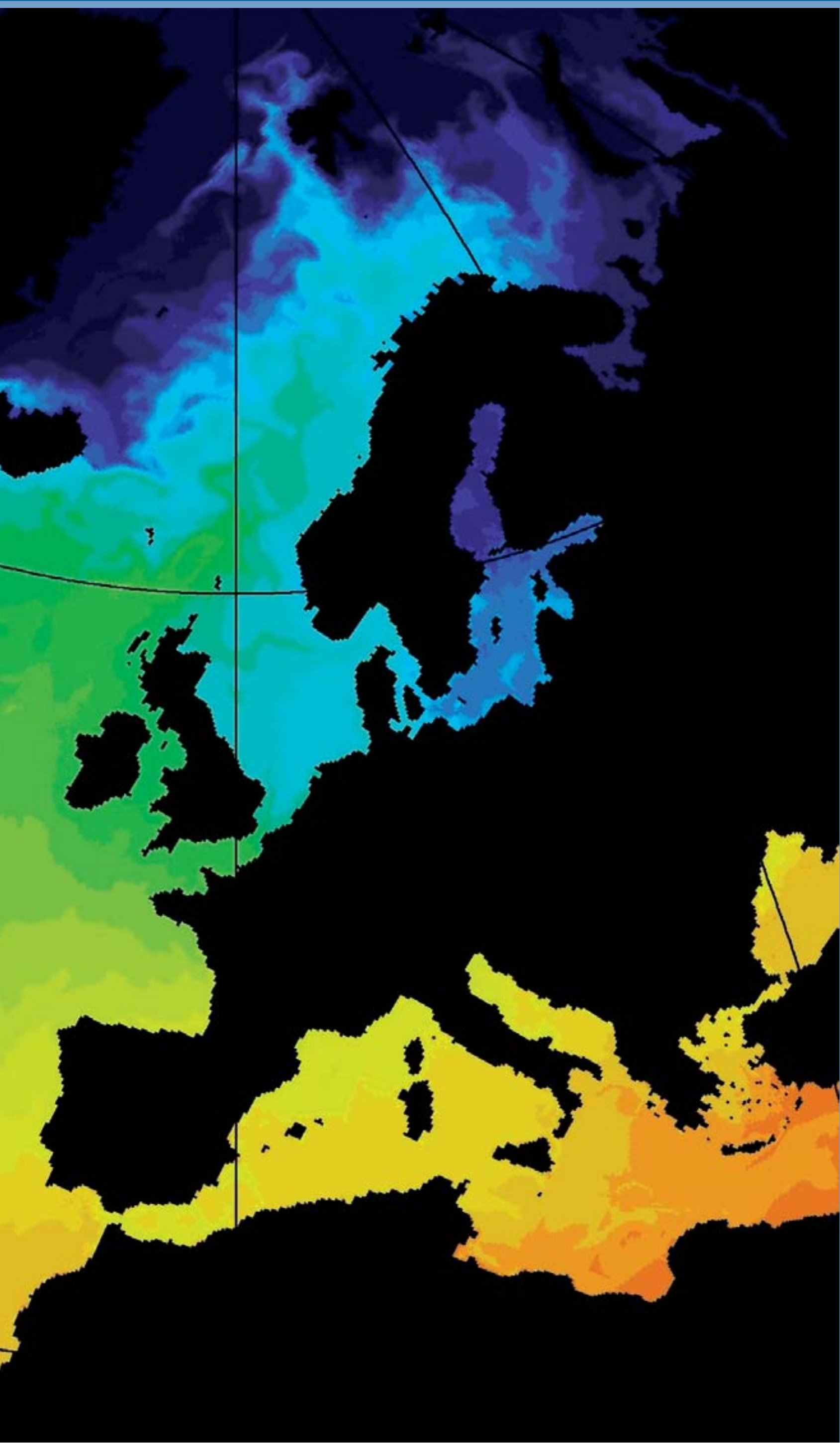
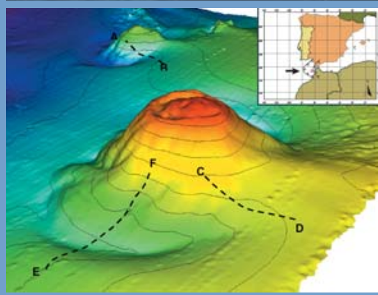
ESF Marine Board Position Paper 6

Navigating the Future –II–

Summary of *Integrating Marine Science in Europe*





Marine Board

March 2003

The European Science Foundation (ESF) acts as a catalyst for the development of science by bringing together leading scientists and funding agencies to debate, plan and implement pan-European scientific and science policy initiatives.

ESF is the European association of 76 major national funding agencies devoted to scientific research in 29 countries. It represents all scientific disciplines: physical and engineering sciences, life and environmental sciences, medical sciences, humanities and social sciences. The Foundation assists its Member Organisations in two main ways. It brings scientists together in its EUROCORES (ESF Collaborative Research Programmes), Scientific Forward Looks, Programmes, Networks, Exploratory Workshops and European Research Conferences to work on topics of common concern including Research Infrastructures. It also conducts the joint studies of issues of strategic importance in European science policy.

It maintains close relations with other scientific institutions within and outside Europe. By its activities, the ESF adds value by cooperation and coordination across national frontiers and endeavours, offers expert scientific advice on strategic issues, and provides the European forum for science.

ESF Marine Board

The Marine Board operating within ESF is a non-governmental body created in October 1995. Its institutional membership is composed of organisations which are major national marine scientific institutes and funding organisations within their country in Europe. The ESF Marine Board was formed in order to improve co-ordination between European marine science organisations and to develop strategies for marine science in Europe.

Presently, with its membership of 25 marine research organisations from 17 European countries, the Marine Board has the appropriate representation to be a unique forum for marine science in Europe and world-wide.

In developing its activities, the Marine Board is addressing four main objectives: creating a forum for its member organisations; identifying scientific strategic issues; providing a voice for European marine science; and promoting synergy among national programmes and research facilities.

Navigating the Future II ***(Position Paper No. 6) is a summary of a more comprehensive and detailed report*** **Integrating Marine Science in Europe** ***(Position Paper No. 5, November 2002, 148pp. ISBN 2-912049-35-0, ESF Marine Board).***
It can be downloaded from the website: www.esf.org/marineboard

Navigating the Future –II–

Summary of *Integrating Marine Science in Europe*

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> ***"Ocean science will have to become more holistic, more interdisciplinary and more international. If we are to adequately address ocean issues at the local, national, regional and global levels, science cannot operate in isolation but will need to integrate more fully a response from society at large. There must also be changes in the way we regulate marine activities, in our social goals and our attitudes to ocean governance. If we are to make the right decisions, however, we must understand how things 'work' in the oceans and how they interact; and we must recognise the role of the oceans in our life-support system and its value for humankind. This will require excellent science, together with the technology for pursuing it, as well as the support of individuals and governments. Ultimately, it calls for a vision of the planet that embraces land, sea, the atmosphere and human societies in all their interactions."***
>
> *The Ocean, Our Future*
> Report of the Independent World Commission of the Oceans (1998)

Acknowledgements

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Preparatory workshops

- Feasibility Study Group on Marine Biotechnology, Galway (Ireland), 25-27 July 2001
- Euroconference *Biodiversity of Coastal Marine Ecosystems: Pattern and Process*, Corinth (Greece), 6-10 May 2001
- Workshop on *Marine Technology Frontiers for Europe*, Brest (France), 26-28 April 2001
- Marine Socio-Economic Working Group, Strasbourg (France), 26-27 March 2001
- Hanse conference *Marine Science Frontiers for Europe*, Bremen (Germany), 18-21 February 2001
- Network on Public Awareness of Marine Science, Strasbourg (France), 5-6 February 2001
- Feasibility Study Group on Marine Biotechnology, Oristano (Italy), 22-24 November 2000
- Hanse conference *Ocean Margins Systems*, Delmenhorst (Germany), 19-23 November 2000
- EurOCEAN 2000 Conference, Hamburg (Germany), 29 August - 2 September 2000

Working groups

- Core Drafting Group of the Position Paper
- Feasibility Study Group on Marine Biotechnology
- Network on Public Awareness of Marine Science
- Socio-Economic Working Group
- Marine Technology Working Group

Sincere thanks are expressed to DG Research of the European Commission for its encouragement to the ESF Marine Board to produce the Position Paper.

Acknowledgement is especially due to all scientists and other experts who have been involved in the preparation and validation processes of the Position Paper.

The skills of the Secretariat of the ESF and the Marine Board were essential during all stages of the preparation and publication of this report and are gratefully acknowledged.

Contents

Foreword

The Oceans have always been of major strategic importance for the economic and social development of Europe. Nowadays, it is clear that living resources are finite, and that scientists have an ethical responsibility to disseminate their knowledge towards the effective management of these resources. Coastal seas, adjacent to which two thirds of the world's major cities are located, are heavily impacted by anthropogenic developments, with increasing conflicts between competing uses. The Oceans, which cover 71% of planet Earth, also provide the inspiration for curiosity driven research, with exciting discoveries in domains such as the origin of life and new deep sea ecosystems.

With its present membership of 25 marine research organisations from 17 European countries, the European Science Foundation (ESF) Marine Board provides a unique forum to express a vision for integrating marine science in Europe. This Position Paper *Integrating Marine Science in Europe* (IMS-E) represents an initiative to establish a Europe wide summation of marine research, prioritise recommendations and identify where future scientific challenges lie, while incorporating European societal needs. Its production is the result of in-depth consultation by the ESF Marine Board with all marine science stakeholders, including aspects of socio-economics, technology and research infrastructures. It represents the first summation of the status and priorities of marine research in Europe.

I welcome this original initiative of the ESF Marine Board, stressing the vital importance for Europe to play an active role in global ocean affairs. I particularly welcome the development of, and commitment to, an implementation process, which demands immediate action. The unique validation process adopted, which involved the scientific community, the ESF Marine Board and the ESF itself, strengthens the relevance of the recommendations and insights, ensuring a commitment to implementation.

The Position Paper was developed not as a blue print, but rather as a compass for navigating a common course for individual national and European research programmes. This common course will strengthen Europe's scientific research capacity and competition globally. It will also facilitate an integrated underpinning of European policies in fisheries, sustainable exploitation of natural marine resources, and the management of coastal and oceanic regions.

I want to emphasise two recommendations in this report which are of great relevance to the ESF's initiatives in European research, namely: coordination of research infrastructure, and the improvement in the use of existing research instruments at national and European levels. By addressing European and national research programmes, the Position Paper provides a tool for scientists to interconnect with and influence both. The ESF has offered to play a role in coordination of infrastructure needs throughout European research, and the proposals for implementation detailed in this Position Paper provide a process for furthering this in the marine field.

This Position Paper, which is complementary to the ESF Scientific Forward Looks and EUROCORES instruments, and the strategy papers of the ESF expert committees, represents another contribution by the ESF to the establishment of the European Research Area (ERA).

I consider this well-researched and cogently argued Position Paper to be a major contribution towards the implementation of a Marine European Research Area, from concept to reality, a process in which the ESF Marine Board expects to play a leading role.

Enric Banda, *ESF Secretary General*

Summary of Recommendations

The Position Paper on Integrating Marine Science in Europe is a milestone in the process of integrating and developing a strong, fully European profile for marine science as a key component of the European Research Area.

The European Science Foundation's (ESF) Marine Board convened a series of workshops and specialist groups during 2000-2001 to identify scientifically challenging and socio-economically important research themes in marine science and technology that are expected to contribute to a sustainable future for the ocean's ecosystems. During this process, two reports were produced: *Towards a European Marine Research Area* in December 2000, and *Navigating the Future* in February 2001, both serving as contributions to the preparation of the European Commission's 6th Framework Programme (EC FP6). Following a wide ranging and in depth consultation with many leading European scientists and policy makers *(see Appendix I),* a draft of the current report was announced in June 2001 on the ESF Marine Board website; comments subsequently received contributed towards finalising this ESF Marine Board Position Paper on *Integrating Marine Science in Europe* (IMS-Europe). Thus, this Position Paper provides a summary of a Europe-wide reflection on marine science, and details specific research actions considered to be of fundamental importance, as a result of this multifaceted consultation process.

During this process, three major strategic drivers were identified and used as the cornerstones for developing the rationale for integrating marine science in Europe.

1. **Understanding and predicting the impacts and feedbacks of ocean climate change.**
2. **Scientific and socio-economic bases for sustainable development of European seas and their resources.**
3. **The ocean as an ultimate frontier for marine research.**

Within the context of these drivers, the aim of the IMS-Europe Position Paper is to provide a profile of the status and priorities in marine research to:

- Marine research teams in Europe, detailing a strategic synopsis of research themes that will assist them in integrating their expertise and contribute to new collaborations.
- National institutes and agencies, to facilitate optimal development of strategic options, which would help in formulating their marine research priorities in a synergistic mode, and so link them within European opportunities such as the European Commission's 6th Framework Programme (2003-2008), and the ESF's EUROCORES and Forward Looks programmes.

The Position Paper is not presented as prescriptive or definitive, rather it is intended to inform and contribute to reflection on marine research issues.

The Position Paper will be widely distributed among the marine scientific community in Europe and beyond, and among policy makers and other stakeholders. This will stimulate ideas and initiatives for effective implementation of integrated marine research, leading to actions and opportunities. The existing role of the ESF Marine Board, as a facilitator in marine research, creating synergy, developing capacities and capabilities, promoting the integration between initiatives and assisting in mobilising the approach to the management and funding structures in Europe, will ensure the effective implementation of the recommendations from the Position Paper. The ESF Marine Board has the commitment, capacity and willingness to play an active role in promoting the implementation of integrated marine research, as documented in this Position Paper; it will not only provide leadership, but will also monitor the implementation process. The ensuing observations, disseminated to the research community and policy makers on a regular basis, will allow readjustments, where appropriate, of the implementation strategy.

In addition to promoting the scientific recommendations, the ESF Marine Board will pay special attention to the implementation of the European and societal dimensions of issues identified in the Position Paper.

Main recommendations

The scientific, infrastructural and strategic recommendations that emerged from the IMS-Europe Position Paper are summarised below, according to the seven thematic categories by which the Position Paper is organised, namely:

1. **European and societal dimensions**
2. **Natural marine resources**
3. **Europe's coastal zones and shelf seas**
4. **Ocean climate interactions and feedback**
5. **New frontiers in marine science**
6. **Critical technologies**
7. **Research infrastructures**

1. European and societal dimensions

Science, society and citizens

1.1 **M**arine research and its discoveries are of strategic significance to Europe and of importance to its citizens. In addition, effective governance requires the participation of informed citizens. The European marine scientific community is encouraged to become more proactive in public debates concerning the marine environment, and in disseminating scientific information and analysis in issues of societal concern such as biodiversity loss, waste disposal, deep sea fishing, genetically modified marine organisms, CO_2 sequestration, climate change etc. *(see also 3.20, 4.9).* Marine scientists should be encouraged to develop an ethical dimension to their research, central to the concept of human stewardship of nature, sustainability and the precautionary principle. The ESF Marine Board network of national experts on scientific public awareness should take an active role in disseminating the latest marine scientific undertakings, discoveries and issues to educational and political institutions, and to the media. The newly created European Centre for Information in Marine Science and Technology (EurOcean), through the development of its Internet Portal, should be in a position to take a proactive role in this area.

Maritime regions, ultraperipheral regions and EU enlargement

1.2 **E**nhanced national and European investment in regional marine research and infrastructures could significantly contribute to the policy of reducing regional disparity in scientific knowledge, innovation, RTD (research and technology development) and competitiveness *(see also 7.2, 7.5, 7.6, 7.7).* Special attention should be afforded to developing cooperation with Newly Associated States, the Russian Federation, Eastern European countries and ultraperipheral regions.

Cooperation at the global level and with developing countries

1.3 **E**urope should actively support marine science and technology towards developing international collaboration on research issues. Europe has a history as an initiator of, and active partner in, international treaties dealing with the sea. It should continue to be proactively associated with research to support resolution of international issues including threats to fisheries resources, marine biodiversity, regulation of wastes and disposal of structures, deep ocean resources, and climate change. Development of scientific capacity, both at the national and collective levels of the European Union (EU), is necessary to support compliance with statutory obligations resulting from international conventions.

1.4 **C**ooperation with other countries, particularly developing countries with insufficient finances and expertise to adequately resource their marine science capability, should be central and prominent rather than peripheral to the integration of marine science in Europe. Europe should provide expertise for sustainability issues in developing countries, in particular where European Union Member States are actively involved in resource exploitation. Negotiation over resource exploitation (e.g. fishing, hydrocarbons) should involve the same precautionary approach to sustainability that would apply if the resources were located within EU waters. Within this context, the identification and establishment of coastal and marine protected areas (MPAs) in developing countries should also be a priority for Europe.

1.5 **E**urope should engage in partnerships to develop training programmes and research in developing countries. A comprehensive approach would involve coordination between European Union Member States, the European Commission (EC), the UN and host countries.

Human resources

1.6 **A**ttracting and retaining young people into marine research, facilitating mobility of researchers and technologists, and networking partnerships with industry *(see also 6.3, 7.2)* is a priority for developing and maintaining Europe's capacity as a leader in global marine research and technology.

Marine European Research Area

1.7 **O**ver 90% of European marine science is supported by national RTD agencies; considerable benefits would be gained from networking thematically similar national marine research programmes. ESF's EUROCORES and similar mechanisms such as the new instruments of the European Research Area (ERA) and the EC 6th Framework Programme (FP6) (e.g. Networks of Excellence, Large Integrated Projects, infrastructure support, ERA-Net, and the network of managers of Member States' national marine science programmes) should be fully exploited in this context.

2. Natural marine resources

Towards ecologically sustainable fisheries and aquaculture

2.1 **M**any commercial fish stocks have been depleted to critical levels and the associated environment degraded by overfishing and pollution. To achieve sustainable and ecologically viable fisheries and protect fisheries resources, research design should be based on the behaviour of the ecosystem. An enhanced strategic alliance and collaboration between fisheries, oceanography, marine ecology and socio-economic researchers, institutes and associations in Europe would facilitate further progression from species-specific research to ecosystem studies and models. Future fisheries research should endeavour to: (i) integrate fish stock studies with oceanographic, biogeochemical and biodiversity studies in an ecological perspective; and (ii) evaluate the ecological and socio-economic driving forces, implications and effects of different management regimes on fish stocks and the marine environment *(see also 2.5, 2.6, 2.12, 2.13)*.

2.2 **L**ong-term observations of fish stocks and environmental variability are essential to detect climatic drivers for predicting how greenhouse and other natural climate change scenarios might affect fisheries *(see also 4.4)*. Application of genetic techniques (*see also 2.4*) to stock assessment will assist in detecting population changes, and possible sources for re-establishment of depleted stocks. At the European level, commitment to decadal funding (beyond the current three to five-year funding cycle of national and EC Framework RTD) is essential for tracking climate variability and its impact on fisheries.

2.3 **R**esearch on technologies for selective and targeted fishing, and reduction of bycatch of other species, including birds and mammals, is essential to ensure that the fishing industry becomes more sustainable and impacts less on the marine ecosystem, by adopting a more ethical approach and taking responsibility for marine stewardship *(see also 2.6)*.

2.4 **A**quaculture production is rapidly increasing to support Europe's demands for consumption of fish. Research is required to: (i) identify new aquaculture techniques for improved husbandry, species diversification and genetic selection; (ii) ensure compatibility with environmental constraints and reduce environmental impacts (e.g. polyculture systems, sustainable feeds, combining ranching with wind farms); (iii) improve the vigour and diversity of stocks (e.g. genetic selection, vaccines, new species); and (iv) ensure compatibility with other coastal and maritime activities *(see also 2.5, 2.6, 3.1)*. State-of-the-art genomics techniques such as quantitative trait loci (QTL) and amplified fragment length polymorphism (AFLP), which have the potential to rapidly identify species-specific genetic markers for species identification, diagnostics etc. should be adopted by aquaculturists. These techniques, in combination with family selection by pedigree analysis, can enable very rapid improvement in strain characteristics, and so facilitate competitive advantage in the aquaculture industry *(see also 3.14)*.

2.5 **M**ethodologies should be developed to evaluate the economic impacts of: (i) implementing new policies; (ii) effects of ecosystem changes on resource characteristics; and (iii) the determinants of fisheries and aquaculture activities *(see also 2.12, 2.13)*.

2.6 **T**he conflicting requirement of sustainable fisheries and aquaculture, environmental protection and other competing human uses (e.g. shipping, recreation and coastal development) in the coastal zone should be a primary focus for marine socio-economic research and modelling *(see also 2.3, 3.1)*. The development of common indicators and indices of ecological status of habitat types, in particular geographical areas, would be of great benefit to fisheries management *(see also 2.12, 2.13)*.

New energies and wealth from the sea

2.7 **T**he ocean holds a vast reservoir of energy in the form of hydrocarbons (oil, gas, gas hydrates etc.), renewables (wind, wave, tides, geo-thermal and ocean-thermal etc.) and materials (aggregates, minerals, sea water chemicals etc.) of strategic or technological value to society. With appropriate incentives, European marine industries and science should forge new partnerships for a better understanding of the origin, location, and responsible sustainable exploitation of these resources. This will contribute to minimisation of environmental impacts and long-term risks from geological and climatic hazards, so that Europe can meet its increasing energy demands, while addressing concerns about greenhouse gas emissions and adherence to the Kyoto Protocol.

2.8 **T**here should be a concerted effort to improve cooperation between marine research groups and petroleum companies to: (i) explore new hydrocarbon reservoirs, especially in deep and ultra deep offshore areas; (ii) study the stability of the sediment layers of the continental margins *(see also 3.10)*; (iii) help understand and reduce the potential impact of hydrocarbon exploitation on the marine ecosystem; and (iv) develop the necessary technology. Research is also necessary to develop adequate observation and prediction systems to monitor oil spills and assess their potential impact *(see also 6.4)*.

Gas hydrates

2.9 The occurrence of global quantities of gas hydrates at continental margins is a potentially important new and relatively clean source of energy for Europe. Research on gas hydrates should afford special attention to: (i) their biogeochemical origins; (ii) their occurrence in association with carbonate mounds; (iii) their stability; and (iv) novel mapping and exploitation technologies. The environmental impacts of exploration and exploitation of gas hydrates should also be assessed *(see also 3.10, 3.12, 5.3, 5.4, 5.5).*

Renewable energy

2.10 Research on requirements for effective location, operation and harnessing of renewable energy sites, and optimal integration into domestic energy grids, is vital so that Europe can meet its increasing energy demands, while addressing concerns about greenhouse gas emissions and adherence to the Kyoto Protocol. Research is also required to estimate the impacts of new offshore structures and their hardground and turbulence effects on local sedimentation, marine benthic and pelagic life, seabirds, marine mammals and navigation *(see also 3.1).*

Aggregates and ore deposits

2.11 Research should be carried out in association with dredging and dumping of sediments to avoid effects of coastal erosion, to maintain the functioning of natural marine systems, and other activities such as fisheries. Enhanced procedures for effective environmental impact studies on coastal marine ecosystems are required before exploitation of ore deposits takes place *(see also 3.1).*

Socio-economics and marine resource sustainability

2.12 The economic and social values of the marine environment contribute to the GDP (Gross Domestic Product) and quality of life in Europe. Economic evaluations of the intrinsic resources of coastal and marine areas and the impacts of pollution damage, biodiversity change and improper management of these resources should be assessed. The conflicting requirements of sustainable coastal and marine resource management and its competing human uses with environmental protection in the coastal and marine area should receive special attention by socio-economic modellers *(see also 2.5, 2.6, 3.1, 3.15).*

2.13 Three categories of indicators should be prioritised for development: (i) indicators of marine science and technology;
(ii) socio-economic indicators;
(iii) environmental indicators to contribute to the implementation of effective resource management and protection protocols *(see also 2.6)*. These environmental indicators would encompass biological, geological, chemical and physical factors characterising the health of coastal and oceanic ecosystems. In addition, indicators should be developed with regard to the nature of pollutants and their relation to human activities and urban concentration *(see also 3.4)*. Such indicators would provide input to the reports on the marine environment produced by European organisations and conventions such as the International Council for the Exploration of the Seas (ICES), the European Environment Agency (EEA), the Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) etc.

3. Europe's coastal zones and shelf seas

Coastal zone

3.1 To meet the challenge of progressing integrated coastal zone management (ICZM) and governance, baseline interdisciplinary research is required. The strategies for ICZM should be based on integrating oceanographic, fisheries, geological and biological research with the requirements of sustainable resource use, maritime transport and offshore industries, and environmental protection *(see also 3.21)*. This will enhance resolution of the conflicting requirements of multi-user needs *(see also 2.6, 2.12)*.

3.2 Across Europe and its ultraperipheral regions, coastal developments and management actions are impacting on regional biodiversity. Within ICZM research, prioritisation should be given to investigating the environmental impacts and biodiversity consequences of increasing tourism and leisure in the littoral zone, port developments, intense aquaculture in inshore locations, selective fishing of top predators, and deep ocean disposal of domestic and industrial wastes including CO_2 *(see also 3.11, 4.9)*.

3.3 Estuaries, shelf seas and ocean margins are reactive highways for the transfer and transformation of terrestrial and anthropogenic products into the ocean. The transformation of these fluxes is generally poorly understood. Systematic research on biogeochemical budgets of nutrients (carbon, nitrogen, phosphorous) and their ecological effects are required for contrasting estuaries and shelf systems. Research should also focus on the fate of terrestrial carbon and pollutants in the ocean, and on the climatically important role of ocean margins as net sources or sinks of carbon *(see also 4.8, 4.9)*.

3.4 Europe faces dramatic increases in the numbers of organic and biotechnological compounds and pathogens discharged into the marine environment. These pollution mixtures exceed the monitoring capabilities of Europe's environmental agencies and there is a risk that major impacts on ecosystems will not be detected. Europe should rapidly adapt new array-biotechnological chips to provide non-invasive, affordable, and high-throughput systems for ecotoxicological screening of water quality *(see also 6.3)*. This would allow ecologically more meaningful toxicity-based discharge consents and toxicity-directed chemical monitoring strategies that can cope with the multitude of new chemicals discharged annually into European coastal waters. It would ultimately contribute to the development of reliable ecotoxicological indices of the status of oceanic and coastal waters *(see also 2.13)*.

3.5 Natural and anthropogenic causes of ecosystem variability should be characterised and distinguished, particularly in the coastal seas. Long-term, high-quality observations of climatic drivers, oceanographic, biogeochemical and anthropogenic parameters should be synchronised at critical points in the European coastal and marine areas *(see also 3.6)*.

Strategic observing and monitoring systems

3.6 Coastal areas are predicted to become increasingly vulnerable to the effects of global warming. Effects include sea level rise, increased frequency and intensity of storms, increased wave height, flooding of lowlands, inundation of installations and settlements (urban and tourist), changing erosion patterns, salt intrusion into groundwaters, littoral zone exposure to extreme winds, and increased river flows due to wetter seasons. A European long-term coastal observing network is required to contribute to monitoring and forecasting extreme events predicted to occur more frequently under greenhouse scenarios *(see also 3.5).*

3.7 **T**here is an overall requirement within operational oceanography for long-term climate simulations, models of climate predictions *(see also 4.2)*, models of monthly ocean currents, weekly meteorological predictions, and coastal current predictions of several days in advance. Few systems are currently in an operational state, and effort is required to improve observing and modelling methods and technologies *(see also 6.3),* capacity building and global collaboration. Updating European bathymetric charts is necessary to contribute to the development of more accurate models for operational oceanography *(see also 3.8, 3.9, 7.6).*

3.8 **R**esearch is required for the development of systematic means of acquisition (and production) of information from satellite and other sensor data delivered in a timely manner. There is a requirement for research to look beyond the oceanographic problem per se and include the processes required for data processing, data merging, and for data and product delivery *(see also 3.7, 3.9, 7.6).*

3.9 **T**he marine element of GMES (Global Monitoring for Environment and Security), as devised by the European Space Agency (ESA), Directorate General (DG) Research and DG Environment of the European Commission (EC), provides a mechanism to coordinate and optimise research efforts with monitoring efforts and improved information systems for operational service providers, which will lead to enhanced product development. There are intrinsic research and technological challenges associated with both the effective implementation of GMES, and the maximisation of the results and ensuing products. The scientific, technical, socio-economic and institutional elements of the marine research community should be supported and coordinated to ensure effective involvement in GMES. The ESF Marine Board is ideally placed to enhance connections between the scientific community and ESA, the EC's DG Research and DG Environment, contributing to effective and optimal implementation and application of the marine element of GMES *(see also 3.7, 3.8, 7.6).*

Ocean margin processes and geohazards

3.10 **S**eabed operations such as oil production and communication cables are vulnerable to geohazards, including gravity slides, earthquakes, and sudden releases of methane from gas hydrates. Deep ocean observation tools and systems fitted with advanced geotechnical sensors are required to supply data on sediment dynamics and stability at ocean margins *(see also 2.9, 3.12, 5.3, 5.5).* This will allow assessment of the scale and frequency of mass sediment flows along ocean margins, and contribute to risk assessment for submarine cables and hydrocarbon exploration structures.

3.11 **T**here is a requirement to investigate the sources, properties, transport and budgets of terrestrial and marine sediments in contrasting European coasts, emphasising the biological influence (stabilisation, cohesion, irrigation, storage) of the global carbon cycle. Evaluation of the carbon depocentre role of different ocean margins and an assessment of the potential for atmospheric CO_2 sequestration at the European continental margins is also necessary *(see also 4.8).*

3.12 Research is required to analyse the role of gas hydrate reservoirs as dynamic components of the global carbon cycle, recharge and discharge fluxes and their controlling factors *(see also 5.4).* There is a requirement to investigate the mechanism of gas hydrate destabilisation and potential geoclimatic hazards and to evaluate the impact of gas hydrates on slope destabilisation. Geotechnical and sedimentological research in association with the hydrocarbon industry is needed to mitigate against these risks *(see also 2.9, 3.10).*

Marine biodiversity: the blueprint for ecosystem regulation

3.13 Marine biodiversity is increasingly impacted by dredging, pollution, overfishing, hydrocarbon exploration and drilling, coastal development, climate change etc. For large-scale monitoring of biodiversity changes in Europe, marine biologists should focus on identifying and agreeing a set of key species (at different taxonomic levels), their niches and functional role. Large-scale biogeographic distribution and biodiversity gradients should be GIS-mapped spatially and temporally in association with oceanographic and geological parameters. Areas identified as of high species and genetic diversity should be the focus for conservation and management efforts, such as the designation of marine protected areas (MPAs) and exclusion zones in shallow and deep waters *(see also 3.14, 3.15, 5.5).* Particular attention should be afforded to establishing the functional biodiversity associated with cold water corals and gas hydrates *(see also 5.3, 5.4).*

3.14 As retiring taxonomists are not being replaced, and yet are vital to research on all aspects of marine biology, there is a requirement to invest in taxonomic education and establish effective career paths *(see also 1.6).* Europe's marine taxonomists should integrate their national research and monitoring activities within large-scale European initiatives in marine biodiversity, and with both population biologists and geneticists. Taxonomic keys require updating, and future taxonomic work should link numerical taxonomy with genomics techniques. Rapid transfer of QTL and AFLP techniques *(see also 2.4)* to a range of marine organisms will greatly improve the ability to resolve population structures and provide estimates of population sizes, and thus status. Europe's classical taxonomic archives, specimen collections and genetic databases are scattered and require integration, and inclusion in the Global Biodiversity Information Facility (GBIF). Further integration of genetic databases with predictive modelling will provide an understanding of the potential impacts of environmental risks, climate change and exploitation.

3.15 Improved understanding of complex marine populations and genomics will yield more robust biodiversity indices required to underpin conservation and socio-economic valuation *(see also 2.12, 3.13, 3.14, 3.16).*

Functional role of biodiversity

3.16 Research by fisheries biologists, ornithologists, mammologists and marine conservation scientists should be coupled to a more general ecological knowledge of the seas and marine food webs to better understand the relative importance of top-down regulation of marine food webs versus the traditional approach in which bottom-up control (nutrients and primary production) is emphasised. A concerted European action should be developed to understand the role of the relatively few key marine vertebrates, as an efficient method of studying how species impact on ecosystem functioning. Efforts should be made to improve the involvement of vertebrate biologists and ecologists in marine biodiversity networks.

Microbial biodiversity

3.17 **R**esearch is required into the role of microniches and microscale dynamics in sustaining symbiotic consortia of microorganisms. The role of infochemicals, toxins, attractants, biopolymers etc. in shaping pelagic microbial communities and in biotechnological products requires further investigation in order to be understood *(see also 5.1)*. There is a requirement for the development of gene probes for *in situ* detection of the abundance and activity of biogeochemically important processes *(see also 3.19, 4.12),* and for classification and detection of viral particles and their infective impacts on bacterial and phytoplankton blooms.

Effects of climate and anthropogenic changes on marine biodiversity

3.18 **R**esearch on the impacts of climate change on marine biodiversity is necessary. Particular attention should be directed towards an agreed set of key organisms, which could act as indicators of ecosystem functioning *(see also 3.16)*. Such information will provide a functional understanding of biodiversity and species composition of communities, which can then be used to model and predict the response to global environmental change.

3.19 **R**esearch on the impacts of climate change on microorganisms should include assessment of those that: (i) are important in shaping the marine food web; (ii) control ocean biogeochemistry; (iii) have potential for bioprospecting and biotechnology; and (iv) have a potential human health impact (e.g. harmful algal blooms) *(see also 3.17, 4.4, 4.12, 5.1).*

Integrated governance of European oceans and seas

3.20 **E**urope needs to rapidly move towards a sound and true governance of its oceans and seas, integrating all components for a comprehensive and responsible management of its marine assets. While the development of effective governance requires as its basis sound scientific knowledge, the European Commission (EC) and the European Parliament should be instrumental in developing this issue. This will lead to an effective assessment and management of the resources within the Exclusive Economic Zone (EEZ) of each maritime Member State. A forum of marine scientists and policy makers should be convened to ensure effective communication and synergy between both parties for timely deliverance of relevant and sound scientific knowledge to policy makers.

3.21 **T**o meet the challenge of progressing integrated ocean management and governance, baseline interdisciplinary research is required. The strategies for ocean governance should be based on integrating oceanographic, fisheries, geological and biological research with the requirements of sustainable resource use, maritime transport and offshore industries, and environmental protection *(see also 3.1).*

4. Ocean climate interactions and feedback

Climate change in Europe

4.1 **R**esearch is required to improve the temporal resolution in the reconstruction of climate history in oceanographic relationships in scales from ten to one hundred years. Numerical ocean and climate models of the climatic events of the past should be improved. Continuous development of organic geochemical proxies is required for reconstructions of past surface CO_2 content, temperature, pH values and nutrients. Improvement of proxies for the reconstruction of palaeosalinity, an important variable for modelling, is required. Documenting climate variations of the Holocene epoch will also be an important area for future research.

4.2 **T**here are extensive requirements for long-term climate simulation models of climate variability and seasonal climate predictions, essential for forecasting. Efforts should also be directed towards research on regional modelling (e.g. in the Mediterranean). There is a requirement for validated methods to turn data into information, in the form of integrated assessments and indicators, and for improved methods to assimilate data into models. There is a strong case for the European Commission to invest in a computing centre and a high-speed network for ocean and climate modelling.

4.3 **T**here is a research priority to gather the vast amount of palaeoclimate records into databases and to analyse them spatially and temporally. The combined use of palaeoclimate data and palaeoclimate models would advance the understanding of mechanisms of climate change.

4.4 **P**redicting the response and feedbacks of marine biota to climate change is required *(see also 3.18, 3.19)*. Experimental and numerical studies using climate-simulating mesocosms (climatrons) could unravel the basic biogeochemical links and responses of climate-critical planktonic species (e.g. diatoms, coccolithophorids, N_2 fixers, bacteria, viruses, Archaea) to physical drivers of climate change (e.g. temperature, pH, CO_2, solar radiation) and their biogeographic consequences *(see also 4.11, 4.12)*.

Ocean thermohaline circulation – Europe's heat engine

4.5 **T**he Atlantic thermohaline circulation (THC) is the regional heat engine responsible for the temperate climate of Northern Europe. Preliminary observations and models suggest that the THC is weakening in response to greenhouse forcing. Multidisciplinary long-term observational networks are required to monitor the evolving dynamics of the THC. Research effort should focus on key deep Arctic or sub-Arctic gateways for outflowing cold dense water, and the return flows of warm surface currents in the world ocean.

4.6 **G**lobal models of ocean-climate coupling and the THC should be downscaled to faithfully incorporate: (i) flux-critical processes of convection, overflows and boundary currents; (ii) teleconnections between the Pacific El Niño and North Atlantic Oscillations (NAO), and between the NAO-IO (North Atlantic-Indian Ocean) dipole and Mediterranean climate; and (iii) local and regional impacts on, and responses of vulnerable European seas to greenhouse forcing. The impact of outflow of Mediterranean waters into the Atlantic and their behaviour in the Atlantic Iberian region also requires further attention.

4.7 With observation networks in place, there will be a requirement for new methods to assimilate data into Atlantic and Mediterranean circulation models *(see also 4.2)*, including the NAO and its regional climate and ecological consequences.

Ocean biogeochemical impacts and feedbacks in a greenhouse ocean

4.8 All future greenhouse scenarios predict a globally warmer, more stratified and acidic upper ocean that could significantly reduce both convective and biogeochemical export sinks of atmospheric CO_2 into the deep ocean. This would accelerate accumulation of CO_2 in the atmosphere, with associated risk of accelerated greenhouse warming. To reliably predict future CO_2 levels, research is essential to further elucidate the drawdown mechanisms, absorption limits and oceanic budget for anthropogenic CO_2 under greenhouse scenarios *(see also 3.3).*

4.9 The United States and Japan are presently undertaking extensive trials in the Pacific Ocean to assess whether deep ocean disposal of liquified CO_2, or iron fertilisation, can be used for large scale removal of CO_2 into the deep ocean. Europe should conduct independent studies and evaluations to objectively debate the environmental feasibility, usefulness, ethics and impacts of ocean carbon sequestration options. Interactions between decision makers, scientists, environmental NGOs and the public should be promoted to avoid any misunderstanding about such sensitive issues, and to ensure effective stewardship of ocean resources *(see also 1.1, 3.20).*

Ventilation of marine biogases and fertilisation feedbacks

4.10 Research on present-day air-sea fluxes of climate critical biogases (CO_2, DMS, N_2O, CH_4), particularly their regional and seasonal variability, is needed for global assessment of their role in climate change. The biogenic sources, distributions and pathways responsible for production, transformation and efflux of climatically reactive marine biogas compounds should be investigated and modelled under present and future climate conditions.

4.11 There is a requirement to develop coupled physical biogeochemical ocean climate models (*see also 4.2*) that incorporate carbon speciation and nutrient dynamics in order to predict changes and feedbacks in global and regional ocean productivity under greenhouse scenarios *(see also 4.4, 4.12).*

4.12 Single-celled marine microorganisms (bacteria, Archaea, protozoa, phytoplankton etc.) are abundant, diverse and productive and are the principal drivers of marine and global biogeochemistry. Support should be directed towards adapting biogeochemical gene probes, coupled with phylogenetic probes, to enable the application of high-throughput bioanalytic technologies (e.g. analytical flow cytometry, microarrays) (*see also 6.3*) for shipboard use in large-scale oceanographic exploration of microbial biodiversity, food web dynamics and biogeochemical feedbacks in diverse oceanic environments *(see also 3.17, 3.19, 4.11, 5.1).*

5. New frontiers in marine science

Marine biotechnology: bioprospecting the planet's largest biotope

5.1 **M**arine biotechnology has the potential to bioprospect the vast genetic richness of the ocean to discover new materials, including pharmaceuticals, agrochemicals and cosmetics. A European flagship project in marine biotechnology is required to bring together the excellent but sub-critical RTD groups in Europe into a common endeavour with industrial biotechnology partners. Enhanced research efforts in marine genetics would also contribute to improved competitiveness in biotechnology *(see also 2.4, 3.14, 3.17, 4.12)*. In addition, bioprospecting should be integrated into future oceanographic expeditions.

5.2 **A** European network promoting dissemination of marine biotechnology discoveries, and collaboration between marine biologists, biotechnologists and industrialists should be established to screen biotechnology compounds from marine organisms, and encourage sustainable exploitation of new biotechnology discoveries in Europe and to limit associated environmental impacts.

New ecosystems at oceanic extremes

5.3 **N**ew organisms, evolutionary lines and geochemical processes are continually being discovered at deep seafloor, sub-seafloor and extreme environments (e.g. hydrothermal vents, cold seeps, sub-seafloor bacteria, cold water corals). It is necessary to develop new technologies for observation, sampling and experimentation in the largely unknown ecosystems of the deep ocean as well as techniques for cultivation of organisms from extreme habitats. Deep ocean vehicles and observatories should be upgraded with smart sensors *(see also 6.1), in situ* experimental capabilities and two-way telemetry for remote exploration, experimentation and monitoring of extreme ecosystems and their response to climatic and episodic events, and to integrate these with historic data for decadal to centennial scale analysis. Such observatories are required to establish baseline studies that adopt an ecosystem approach, a priority in advance of management of deep ocean resources *(see also 2.9, 3.21, 6.2)*. Improved long-term observation of key terrestrial biomarkers and xenobiotics at specific deep oceanic locations will increase understanding of how the flux of material from land, or the alteration of surface ocean processes, ultimately affect the deep sea ecosystems. Marine protected areas (MPAs) will be needed to safeguard the recruitment of species and the biodiversity of the associated ecosystems (*see also 3.13*). The choice of such areas has to be guided by scientific insight and not solely by the requirements of the fisheries industry.

5.4 **A**n assessment of the role of oceanic gas hydrate reservoirs as hosts of deep biosphere ecosystems is also required. Major consideration should be given to developing a European research programme on gas hydrates to facilitate an integrated implementation of the various recommendations related to gas hydrates in this Position Paper *(see also 2.9, 3.13, 5.3, 5.5)*.

5.5 **R**esearch on the specific adaptations of organisms to a range of extreme conditions found in habitats of the deep ocean is required. Research on the vertebrate populations supported by these extreme habitats should also be initiated, and can largely be done in an interdisciplinary manner concurrent with geological and oceanographic surveys. The results of such baseline studies will contribute to effective management and governance of ocean resources *(see also 3.13, 3.16, 3.21, 5.3, 5.4).*

Vents and seeps

5.6 This area of research requires quantification of the transport of material and energy in hydrothermal systems and improved modelling of fluid convection systems. Distinction between fluids originating from heated sea water and those released by fractional crystallisation of underlying magma is required. There is also a requirement to understand and quantify the influence of fluids on sea water composition. Understanding primary generation of hydrocarbons at mid-ocean ridges and considering the volumetric importance of oceanic serpentines, the associated catalytic reactions and the resulting fluxes, requires attention.

5.7 The thermal structure and fluid regimes in areas of colliding plates should be investigated. Quantification of the contribution of cold vents to the geochemical balance of various elements with fluids is also required (i.e. how much carbon, sulphur, water and halogens are introduced into the ocean). Research is required to determine transport paths in mass transfer and the respective contributions of focused and diffuse dewatering. There is a requirement for research on: (i) biological mediation of precipitations at fluid flow sites; (ii) periodicity and transient effects; (iii) integrating early diagenetic material fluxes in models of ocean circulation; and (iv) the relationship between flow, tectonics and earthquakes.

6. Critical technologies

6.1 Marine science and oceanography are critically dependent on advanced technologies to observe and understand ocean ecosystem dynamics and processes. Marine technologists should be encouraged to: (i) assess, convert and apply novel miniature sensors arising from bioanalytics, nanotechnology and advanced materials science (*see also 3.4*); (ii) standardise interfaces of system components, and components of novel technologies; and (iii) network national calibration facilities.

6.2 To understand and predict ocean-climate coupling and the sustainable use of marine resources, and to describe the European component of global systems, long-term baseline funding for the development and operation of ocean observatories is required *(see also 5.3).* These are European responsibilities of profound significance to its citizens, and also to the world, transcending the responsibilities and resources of most national programmes. Therefore, a special effort should be made to ensure a visible and effective research contribution by Europe to this domain.

6.3 Development of effective industrial partnerships would accelerate development, sales and use of sensors by marine scientists *(see also 1.6, 7.2)*. Particular priorities for sensor development include: (i) development of new sensors for biological and chemical parameters; (ii) development of new systems: multiparameter, networking architecture; (iii) ensuring cost effectiveness: long-term components and high spatial density deployments; and (iv) appropriate infrastructure: two-way data communication and control.

6.4 Collaboration with offshore oil and gas platforms, with their own network of telecommunication cables and infrastructure that could be efficiently adapted for shelf ecosystem and pollution observation, would clearly benefit European marine science, technology and industry *(see also 2.8).*

7. Research infrastructures

7.1 **A**vailability of an oceanographic fleet, and associated equipment including underwater vehicles, will continue to be essential for research at sea. There are strategic requirements for a set of European policies and arrangements to maximise the use of these infrastructures on a pan-European scale and to advise the European Commission and national agencies on new specifications, improved access and cost sharing for these infrastructural investments. The strategic vision exists and the tools for collaboration and coordination are already available, and should be consolidated within the timeframe of the European Commission's FP6.

7.2 **E**urope should widen its support for integrated marine science by incentives for scientific and industrial partnerships and enhanced mobility. Researchers must be encouraged and facilitated in developing industrial links, including Public Private Partnerships (PPPs), to maximise the manufacture and exchange of novel technologies within Europe and to maximise European industrial competitiveness, for the benefit of both marine science and society *(see also 2.8, 5.2, 6.3).* Attracting and retaining young researchers into marine science is particularly important to ensure continued development of European capacity and capability *(see also 1.6).*

7.3 **A** revised effective European data policy should be rapidly elaborated and put into action to ensure: (i) secure storage of appropriate data; (ii) quality control; and (iii) interoperability and open access for science in a timely manner to the petabytes of data and products expected from the next generation of ocean observatories and operational forecasts.

7.4 **A** forum should be established to address the issues of data standards, indexing, transfer and storage. This forum would provide a focus for increased coordination and cooperation between researchers, agencies and authorities.

7.5 **A**s part of the European enlargement process, investment in regional marine research and infrastructures should be enhanced so as to reduce regional disparity in scientific knowledge, innovation, RTD and competitiveness *(see also 1.2).*

7.6 **E**urope's capacity for oceanographic monitoring from space should be enhanced, in particular with regard to research satellites for observing new parameters such as thickness of sea ice, surface salinity etc. In addition, there should be further investment in periodic satellites for observing oceanic evidence of climate change *(see also 3.8, 3.9).*

7.7 **I**nvestment priorities for marine research should be agreed across Europe, and should be designed so that they are not constrained by the limited lifecycles of national and European Union funding programmes. This will ensure not only long-term viability of observation networks, but also retention of capacity and capability within Europe.

Summary of Actions for Implementation

The focus for implementing the recommendations from the IMS-Europe Position Paper will be on the use of the existing instruments, primarily national, ESF and European Commission instruments. Through an iterative process of consultation, barriers to the use of the existing instruments will be identified and brought to the attention of the responsible bodies. The following steps will be taken to put the recommendations of the Position Paper into action.

National level

1. The ESF Marine Board Member Organisations will take initiatives at the national level in their own country to disseminate information and promote the implementation of the recommendations among the scientific community and the decisions makers. This in turn should contribute to national marine science programmes and the outcomes should be brought back to the ESF Marine Board as part of an ongoing process. This process should ideally lead to initiatives by national scientific communities and national funding agencies for a European-scale cooperation, possibly through bilateral and multilateral programmes.

European Science Foundation (ESF) and other European organisations

2. The ESF Marine Board will initiate internal consultations with the other ESF bodies with regard to joint European initiatives to promote the implementation of the recommendations in the Position Paper. It will promote activities towards the further development of such initiatives in the scientific and technological communities. Within the ESF, useful instruments include Networks, Programmes, Scientific Forward Looks and Conferences. For the development of collaborative research programmes with broad participation of the scientific community, instruments such as the new ESF EUROCORES scheme offer promising opportunities.
3. The recommendations from the *ESF Forward Look on Earth System Science: Global Change Research* will be considered for initiatives in the area of monitoring and technology development, as well as for research into the role of the oceans and seas in the climate system.
4. The ESF Marine Board will actively participate in discussions in the development of the European Research Council (ERC) concept. This Position Paper will be instrumental in ensuring the inclusion of marine science within the ERC and facilitating the use of marine science as a pilot case.
5. The ESF Marine Board will develop cooperation with existing European organisations with interests in marine science and technology in order to promote synergies and to avoid duplication of activities, in particular through improved exchange of information. To achieve this objective, the ESF Marine Board will work in association with the European Centre for Information in Marine Science Technology (EurOcean) and other relevant European organisations.

European Union

6. The European Commission has, within FP6, a range of instruments that are highly relevant to the implementation of the goals of this IMS-Europe Position Paper. As a result:
   - The ESF Marine Board will support the European Union Member States' initia-

tive to create a network of managers of national marine science programmes.

- The ERA-Net instrument of EC FP6 will, if possible, be used to help support the cost of coordination of collaborative programmes.
- The ESF Marine Board will observe the development of Networks of Excellence and Large Integrated Projects under FP6, and if necessary take steps to stimulate the development of such initiatives in specific areas, as defined in the Position Paper, which are not yet covered.
- Comprehensive research infrastructure is an important prerequisite for the success of a European marine research strategy. The ESF Marine Board will play an active role, through, among other things, discussion with the European Commission and networks established by European Union Member States, in contributing to the long-term strategy for marine infrastructure investment, including progress towards coordination of infrastructural management, and facilitating European-wide access to existing national infrastructures. If necessary, the ESF Marine Board will take additional initiatives in line with the role outlined for the ESF in the European debate about research infrastructure in general.

7. The motivation for the ESF Marine Board in producing the IMS-Europe Position Paper was to provide an integrated marine science vision for input to national RTD, and to the European Research Area (ERA). Thus, this Position Paper has a specific role in elaborating and promoting the European Research Area (ERA). Achieving the goals of the IMS-Europe Position Paper go beyond DG Research to other relevant Directorates General of the European Commission (e.g. DG Fisheries, DG Environment, DG Regions, DG International Cooperation). Specific actions for collaboration with these Directorates General and other appropriate European bodies (e.g. the European Parliament, Council of Europe, Committee of the Regions, Committee for the Ultraperipheral Regions) will be developed by the ESF Marine Board.

International level

8. Progress in marine science requires global cooperation. Europe itself has strong global interests as a consequence of its links with overseas areas. The responsibility for capacity building in developing countries requires a global perspective. A strong, well-articulated and integrated European marine science effort is also a prerequisite for effective partnerships with the United States and Japan. The ESF Marine Board has the commitment, willingness and capacity to play a leading role in the development of research links between Europe and its partners on a global scale and with international organisations (particularly the UN International Oceanographic Commission, IOC, and the International Council of Science, ICSU).

> ***"More has been learned about the nature of the oceans in the past 25 years than during all preceding history…. However, what we know about the oceans is still far outweighed by what we do not know".***
>
> "The Ocean, Our Future", Report of the Independent World Commission on the Oceans (1998)

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