GLOBAL CHANGE AND ECOSYSTEMS
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Coordinator: Hellenic Centre for Marine Research, Greece

A SCIENCE PLAN FOR THE REGION

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1. Introduction

The outcome from each WP, has been used to create the Science Plan for the Mediterranean and Black Sea Region. Apart from project deliverables, synthetic reports containing description of status, conclusions and recommendations have been produced within the WPs, in order to enable WP6 members to elaborate the Science Plan. A draft version has been presented to the Project's Final Conference in Istanbul, May 11th 2006 and proved to be very realistic and comprehensive. Comments and contributions after the Conference, as well as the particular needs of the two Conventions (UNEP/ MAP and BSC) as they were presented during the Conference, have been taken into consideration in order to upgrade and finalise the Plan.

The structure of the Plan follows mainly the categorization adopted in IASON Project, reflected also in the formation of the particular WPs.

2. Ecosystem functioning of the Mediterranean and Black Sea

The Mediterranean and the Black Sea are very sensitive areas, with highly stressed ecosystems. The complete recovery of the Black Sea in particular is expected to be a long process whose continuation without human intervention is questionable, so that in the future a joint effort of the riparian countries is deemed as absolutely necessary for recovery through for instance the adoption of adequate legislation addressing pollution and other pressures on the marine ecosystem, the construction of purification plants in the littoral human settlements and along the tributary rivers, supporting research and monitoring through national and international programmes and strengthening international cooperation in the framework of existing organizations.

Over the next decades, ecosystem pressures are expected to increase and it is therefore imperative to predict possible scenarios depicting the future state of the two seas. The evaluation of a described pattern, after the identification of the processes leading to it, should be made by using the "tools" provided by ecological theory, in order to make scientifically sound decisions about our future behavior. The current findings of the synthesis of the physical features of SES with their bio-ecological conditions have been put into a theoretical framework, to develop a series of evaluations and projections on the possible future of SES ecosystems.

Past and present policies of the European Union are based on key concepts, stemming from prevailing theories. Popular examples are: the precautionary principle, the ecosystem approach, the importance of habitats for biodiversity management and protection. A leading perception of the value of biodiversity, stemming from ecological economics, is not linked to its intrinsic value but on the benefits that we might draw from it, in terms of goods and services. Ecosystem stability is perceived as one of the advantages deriving from conservation, in order to have a constant flow of benefits from the protected environment. The concept of stability, however, has been challenged in its generality since several decades. Furthermore, in the case of marine habitats, stability is not perceived as the same as for terrestrial ones. A sister concept to stability is more applicable to the marine environment: multiple stable points. Stability, according to this view, is both dynamic and recurrent.

In comparison with that of NES, the thermal excursion of SES is great, with the spatial (but not temporal) coexistence of two types of biota: a cold-temperate one in the cold season (at least in the coldest parts of the basin) and a tropical one in the warm season. It is obvious that the two seasonal systems are very different in features and it is also obvious that the greatest biological diversity (in terms of different adaptations) of the European marine biota resides in the SES. However, this peculiarity is not recognized by proper legislation. There is a rather land-based approach with a tendency to concentrate on marine aspects that regard only marginally the peculiarities of SES. Therefore future policies need to be greatly re-elaborated in order to include the core of marine biodiversity of the European Seas, both as habitat types and as species. **The threats to the integrity of SES can stem only from a proper appreciation of the targets of possible impacts**.

A commented list of possible threats and hazards to the Mediterranean and Black Sea ecosystems includes urban pollution, harmful algal blooms, agricultural pollution, industrial pollution, coastal erosion, over-fishing, the transport of alien species, global warming and an increase in the success rate of opportunistic species. The advised actions to address these threats and hazards involve:

Improve the understanding of ecosystem functioning

Even though this seems a rather logic issue, basic research on biodiversity and ecosystem functioning is far from being pursued in a strategic way. The required actions are manifold:

- ⇒ Enhancing existing monitoring activities, identifying possible improvements of the existing operational oceanography projects in order to improve our capacity to monitor (and possibly predict) inter-annual variability.
- ⇒ Deploy additional dedicated networks. Focus on measuring trends of hydrographic properties in deep isolated basins and volume fluxes across Straits. Find a reference level for all tide-gauges measurements. Improve assessment of air-sea and riverine fluxes for the two seas. Deploy dedicated moorings for improvement of air-sea bulk formulas for Mediterranean and Black Sea regions. Establish WOCE-type transects and stations to monitor the variability through the water-column.
- ⇒ Improve understanding of physics regarding the exchange of the two seas. Develop models where the two Seas are fully coupled, as well as fully coupled with the atmosphere.
- ⇒ Improve the understanding of the role of teleconnections on the system, as well as the way teleconnections will be affected by global warming.
- ⇒ Possibly, identify means for international organizations to contribute to nationally funded long-term monitoring projects.
- ⇒ Make a complete biodiversity inventory for SES, both in terms of species and habitat types.
- ⇒ Map the distribution of habitat types; this is currently being carried out only for *Posidonia spp*.
- ⇒ Build conceptual models of ecosystem functioning and test its variation with proper experiments, coupling physical change with biotic change, and vice versa.
- ⇒ Improve the understanding of how anthropogenic forcing (mainly eutrophication and over fishing) may lead to an increase in harmful algal blooms in SES.

Improve the understanding of thermohaline variability.

While meteorological climate projections converge to more warm and dry climate for the SES regions during the twenty first century, it is not yet possible to convert such meteorological information to projections regarding the response of the thermohaline circulation and hence the biogeochemical functions of the marine ecosystem. The required actions involve:

- ⇒ The gradual construction of good-quality, consistent time series concerning the thermohaline circulation of the SES system, in parallel with
- ⇒ The development of circulation models of the combined SES system, fully coupled with the atmosphere.
- ⇒ Assessment of the models' validity for long-term climatic projections through comparison with the observed thermohaline variability during the instrumented period, and improvement of the monitoring strategies currently employed

Acquire the conceptual tools for distinguishing between "normal" and "altered" and to detect the sources of alteration

The necessity for such tools is linked to the fact that changes in ecosystem functioning derive from changes in the drivers of ecological processes. These drivers can be physical (e.g. temperature increase), biological (sudden bloom of an opportunistic species that forms a huge population for a short time and then disappears, arrival of an alien species that impacts on other components of the biota, etc.) or driven by human activities that must be mitigated. Usually the three drivers are not mutually exclusive. Natural systems are driven by multiple causalities so that it rarely occurs that a single cause might explain a given situation.

Improve public awareness on environmental problems

A bridge is to be built connecting for instance the scientific world and the general public, and scientists are to be taught how to communicate their findings, especially to decision makers (including EU officials).

3. Current state and trends of marine resources

Sustainable exploitation of non-living marine resources

The unique hydrography of the Mediterranean with warm deep waters, deep-water mass formation and its oligotrophic character, coupled with the extreme environmental conditions encountered in the Black Sea make the issue of sustainable exploitation of non-living resources very important in the area. Significant questions on the regional and global (worldwide) importance of fluid vents and associated gas hydrate accumulations are still pending.

Future requirements, particularly in the eastern Mediterranean area point to the need for:

- ⇒ detailed sea mapping to locate hydrothermal areas and volcanic hot spots as well as
- ⇒ where further gas hydrates occur, their quantity and whether they can be recovered
- ⇒ ecosystem research on areas of hydrothermal activity and mud volcanoes
- ⇒ a better understanding of the inter-connectivity of these unique ecosystems

The most important research issues yet to be addressed in the Black Sea area relate to:

- ⇒ The role of sub-surface methane and other gases to global climatic changes, particular those related to marine geochemical cycles;
- ⇒ The relative importance of sea-floor seepage as indicators of hydrocarbon fields below the surface;
- ⇒ Ecosystem research on mud volcanoes and other areas of significant gas seepage;
- ⇒ Gas hydrates as proxies for old climatic conditions, development and preservation of gas hydrates on continental margins;
- ⇒ Gas seepage and gas hydrates as inducers of slope instability on continental margins.

Sustainable exploitation of marine fishery resources

Fishing activity in the region is a substantial source of food resources and economic gain for people engaged in this sector. At the same time the collapse of fish stocks worldwide is indicative of management failure to sustain this natural resource.

It would appear that a negative shift in the state of most commercially important fish species necessitates developing and applying measures guaranteeing the sustainable utilization of all living marine resources that while recoverable are not inexhaustible and thus have to be used and managed in an appropriate manner. This poses the question as to whether there is also a need to re-examine the concept of marine sustainability, possibly placing greater emphasis on the concept of marine adaptability.

At present, the management of commercially exploited stocks is based on scientific advice. The uncertainties inherent in this advice are generally large and the costs to the fishing industry and the environment are substantial. Obvious limitations in current approaches are due to a variety of causes: imprecise survey methods, the neglect of ecosystem constraints and climatic effects in final resource assessment, erroneous reporting from the fishing industry itself.

The adequacy of provisions concerning gear specification, gear deployment, fishing practices or techniques, fishing seasons or areas, and resource exploitation patterns, commonly known as technical measures have yet to be verified, in the absence of satisfactory results from

scientific investigations on spawning or nursery grounds, first maturity sizes, mesh selectivity studies etc. Clearly there is a need for an improvement of scientific knowledge regarding these investigations.

The lack of reliable official statistics on i.e. fish catches and the structure and capacity of fleets is a considerable handicap for researchers who must devote a significant proportion of their resources to estimate the corrective factors to apply to official statistics.

Recent policy deliberations are putting particular emphasis on the ecosystem effects of fishing. Challenges in assessing and responding to the ecosystem effects of fishing include determining the magnitude, spatial extent, and mechanisms of change in marine food webs. Ongoing research and assessment would be required in the region to understand the temporal and spatial extent of fishing impacts and to support the implementation of ecosystem considerations in fisheries management actions.

The scientific basis for a fisheries management system taking into consideration the conservation of Mediterranean and Black Sea ecosystems is suggested to be:

- The cooperative setting up of a fishing effort control system, the basic requirement being to build a close to real-time database of information on fishing vessel operations, linked to some form of regularly updated vessel registration list, according to a proper fleet typology that allows to establish standardized fishing vessel lists, which have to be regularly upgraded.
- The development of cooperative research programmes to monitor the environment and resources and to support the implementation of ecosystem considerations in fisheries management actions.
- Regional standardization of the methods, means of sampling, processing, analysing and interpreting the data.

4. Current state and pressures on the Mediterranean and Black Sea coastal zone

The compilation of all available information concerning anthropogenic pressures on the Mediterranean coastal zone has clearly revealed a number of coastal 'hot spots' that deserve special attention in the future: i.e. the Spanish coast, the Gulf of Lions, selected coastal areas in the Ligurian Sea, the northern Adriatic Sea and the Albanian coast, Saronikos and Thessaloniki Gulfs in the Aegean Sea, and the Nile Delta. It appears that the above regions are influenced both by river discharges and coastal urbanization and industrialization, resulting in euthrophication, heavy metal and organic substances pollution, as this is recorded in surface sediments. It remains to combine the above results with the impacts on ecosystem functioning and biotic resources. In an overall assessment, it can be deduced that pollution problems affect in most cases relatively confined areas and the phenomena are generally not widespread along the Mediterranean coast. Data from the northern African coast are generally lacking and emphasis should be stressed in the future on the participation of northern African countries in research projects.

When focusing on anthropogenic pressures on the coastal zone, one encounters lack of consistent and reliable scientific knowledge and information on many processes and phenomena in the Black Sea that are essential for policy and decision-making. Future needs point out to:

- ⇒ Further studies on biological effects of pollution;
- ⇒ Harmonizing analytical methodologies and implementing QC and QA procedures at regional level, in order to provide reliable data.
- ⇒ Development and harmonisation of marine environment quality standards in the Black Sea region for seawater and sediments

The effects of global change and anthropogenic forcing on the coastal zone exhibit many similarities in both Seas. While the findings point to a clear and urgent need for complex, continuous and detailed research and observation systems on combined stresses, **coastal erosion** has been singled out as a resulting phenomenon of particular concern.

Prospective studies in the Mediterranean will focus on addressing the requirement to properly quantify the extent and validate the appropriate means of coastal erosion protection or remediation in both the near term and long term. To achieve this it is necessary that appropriate sedimentological studies are carried out, at least at existing and future potential hot spots, using advanced sedimentological numerical models, such as DELFT3D or MIKE21. These models need to be calibrated and validated based on high resolution bathymetric and topographic repetitive maps employing multi-beam and Lidar systems, good quality data of wave and currents climate based on measurements using directional wave gauges and ADCP systems as well as wave hindcasting and forecasting modelling.

Priority issues in the Black Sea to be addressed in future programmes include:

- ⇒ The development of a coherent, systematic and sound monitoring system to survey hydrodynamic, geological, sedimentological and geomorphological aspects of coastal dynamics, employing state of the art, comparable and compatible methodology around the entire Black Sea coast. Enhancing the Global Ocean Observing System, Earth Observing System and GEOSS by improving the technical facilities at sea-level and waves measurement stations adding equipment for the measurement of earth vertical movement (CGPS);

⇒ The development of scientific co-operation in all the Black Sea countries and with the Mediterranean science community by creating a research network of excellence regarding coastal erosion, processes, factors, dynamics and coastal protection;

⇒ The creation of a freely accessible common data-base comprising the factors of coastal dynamics linked to coastal erosion and the state of coastal erosion for the entire Black Sea.

⇒ The detailed identification of coastal process mechanisms affecting critical areas, in order to offer the scientific background for ICZM.

The Mediterranean and Black Sea appear to be the richest European region, in terms of species diversity. This high diversity richness is attributed primarily to the eventful geological history and to the large variety of habitats present in the region. **Changes in the marine biodiversity** have been documented in many parts of the region and are attributable both to natural phenomena, global change and anthropogenic activities. Research has shown that changes in biodiversity may well affect the ecosystem functioning, even in the case of invasions by a single species, with important consequences both to nature and society.

Although considered as one of the best-studied seas of the world, there are still major gaps to be covered in the field of biodiversity of the Mediterranean and Black Seas. This means that scientists are not as yet able to translate their scientific information into precise conclusions and guidelines to support adequate political decisions. In particular:

⇒ More information is still required on the variability of biodiversity at different scales (from local and meso-scale, to the seascape level). Hypotheses at these scales such as whether the local species pools are random samples from the regional species pools, still need to be tested.

⇒ There is still limited knowledge on the role of physical processes in the development and maintenance of biodiversity. The identification of suitable locations for the study of the physical processes that control marine biodiversity constitutes a major gap to this end.

⇒ A cross-nation effort to establish baseline information for assessing historical trends in marine biodiversity, is also required.

⇒ The effects of anthropogenic impacts (eutrophication, environmental stressors and micro pollutants) on both the structural and functional aspects of biodiversity are of particular interest for the region. This is because the region is subjected to a high degree of human activities, leading to an ever increasingly large expansion in coastal development. Accurate methods and tools are required to detect changes at the regional, coastal and national scales. The potential of recently developed research fields in the marine science, such as microbial-molecular parameters and the trophic breath should be tested. The development of indices integrating both ecological and social values is urgently needed.

⇒ A considerable gap still exists in the coupling of classical and molecular techniques in the study of biodiversity. Classical taxonomy could benefit from the recently developed molecular and genetic techniques, which would allow for testing hypotheses already in place

A comprehensive list to serve as a guideline for further future activities would include:

- ⇒ networking: joining efforts, setting the essential questions, re-developing a regional strategy for the southeastern Mediterranean and the Black Sea, in compliance with European and international Treaties and Conventions
- ⇒ data base development : creation of a central depository of reliable data from the marine environment; digitalization of existing historical data stored on paper for a long time
- ⇒ coverage of large, unexplored geographic areas
- ⇒ standardization of methods for biodiversity research on a basin-wide scale
- ⇒ development of Rapid Assessment Techniques (RATs) for the assessment of the marine environment, integrating multidisciplinary knowledge
- ⇒ setting up common large-scale-long-term projects
- ⇒ linking with other disciplines (e.g. socio-economics, decision making, integrated coastal zone management)
- ⇒ a lack of expertise in several disciplines points to the need for capacity building for the new generation of scientists, based on multi-disciplinary education

5. Proposed monitoring system requirements for the Mediterranean and Black Seas

Broad recommendations

Experience of monitoring in the Basin has pointed out that considerable geographical gaps in data at both regional and local scale are (or might continue to be) evident in both regions, thereby posing an obstacle to addressing specific environmental problems threatening coastal ecosystems. In addition, the obtained or proposed temporal resolution of data (sampling frequencies of on-site monitoring activities) is not usually adequate to understand the real status of the environment and to support models. Furthermore the inclusion of sites representative of all coastal waters and open seas in routine monitoring efforts (usually restricted to inshore and near shore areas), is virtually impossible. Yet another critical point is the nomination by local experts and authorities of monitoring sites (often limited in number and scale) intended to reflect areas that are usually under direct anthropogenic pressure whose choice of site and station however may not always be appropriate for the task. Finally, even if the programmes are designed for ideal conditions (good sampling design, including all necessary ecosystem components etc), no entity can ensure their smooth implementation.

Recommendation 1: The proposed system for monitoring and assessment of environmental and ecosystem quality should consider the gaps described above.

The GOOS objectives and the regional development of GOOS-related activities are already considering these facts and subsequently developing products on observation and forecasting for different end-user requirements. The generally accepted approach is to use a downscaling strategy moving from global, to regional, shelf seas and coastal scales. This applies to both the observing systems (from basin scale to coastal monitoring) and modeling components (through sequential nesting procedures that increase the spatial resolution and improve initial and boundary conditions). However, there are still a lot of issues to be addressed to achieve an integrated coastal water observing – forecasting system. The main problems to be addressed are related to the limited range of biochemical sensors, their accuracy and long term stability. Based on MFS and POSEIDON, that provide the larger scale information, an initial coastal observing system could first be developed, as a test case, and its capacity to meet the monitoring requirements could be evaluated. Such a system would also help to explore sustainability and operational issues related to resource limitations (funding, infrastructures, expertise etc.).

Recommendation 2: To further explore the available tools of GOOS related activities and projects in both regions and promote the further development of such activities to address the monitoring requirements of the regional conventions.

Recommendation 3: To promote the organization of regional or sub-regional surveys at project level to complete the data and information gaps evident in both seas to support state assessments with actual and recent data as well as to support various models.

Regarding the assessment methodologies employed by the two convention areas the most important common feature is the realisation of Transboundary Diagnostic Analyses (TDAs), along with the assessment of land-based inputs and a number of other assessments regarding water quality and partially covering ecosystem quality. Indicators as assessment tools are also being developed in the two regions but can not yet be considered as a mature process.

The European Marine Strategy and its future implementation shall be a crucial element for the identification and assessment of marine research gaps and needs. In general terms research will be required for the following:

- ⇒ making the assessments of European marine waters comprising the analysis of the essential characteristics and current environmental status of those waters, the analysis of the predominant pressures and impacts on the characteristics and environmental status of those waters and the economic and social analysis of their use and of the cost of degradation of the marine environment;
- ⇒ the determination of good environmental status taking into account the physico-chemical characteristics, the hydromorphology, the biological components and the habitat types;
- ⇒ the establishment of environmental targets and associated indicators.

The quality classification of coastal waters according to chemical status and ecological status and the development of Environmental Quality Objectives (EQOs) as required in the Water Framework Directive, are being handled by the BSC in the assessment studies. Recently, UNEP/MAP, in cooperation with the EU, has initiated a new project for the Mediterranean to develop a road map for the implementation of the ecosystem approach in the region. The project also aims to provide guidance for the development of EQOs which would be the backbone of the organization of future monitoring and assessment activities in the Mediterranean.

Recommendation 4: To define approaches for defining good environmental status and for setting EQOs and their elaboration, as required in both regional seas.

Recommendation 5: To further develop indicators and continuously update indicator fact sheets through actual monitoring data

Monitoring of biodiversity

Regarding the efforts of monitoring and inventorying of biodiversity in the region, it is widely accepted that considerable work has been carried out and is planned in both the Mediterranean and Black Seas, despite the absence of a consistent monitoring system with clear objectives and criteria.

In this direction, drawing from existing comprehensive scientific overviews, the essential requirement that prevails is that all opportunities are to be taken and used to monitor biodiversity changes, through the use of individual species that are easy to survey (big macrofauna or macroflora species, charismatic or invasive, and so on), indicator species, or communities. We should have a very good knowledge of:

- ⇒ the exact taxonomic (and eventually genetic) signature of the used organisms;
- ⇒ their ecological role;
- ⇒ reliable previous data on which to base the comparison.

This in turn implies the following:

- ⇒ promoting existing efforts to elaborate national or regional floras and faunas, and encourage them if these efforts do not exist already.
- ⇒ fostering taxonomy, be it conventional (based mainly on morphology) or more recently developed (molecular and genetic techniques).

- ⇒ encouraging the compilation of long term series of data , from plankton inventories to photographic censuses of benthic communities, from commercial fish catches to weather conditions and hydrographic data.
- ⇒ compiling the existing biogeophysical information in a comprehensive geographic information system (GIS). Use GIS to identify gaps in the information and changes in "boundaries"

The nature of these monitoring efforts implies that there is to be a previous knowledge, be it in the form of specialists on the different taxonomic groups, or on the ecological functioning of the littoral or marine communities to be surveyed, or on long term series of data on plankton, benthos, fish catches and so on. Thus the active participation of marine research institutes and experts on these areas is mandatory in these monitoring efforts.

Some national or international efforts already in force should be encouraged, such as those aimed at monitoring hard bottom benthos as a tool to detect biodiversity changes; or the long-term monitoring of protected areas in different countries, as a very useful by-product of these rather pristine areas. This encouragement should take place both at the national and regional level, and with special care to include the southern and eastern, non-European Mediterranean and Black Sea countries where most of the biodiversity resides. Special attention for instance has to be paid to continuous monitoring of the effects of the Suez Canal and Lessepsian migration and the Aswan Dam on the communities of the eastern Mediterranean.

Monitoring to detect the impact of coastal constructions and urban sprawl along the coast also deserves to be addressed as a priority, in addition to monitoring to detect the impact of fishing gear on biodiversity, through comparative studies of protected areas in relation to fished areas in specific habitats.

Regarding the monitoring of invasive species, among the proposed priorities and actions, special attention is to be given to the following:

- ⇒ an understanding of invasion patterns: evaluations of described records, collection of specimens, field surveys, targeting habitats and areas which are most closely linked with known introduction vectors, and molecular analyses
- ⇒ monitoring, modelling and predicting the behaviour of an invasive species in the recipient ecosystem and its effect on its food web
- ⇒ comparative analysis of the variability of species diversity, dominant species in space and time and environmental processes in the Mediterranean and Black Sea in the context of global climate oscillations and their effect on regional climate variations and the presence of exotic species

Monitoring of fisheries

A future approach to fisheries monitoring in the region could draw from the requirements set in the current European regulation on fisheries data collection. Under this new regulation the priority is to meet the new demands set by the need to move towards a fisheries-based management approach and an ecosystem approach. Furthermore, the intention is to develop a long-term, well-integrated regional sampling programme. More specifically the new data collection system will revolve around the following issues:

- ⇒ Support for new approaches to fisheries management (fleet- and area- based management, rather than fish stock-based)
- ⇒ Support for moving towards the ecosystem approach to fisheries management
- ⇒ Promoting implementation of a more regional dimension to fisheries management

⇒ Increasing the quality and validation of data used in fisheries management
⇒ Improving access to and exchange of data
⇒ Improving the use of the data
⇒ Promoting simplification of the data collection framework

Fisheries data collection programmes are to be established on a national basis and then the initiative will be taken to try to ensure that the programmes converge at the regional level. The new approaches for fisheries management (fleet-based and ecosystem-based) will therefore require more cooperation among participating countries and more integration of the national programmes at the regional level. Countries will continue to be responsible for the collection, the storage, the maintenance in their national database (raw data) and the transmission of the data.

The information will have to be made available to the scientific community, the rule for confidentiality being respected. The underlying principle is that detailed data on fishing activities, landings etc. should be made available except such information that could be specifically related to individual or vessel. In practice, availability to the scientific community means that there will be an obligation to transmit the data for scientific needs and to have the capacity of doing so. The raw data will have to be aggregated to a level defined by the users, before their transmission.

In order to finalise the requirements regarding the fleet-based approach, special attention is being devoted to the small-scale fisheries and their specificities (multi-species multi-gear fisheries, heterogeneity, high variability in fishery activity over the time, lack of information concerning landings, discards and effort).

Considering the requirements to put into practice an ecosystem based approach, the prioritization of the fishing effects and associated indicators to support environmental integration under the Common Fisheries policy has been achieved. A first set of data requirements to support the environmental integration process and the development of an ecosystem approach to fisheries management has been established (fishing effort and spatial distribution, assemblage composition, diet composition, key species , by-catch of marine mammals, turtles and seabirds, physical-chemical conditions, seabed conditions). The intention is to use this first set of data for more discussion in the regional framework, where the specificities of some areas, particularly the Mediterranean and Black Seas will be given special attention.

6. The specifications and requirements for a coupled physical and ecosystem model of the Mediterranean and Black Seas

The objectives that should be pursued in designing a coupled physical-ecological model for the Mediterranean and Black Sea basins are considered as the following:

- ⇒ Resolve the physical biological coupling of the system at the relevant spatial and temporal physical scales.
- ⇒ Envisage a marine ecosystem description allowing for spatial and temporal trophic structure shift in dependence of the variability of the forcing functions acting on the system.
- ⇒ Provide adequate description of the coastal zone ecosystem dynamics.
- ⇒ Provide relevant information for socio-economic studies focusing on integrated coastal zone management.

The development of a Mediterranean and Black Seas coupled physical-ecological model would therefore adhere to the following characteristics:

- ⇒ The regional/coastal system should be coupled with a large scale system in order to provide an effective and explicit simulation of the influence of the large-scale circulation on the coastal dynamics.
- ⇒ The nesting between the regional coastal system and the large scale one should be based on established nesting techniques complying with the volume (circulation model) and mass (ecological model) conservation constraint.
- ⇒ The coupling between the physical and the ecological model should be carried out in the on or off-line mode. For the off-line mode, however, the frequency of the update of the physical fields should be carefully established.
- ⇒ The ecological model should explicitly resolve for the time-space variability of the trophic web structure.
- ⇒ The ecological model should be a multi-nutrient one and (for the lower trophic levels) a biomass based one making use of the functional group approach.
- ⇒ Attempt to couple the biomass based approach for the lower trophic levels with individual based models for the secondary producers should be encouraged. In order to have the coupled models providing relevant information to the environmental policy makers and environmental managers, a modelling effort toward the simulations of anoxia processes, HaB's and gelatinous zooplankton dynamics is recommended.