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INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)

IOC OCEAN SCIENCE SECTION:
A BASIS FOR RESTRUCTURING

This document presents a proposal by the IOC Secretariat to the 21st Assembly for the restructuring of the Ocean Science Section. The proposal is consistent with the External Evaluation of the IOC, the review of the Ocean Sciences in Relation to Living Resources (OSLR) Programme, and the review of the Ocean Science Section. It embodies the preliminary suggestions regarding the restructuring of the GIPME Programme presented to the 33rd Executive Council. The proposal is also consistent with the IOC Statutes, needs of the Member States, international policy perspectives and emerging priorities in ocean science.

The document provides greater detail regarding the rationale for the conclusions and recommendations made in the working document IOC-XXI/ 2 Annex 6 submitted to the 21st Assembly.

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1. INTRODUCTION

This document presents a proposal by the IOC Secretariat to the Assembly for the restructuring of the Ocean Science Section. The proposal is consistent with the External Evaluation of the IOC, previously presented to the 33rd Session of the IOC Executive Council (Document IOC/EC-XXXIII/2 Annex 3), the review of the Ocean Science Section completed in 2001 (Annex I), and the review of the Ocean Sciences in Relation to Living Resources (OSLR) Programme also completed in 2001 (Annex II), and. It embodies the preliminary suggestions regarding the restructuring of the GIPME Programme presented to the 33rd Executive Council (Annex III). The proposal is also consistent with the IOC Statutes, needs of the Member States, international policy perspectives and emerging priorities in ocean science.

The main objective of the proposal is to reorganize the activities previously carried out under the OSLR, OSNLR, and GIPME Programmes along with new initiatives within the Ocean Science Section into a new, interdisciplinary branch called *Ocean Ecosystems Science*. The Ocean Science Section would thus have the following three interactive lines of work:

- Oceans and Climate;
- Ocean Ecosystems Science; and,
- Marine Science for Integrated Coastal Area Management.

2. BACKGROUND

At the request of the Director-General of UNESCO in 1998, and as part of an overall evaluation programme of UNESCO, an External Evaluation of the IOC was carried out during 1999-2000 by three independent experts (IOC, 2000a). The report of this evaluation was submitted to the Director-General of UNESCO in February 2000 and subsequently presented to the 33rd Session of the IOC Executive Council in June 2000. It will be further considered during the 21st Assembly.

This evaluation report contains conclusions and recommendations pertaining to scientific, organizational and administrative issues. One of the evaluation report's principal conclusions concerning scientific issues was that, while the IOC has an enviable record of success, with the passage of time it has become unfocussed and too thinly spread to adequately maintained its programmes and activities. Accordingly, it recommended,

> *"that the IOC give very high priority to the further review of its scientific and technical programme structure and management with a view to implementing a more strategic and systematic approach to programme planning, management and evaluation."*

The IOC Executive Secretary further commissioned a group of experts to review Ocean Sciences Programme pursuant to a request from the 20th Session of the IOC Assembly in 1999. The request from the Assembly specified that the group of experts should review the framework of the existing ocean sciences programmes of the IOC in light of new developments and requirements in ocean science and identify new approaches for the IOC to meet the evolving aspects of interdisciplinary ocean science, in the context of bringing benefits to Member States. The review group, in a report submitted in early 2001 and summarized at Annex I, concluded that there was a need to restructure IOC activities overall and the Ocean Science Section in particular to provide more appropriate alignment of activities. The review group recognized three natural groupings of activities within the Ocean Science Section that fall within the headings: Global Ocean System, Coastal Environmental System, and Integrated Management System. It proposed the retirement of the names OSLR (Ocean Sciences in Relation to Living Resources) and OSLNR (Ocean Sciences in Relation to Non-Living Resources) and a restructuring of all activities within the Ocean Science Section into these three new components.

The 31st Session of the IOC Executive Council instructed the Executive Secretary of the IOC to convene a meeting of experts to review the Ocean Sciences in Relation to Living Resources (OSLR)

Programme. This review was undertaken in the latter half of 2000 and a draft final report was submitted to the IOC Secretariat in February 2001. A summary of this review is presented at Annex II. This review examined the range of IOC activities within the OSLR programme and a wide variety of international scientific programmes of other agencies, some linked to IOC activities and some not. The principal conclusion of this review is that future OSLR activities should be based on an ecosystems approach.

A further initiative relating to the nature and organization of ocean science activities of the IOC is relevant background to this document. During the 19th Session of the IOC Assembly in 1997, a decision was made to revise the manner in which the Programme of Global Investigations of Pollution In the Marine Environment (GIPME) was conducted. A result of this decision was a requirement to restructure the GIPME programme to achieve improved alignment with current international and national marine pollution issues. A first draft of a restructuring plan (IOC, 2000b) was prepared and subsequently presented in summary form to the 31rd Session of the IOC Executive Council in 2000 (see Annex III). The principal recommendation of the plan was that the scientific components of core GIPME activities be identified within two core activity envelopes: "Transport, cycling, fate and effects of contaminants", and "Indicators of marine environmental condition and effects". During the ensuing discussion some suggestions were made for revisions of the scientific activities proposed to form the main focus of GIPME activities in the future. It had been intended that a revised proposal for GIPME restructuring would be prepared and submitted to the 21st IOC Assembly. However, in the light of the conclusions of the reviews referred to previously, it was considered preferable by the IOC Secretariat to develop a proposal for top-down restructuring of the entire Ocean Science Section.

In 1999, a group of experts was convened to consider a plan for the development of the Ocean Sciences in Relation to Non-Living Resources (OSLNR) Programme in the context of the IOC coastal zone strategy. The report of this meeting (IOC, 1999) provides background to OSLNR activities and the potential directions for realignment of this programme, with particular emphasis on marine science needs for integrated coastal area management (IOC, 1997). This latter document had noted that:

> *"Though many of the IOC traditional marine science and ocean services programmes such as OSLR, OSNLR, GIPME, Ocean Mapping, GLOSS, IODE, etc., already represent IOC inputs to ICAM due to their component in the coastal regions* [sic], *these inputs are basically disciplinary in nature and are not necessarily designed for serving ICAM purposes."*

This document presents a proposal for restructuring the Ocean Science Section in a manner consistent with the recommendations of the several reviews and the previous proposal for the restructuring of GIPME.

3. SETTING THE STAGE: MAJOR COMPONENTS OF THE OCEAN SCIENCE SECTION

As a first step it is necessary to define the nature of the constituent activities and programmes of the current Ocean Science Section (OSc.). The major components are:

- Oceans and Climate;
- Ocean Sciences in Relation to Living Resources (OSLR);
- Ocean Sciences in Relation to Non-Living Resources (OSNLR);
- Global Investigations of Pollution in the Marine Environment (GIPME); and
- Marine Science for Integrated Coastal Area Management (ICAM).

The first four of these components deal strictly with scientific issues related to improving our understanding of the condition of the marine environment and developing mechanisms for improved marine resource management and protection of the global environment. The fifth component is concerned with the marine science underpinning for the management of coastal areas through multi-sectoral, multi-stakeholder participation. Thus, ICAM represents the more applied issues of Marine

Science that provides guidance to governments on the techniques to address one of the dominant marine environmental issues – the quality of the coastal marine environment.

The following subsections outline each of these Ocean Science Section components.

3.1. OCEANS AND CLIMATE

Oceans and Climate is an activity driven largely by issues of ocean circulation and exchanges of properties between the ocean and atmosphere. The main interest is developing a better understanding of the role of the ocean in global climate dynamics. Activities address heat and gas exchange across the ocean-atmosphere interface, the response of the ocean to changes in atmospheric conditions and forcing, and the influence of the ocean on the formation of global and meso-scale climatic conditions. This is an active and successful package of activities within the Ocean Science Section. The OSC sponsors and participates in programmes in the areas of :ocean circulation and atmosphere-ocean physics (WCRP, WOCE CLIVAR, and GOOS via the OOPC); process studies of the biogeochemical cycling of carbon in the ocean and carbon sequestration research (JGOFS, the SCOR-IOC CO_2 Panel); and boundary fluxes of nutrients and carbon (JGOFS/LOICZ Continental Margins Task Team).

These programmes serve not only as research-based science programmes, but also provide much of the scientific development base that underpins the overall design of the Global Ocean Observing System (GOOS) and in particular, its Climate Module (OOPC).

3.2. OCEAN SCIENCES IN RELATION TO LIVING RESOURCES

Ocean Sciences in Relation to Living Resources was established in 1982 with FAO co-sponsorship. The OSLR Programme had an initial strategic focus on physical-biological linkages and their effects on fisheries recruitment variability with the core activity being the International Recruitment Project (IREP). Despite a number of successes, the fisheries recruitment studies fell into decline in the early 1990s. The reasons given for this decline have been attributed to: the complexity of the fisheries recruitment problem and the demanding nature of the research that made it difficult to get active participation by developing countries; the difficulty of obtaining full involvement from fisheries scientists in developed countries who already have their own research programmes and international institutions such as ICES; an element of protectionism by existing fisheries organizations from the involvement of a new organization; and the narrow focus on fisheries recruitment that prevented focus on other issues. In the late 1980s and early 1990s, some new issues emerged that were appropriate for incorporation into the OSLR Programme. The IOC created the Harmful Algal Blooms (HAB) Programme and arranged to co-sponsor with ICES the ICES/IOC Study Group on the Dynamics Harmful Algal Blooms and with SCOR a Working Group on the Physiological Ecology of HABs. These activities led subsequently to the establishment of the interdisciplinary IOC-.SCOR Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) programme, which works toward developing international capabilities for assessment, prediction and mitigation of HABs. There is an Intergovernmental Panel on HAB (IPHAB) attached to the Programme that functions as the overall coordinating body for most international and regional HAB initiatives. It sets priorities, revises and updates the HAB Programme Plan, and is responsible for interaction with other relevant organizations and programmes. The HAB programme includes permanent regional working groups in South America (COI-FANSA), the Caribbean (COI-ANCA), and the Western pacific WESTPAC/HAB. The Global Coral Reef Monitoring Network (GCRMN) was established jointly with UNEP, IUCN, ICLARM and WB and focuses on (i) improving the conservation, management and sustainable use of coral reefs and related coastal ecosystems by providing data and information on the trends in biophysical status and social, cultural and economic values of these ecosystems, and, (ii) providing individuals, organizations and governments with the capacity to assess the resources of coral reefs and related ecosystems and to collaborate within a global network to document and disseminate data and information on their status and trends. In addition, the IOC co-sponsors the Global Ocean Ecosystem Dynamics Programme (GLOBEC) and contributes to the study of processes in large

marine ecosystems through support to the Large Marine Ecosystem (LME) Initiative. OSLR has been involved in the development of the Living Marine Resources Module of GOOS.

These current activities within the OSLR envelope are related to HAB/GEOHAB, GLOBEC, GCRMN, and LME, and are concerned in one form or another with the effects of anthropogenic forces and climate variability on marine ecosystems.

3.3. OCEAN SCIENCES IN RELATION TO NON-LIVING RESOURCES

Ocean Sciences in Relation to Non-Living Resources has been a less active programme in recent years. It has been driven largely by interests in ocean (bathymetry) mapping and the exploitation of non-renewable marine resources such as sand and gravel and hydrocarbons. One of its most recent activities was the development of guidance on the definition of the continental shelf edge in relation to the United Nations Convention on the Law of the Sea (Cook and Carleton, 2000). While the OSLNR Programme has been experiencing a decline in activities (especially in deep water) in recent years, this does not imply that interests in marine geological resources have diminished. The rapid development of hydrocarbon exploration and recovery technology in recent years is resulting in the development of oilfields beyond the continental shelf edge and it is projected that the ability to recover such resources from depths exceeding 2,000 meters will be available within a decade. This may accelerate interests in other energy-related resources such as sedimentary methane clathrates.

The geomorphology expertise residing among those involved in OSLNR is particularly relevant to integrated coastal area management concerns, especially coastline erosion and accretion, saline intrusion, groundwater exchange, coastal mineral resource mapping and the transport of both bed and suspended sediments. Equally, marine geological expertise, particularly in marine topography and resource characterization, is directly relevant to the development of the Global Ocean Observing System (GOOS).

3.4. GLOBAL INVESTIGATIONS OF POLLUTION IN THE MARINE ENVIRONMENT

Global Investigations of Pollution in the Marine Environment has been a long-standing programme of investigations of contamination and pollution in the marine environment. Since its adoption in 1976, this programme has been periodically redefined to adapt to changing perspectives on marine pollution issues and changing international priorities. This first occurred in 1984 (IOC, 1984) and further restructuring was in progress in 2000 (IOC, 2000b) following an IOC Assembly decision in 1997 to revise the organization of the programme. The predominant approach used in the original programme was the development and proving of measurement technology, contamination assessment, pollution assessment and environmental management with inbuilt monitoring. The programme, at its peak, had three Groups of Experts dealing respectively with methodology, biological effects and standards and reference materials. It had considerable success assisting in the development, proving and standardization of analytical techniques at an international level, partly in co-operation with the International Council for the Exploration of the Sea (ICES). In addition, GIPME interacted strongly with the UNEP Regional Seas Programme in the development of methods, inter-calibration and pilot projects on monitoring marine pollution, especially at the regional level. Over the period 1986–2000, GIPME also completed a very successful baseline survey of the entire Atlantic Ocean, the results of which have been published in the open scientific literature [See special issues of *Marine Chemistry* (vol. 49, 1995; vol. 61 1998) and *Deep-Sea Research II* (vol. 46, No. 5, 1999)].

The recent GIPME activities include development of indicators of the health of benthic communities (through an *ad hoc* group), sediment quality guidelines (jointly with UNEP and IMO), and rapid assessment techniques for marine pollution. Significant contributions have been made to the GESAMP activities, most particularly in the publications in 2001 of two reports entitled "*A Sea of Troubles; Issues in Focus*" and "*Land-based sources and activities affecting the quality and uses of the marine, coastal and associated freshwater environment*". The former deals with the state of the marine environment and addresses current major issues and emerging problems. The second report

addresses the assessment needs of the GPA-LBA. Both reports are being widely disseminated to the Governments, international organizations and the marine environmental management community. GIPME has been involved in the development of the Health of the Oceans Module of GOOS.

3.5. MARINE SCIENCE INPUTS TO INTEGRATED COASTAL AREA MANAGEMENT

Marine Science Inputs to Integrated Coastal Area Management was adopted as a specific programme by the 19th Session of the IOC Assembly in 1997. Its objective is to assist Member States to develop marine scientific and technological capacity for integrated coastal management. This program has five components: interdisciplinary approaches, monitoring, information, the development of methodology, and capacity building, these last three components being common to all IOC programme. The External Evaluation Report (IOC, 2000a) noted that

> *"ICAM had the support of Member States but the scope of issues within vulnerable coastal areas is enormous and the number of agencies dealing with these issues is huge."*

It further warned:

> *"The IOC cannot hope, within even optimistic limits of foreseeable resources, to cover all the expectations of its Member States. The programme will therefore have to be very specific about what it is unable to tackle. Although coastal issues have long been cited as priorities with the IOC, the ICAM programme is a recent initiative that needs to be monitored closely and critically."*

Another critical aspect of the science requirements for ICAM is that integrated coastal area management requires not only the incorporation of marine issues and the capacity to address them but also the ability to deal effectively with land and freshwater issues. To accomplish this successfully, it must include, either internally or through close cooperation with other agencies, the terrigenous and limnological aspects of the subject. The cooperation with International Geographical Union (under Oceans 21 Project), GPA-LBA and the UNESCO Water Science Division has thus been established.

Regarding the specific marine science activities, a study group has been established to investigate some of the scientific aspects of the ground water flow in relation to the quality of the coastal environment. The Programme is a partner in the LOICZ Basins Effort, which is concerned with the catchment-coastal interactions on a regional basis, fresh water issues, and relevant economic and social aspects. The programme has recently been assigned the responsibility of coordinating the GCRMN South Asia Node, which focuses on the socio-economic aspects of coral reefs in the region. Efforts are underway to establish a working group on aggregated environmental-social-economic indicators for coastal areas.

4. CONSIDERATIONS RELEVANT TO THE ORGANIZATION AND STRUCTURE OF THE OCEAN SCIENCE SECTION

The recommendation has been made, both in the External Evaluation Report (IOC, 2000a) and in the Report of the Committee to Review the Ocean Sciences Programme of the IOC (Annex I), that the entire structure of the Ocean Science Section be revised.

The question therefore arises,

> *"How can ocean science activities be categorized in a way that achieves the refocusing required while preserving those parts of the existing Ocean Science activities that are clearly working well and meeting Member Country expectations?"*

There are some key considerations regarding the organization of ocean science activities within the IOC. Specifically, the programmes and activities of the Ocean Science Section must be consistent with IOC statutes, the expectations of Member States, international policy perspectives on the basic approaches that should be followed in the application of science to ocean management issues, as well as the emerging and existing global environmental research priorities.

4.1. IOC STATUTES

The background for the development and organization of IOC activities is given in the IOC Statutes (UNESCO, 2000). Article 2 (Purpose) and Clause 1 of Article 3 (Functions) are the most relevant to the present document. These are:

Article 2 – Purpose

The purpose of the Commission is to promote international cooperation and to coordinate programmes in research, services and capacity-building, in order to learn more about the nature and resources of the ocean and coastal areas and to apply that knowledge for the improvement of management, sustainable development, the protection of the marine environment, and the decision-making processes of its Member States.

The Commission will collaborate with international organizations concerned with the work of the Commission, and especially with those organizations of the United Nations system which are willing and prepared to contribute to the purpose and functions of the Commission and/or seek advice and cooperation in the field of ocean and coastal area scientific research, related services and capacity-building.

Article 3 – Functions

The functions of the Commission shall be to:

- *recommend, promote, plan and coordinate international ocean and coastal area programmes in research and observations and the dissemination and use of their results;*
- *recommend, promote and coordinate the development of relevant standards, reference materials, guidelines and nomenclature;*
- *respond, as a competent international organization, to the requirements deriving from the United nations Law of the Sea (UNCLOS), the United Nations Conference on Environment and Development (UNCED), and other international instruments relevant to marine scientific research, related services and capacity-building;*
- *make recommendations and coordinate programmes in education, training and assistance in marine science, ocean and coastal observations and the transfer of related technology;*
- *make recommendations and provide technical guidance to relevant intersectoral activities of UNESCO and undertake mutually agreed duties within the mandate of the Commission;*
- *undertake, as appropriate, any other action compatible with its purpose and functions.*

This essentially sets the stage for all IOC activities. The principal concern for the Ocean Science Section is with:

- the promotion, planning and coordination of international ocean and coastal area programmes in research and the dissemination and use of their results; and
- collaboration with and response to international organizations, especially with those UN organizations that are pertinent to the purpose and functions of the IOC, as the UN focal point for Ocean Science.

4.2. MANAGEMENT DEMANDS AND PRIORITY EXPECTATIONS OF MEMBER STATES

Because the ultimate goal of science is to improve the knowledge of the ocean and thus contribute to better environmental management and protection, it is important to examine the requirements for ocean science from management perspectives and the needs expressed by the Member States. The emerging management priorities both at international and national levels are:

- prediction of climate change;
- predicting effects of anthropogenic forces and climate variability on marine ecosystems, and consequences for living resources;
- marine non-living resource identification, exploitation and provision of base lines for future management; and
- coastal zone management.

Many of the current and developing initiatives within the IOC pertain to more than one of these categories. The scientific issues relating to any one of these areas frequently relate equally to others. Indeed, it could be argued that the most profitable focal areas for scientific investment by the IOC are those that potentially satisfy more than one area of demand (multipurpose approach).

4.3. INTERNATIONAL POLICY PERSPECTIVES OF THE UN SYSTEM

In accordance with its Statutes, IOC responds, as a competent international organization, to the requirements deriving from the United Nations Law of the Sea (UNCLOS), the United Nations Conference on Environment and Development (UNCED). IOC is also expected to respond other international instruments relevant to marine scientific research, related services and capacity building.

Two recent sources of information regarding international policy perspectives of the United Nations on oceans are the Decision CSD 7/1 of the Seventh Session of the Commission on Sustainable Development (April, 1999) and the results of the Informal Consultative Process on Oceans and the Law of the Sea (Consultative Process). The Consultative Process considered many of the decisions from CSD 7/1 and in the first report of the Consultative Process (UN, 2000) thirteen issues were identified as warranting consideration by the UN General Assembly. These include the following:

The importance of marine science for fisheries management - *There is specific reference to ecosystem-based approaches and improvement of status and trend reporting for fish stocks.*

The importance for achieving sustainable development, of combating marine pollution and degradation - Emphasizes *addressing all aspects of ecosystems.*

Integrating action to combat the adverse economic, social, environmental and public-health effects of marine pollution and degradation from land-based activities into regional and national sustainable development strategies and their implementation - *In the subordinate text there is a reiteration of the need for regional, national and local action programmes, as envisaged in the 1995 Global Plan of Action for the Protection of the Marine Environment from Land-based Activities (GPA-LBA), to identify the problems of marine pollution and degradation from land-based activities, to establish priorities and identify, evaluate, select and implement strategies and measures; and underlies an integrated ecosystem-base approach.*

Integrating action to prevent and eliminate marine pollution and degradation from land-based activities into main investment programmes - *Emphasis is place on the need for investment in combating marine pollution and degradation from land-based activities.*

Building the capacity to manage the coastal zone in an integrated manner - *Emphasis is place on the widespread need for capacity building for integrated management of river basins and the coastal zone and the development of an ecosystem approach.*

How to implement effectively Part XIII (Marine scientific research) and Part XIV (Development and transfer of marine technology) of the United Nations Convention on the Law of the Sea - *This stresses the important role of marine science and technology in promoting sustainable management and use of the oceans and seas and the need to ensure support for the production and diffusion of factual information and the accessibility of marine science and technology information by*

decision makers. This section also contains an invitation to a wide range of United Nations and Bretton Woods organizations including the IOC, to assist in fulfilling these obligations including evaluations of the steps taken to determine the social and economic effects of marine pollution and degradation.

It is clear that there is a strong call for an ecosystem-based approach in the sustainable management of oceans and coastal areas in matters ranging from fisheries to marine pollution to capacity building. This call by the UN system is echoed by nongovernmental organizations such as IUCN as well as the Convention on Biological Diversity. For the purposes of this document we adopt the definition of the 'ecosystem approach' to management of marine and coastal environments by the ICES Advisory Committee on Marine Environment (ACME):

> *" Integrated management of human activities based on a knowledge of ecosystem dynamics to achieve sustainable use of ecosystem goods and services to preserve ecosystem integrity."*

and provide further discussion in Annex IV. Clearly, the essential issue pertinent to the Ocean Science Section is the requirement to better understand ecosystem dynamics. This requirement persists in other definitions and descriptions of the ecosystem-based approach in the sustainable management of oceans and coastal areas. Furthermore, as will be seen below, the required knowledge is not only relevant to management but also the emerging scientific perspectives.

In addition to these two policy perspectives, Chapter 40 of *Agenda 21* requests countries at the national level, and international governmental and non-governmental organizations at the international level, to identify and develop indicators of sustainable development. Indicators are measures of condition, and can be social, economic, or scientific indices of the state of the environment. These indicators can provide quantitative information about the forces that drive a system, responses to forcing functions, or previous, current or future states of a system. When they are used effectively, indicators are expected to reveal conditions and trends that help in development planning and decision-making. Policy makers set the targets and measurable objectives, while scientists determine relevant variables of the marine and coastal environment, monitor its state and develop models to make projections of future state. In this sense indicators are intended to close the gap between the fields of policy making and science.

While there exists a strong need to develop integrated mechanisms for observing, assessing and forecasting the effects of anthropogenic activities on the marine environment, the identification and development of indicators of the health of marine and coastal ecosystems lags significantly behind socio-economic indicators of sustainable development. Specific needs involve biological indices for anthropogenic stresses to be identified at molecular, organism, population and community levels of biological organization, which will require scientific considerations that are multi-disciplinary, multi-scale and multi-purpose. IOC has already initiated several activities that aimed at developing indicators for the health of oceans that are reliable in their ability to detect stress where stress is likely occurring (e.g., due to high contaminant levels), powerful in their ability to discriminate between anthropogenic versus natural sources of stress, and easy to use and broadly applicable in different parts of the world.

These efforts should be strongly coupled to the development of observing systems that also involve the development and adoption of common methodologies, capacity building, harmonization, quality control, and assessment processes. The observing systems will provide, in turn, supporting information that can assist in the generation of new indicators or the modification of previously adopted ones. The IOC initiatives will be considered in Section 6 of the present document. It would be preferable for these areas of investment to take into account, and be coordinated with, ongoing SETAC activities on these topics.

It is worth further noting that international conventions in addition to UNCED and other multilateral environmental agreements, in particular, call for the development and use of indicators. For instance, in accordance with the Decision IV/1 A of the Conference of the Parties to the

Convention on Biological Diversity requesting the initiation of a Programme on biodiversity indicators, a core set of generic state and pressure indicators intended to assist Parties and other Governments to design, initiate, and/or improve their national monitoring programmes have been proposed. The proposal

> *"emphasizes that the indicators would serve as a tool for adequate management of biological diversity at local and national levels, for regional and global overviews of the status and trends of components of biodiversity, in the context of the ecosystem approach and the three objectives of the Convention. They may also have a wider role, for example, in increasing public awareness to facilitate the implementation of national monitoring programmes. The level of sophistication of indicator variables to be included in these monitoring programmes will depend on data availability in each country and on the specific sectors being monitored"* (UNEP/CBD/SBSTTA/5/12; 22 October 1999).

Finally, in developing indicators it is important to address the challenge of fully integrating the social, economic, environmental and institutional aspects of sustainable development. Much further work, primarily by the scientific community, is needed in order to understand and explore these linkages.

Several international marine environmental protection agreements, principally the London Convention of 1972 and the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA-LBA) adopted in 1995, have a requirement to assess the extent to which marine environmental conditions are perturbed by human activities. In the case of the London Convention, there is a need to identify the extent to which the composition of sedimentary material is natural or influenced by human activities such as the discharge of contaminants into the environment. It also requires judgments to be made regarding the damage to the ecosystems that would result from dumping of such materials into new locations in nearshore and continental shelf areas. Similar requirements exist under the GPA-LBA to assess the damage and/or risks associated with the introduction of materials into the marine environment from land discharges. The IOC, in collaboration with IMO and UNEP, has undertaken initial work on the development of guidelines for marine sediment quality that can be used to make judgments about the nature of marine sedimentary material and procedures that might be employed to assess the extent of biological effects (IMO, 2000).

4.4. SCIENTIFIC PERSPECTIVES AND PRIORITIES IN OCEAN SCIENCE

Scientific Perspectives as well as the emerging and existing priorities in Ocean Science (as an integral part of Earth System Science) are considered in this section.

Recently, the US National Academies' National Research Council (NRC) has identified eight grand challenges in Environmental Sciences (NRC 2001. See also http://books.nap.edu/catalog/9975.html). Four of these challenges are strongly interrelated and are identified as Biogeochemical Cycles, Biodiversity and Ecosystem Functioning, Climate Change, and Hydrologic Forecasting. Under Biogeochemical Cycles, the NRC report points out the critical importance of understanding of the cycling of six nutrient elements (carbon, oxygen, hydrogen, nitrogen, sulfur, and phosphorus) in relation to functioning of ecosystems, atmospheric chemistry, and human health. Under Biodiversity and Ecosystem Functioning, the report calls for an improved understanding of the factors, including human activities, that affect biodiversity, and of how biodiversity relates to the overall functioning of an ecosystem. It is pointed out in relation to climate variability that the challenge is to increase our ability to predict climate variability, from extreme events to decadal time scales; to understand how this variability may change in the future; and to assess its impact an natural and human systems.

The recent 1999-2000 United States NSF reports on Future of Basic Research in Ocean Science points out that anthropogenic forces, in addition to climate effects, have significantly and ubiquitously affected the ocean ecosystems(see http://www.geo.nsf.gov/oce/whatis/ for short summaries and http://www.joss.ucar.edu/joss_psg/publications/decadal/ for a draft synthesis report called "Ocean Sciences at the New Millennium). These forces reflect fisheries, aquaculture, introductions of non-native species, modification or destruction of critical habitats, and additions of

nutrients and chemical pollutants. The need for improved understanding and prediction of the perturbations that affect the composition, structure and functioning of marine communities is stressed (OEUVRE, 1999). The importance of nutrients is pointed out by noting that the transport and redistribution of nutrients strongly affects the

> *"ocean's ability to support life and the role of life in maintaining the chemical constitution of the ocean".*

The critical issues include the transport of nutrients to the euphotic zone, the ways they affect the community structure and how these processes are influenced by natural changes and human inputs. A major issue in this context is the ways nutrient dynamics affect "end states of great importance", such as fisheries and HABs. In addition, the understanding of land-sea exchange at the ocean margins is emphasized for

> *"Unraveling the highly variable complex of chemical, physical, geological, and biological linkages in margins (that) will provide needed context for human colonization of the coastline".*

Assessment of natural variability is critical to determination of anthropogenic effects. In fact, resolving and understanding anthropogenic and natural sources of variability and change on coastal and basin scales is identified as the greatest challenge to ocean science for the foreseeable future. Finally, the importance of interdisciplinary research is stressed for better assessment of the role of the oceans in global environmental change.

The European Commission's Fifth Framework Programme in the "Sustainable Ecosystem Theme" (see http://www.cordis.lu/fp5/home.html) identifies, among others, as a priority 'improved knowledge of marine processes, ecosystems, and interactions'. The specific priorities under this topic are defined as:

- effects of physical forcing;
- environmental factors and interactions at ocean boundaries and interfaces in relation to ecosystem functioning and alteration;
- distinguishing natural from anthropogenic variability;
- analysis of long-term trends in ecosystem variability through integration of innovative modelling, retrospective analysis and process studies; and,
- transport (including to/from the atmosphere), cycling, coupling and storage of carbon, nutrients and pollutants.

In the proposal for the Sixth Framework Programme's thematic area of research concerned with Sustainable Development and Global Change priorities have been assigned, *inter alia*, to climate change and its impacts, biodiversity and interactions of terrestrial and marine ecosystems and human activities.

The Scientific Committee on Problems of the Environment (SCOPE) and the United Nations Environment Programme (UNEP) has undertaken an evaluation of emerging environmental issues for the 21st century (Munn et al., 2000). In this study, the views of a wide range of experts were sought and these are presented in 'natural resources', 'pollution related', 'global change', and 'social/health related' categories. Under 'global change', the highest priority topics were climate change, ecosystem functioning and biogeochemical cycle disruption.

The most recent GESAMP Review of the State of the Marine Environment (GESAMP, 2000) highlights the most serious compromises and threats to the marine environment as climate change, physical alteration, overfishing, sewage, nutrient influxes and eutrophication, and changes in sediment transport. Of these, only sewage constitutes a "classical" pollution issue (for which much scientific knowledge already exists); the others result from new information and new perspectives on damage and threats to the marine environment on global and regional scales.

It can be inferred from the information given above that climate and ecosystem science are the dominant challenges of the 21st Century. There is thus a strong need for placing emphasis within IOC

on marine scientific activities related to climate change, biogeochemical cycling, and the effects of anthropogenic forces and natural variability on ocean ecosystems. This emphasis calls for interdisciplinary organization of the Ocean Science Section. Ocean science is undergoing a conceptual revolution. This conceptual revolution is related to the revolutions in computing power and in remote sensing and communication that enable us to observe and model the oceans at a global scale and daily time step. Progress in the study of the physical and biogeochemical processes of the marine environment has been so substantial that previously intractable areas of interdisciplinary research are now amenable to concerted study. It can be further argued that the pressing demands of modern society can no longer be satisfied with scientific activities organized strictly on disciplinary lines. Increasingly, insistence on efficiency and cost-effectiveness demand that investigations be conceived using a "systems approach", eventually leading to the development of predictive models that incorporate all relevant disciplinary components - physical, chemical, biological and geological- as well as the observation systems. Indeed, there exists a growing conviction that ocean science required for sustainable development and management of the marine environment, its resources and amenities, can only be achieved by a truly interdisciplinary approach and sustained observations systems such as GOOS. The *targeted* research that is required to meet the demands for the scientific tools to enable protection and management of the ocean should be increasingly organized and conducted along interdisciplinary lines.

In summarizing this section, it can be seen that a major challenge that needs to be met is the development of scientific mechanisms for an ecosystem approach to the management of ocean and coastal areas, including fisheries management. The development of robust, simple, and globally applicable indicators of health of marine ecosystems is an integral part of this challenge. Consistent with this challenge are the emerging and existing global environmental research priorities include climate change, marine biogeochemistry and ecosystem dynamics, biodiversity and the hydrological cycle. The Ocean Science Section should be developed further to address global interdisciplinary science issues, especially an increased understanding of the response of ocean ecosystems to human-induced and natural changes in the chemical and physical processes in the marine environment

5. STATUS OF EXISTING PROGRAMMES

In the light of the above discussion, a consideration of the status of some of the existing Programmes of the Ocean Science Section follows.

5.1. OCEANS AND CLIMATE

The IOC activities under Oceans and Climate are now well integrated with the climate-related initiatives of other agencies and international scientific bodies. They meet the expectations of the Member States, international policy perspectives and the existing scientific research priorities. They should thus be maintained in essentially their current form as a major component of the Ocean Science Section. No doubt, with time, the range and focus of such initiatives will change. Where these involve oceanographic questions, irrespective of discipline, the IOC can participate in new endeavors based on its institutional strengths and capacity.

5.2. GLOBAL INVESTIGATION OF POLLUTION IN THE MARINE ENVIRONMENT (GIPME)

For the past 20 years, the Global Investigation of Marine Pollution in the Marine Environment (GIPME) Programme has been working on issues of marine contamination and pollution. Through method development programmes, workshops and intercomparison exercises, techniques have been developed to assess contaminant concentrations in several marine matrices and the effects of contaminants on marine organisms.

Much has changed in the field of marine pollution since the inception of GIPME and major changes in policy perspectives have taken place in recent years regarding the protection of marine

environment. Specifically, reassessment of the relative importance of different pollutants has taken place because of either the advancement of science or the need to prioritize regulatory actions. In addition, new perspectives in marine environmental protection require new integrated approaches in research as well as management. The challenge for marine environmental research is now to link root causes with effects. Links invariably involve interdisciplinary research, including modelling. For example, the issue of effects of increased nutrient fluxes on ocean ecology encompasses understanding and prediction of fluxes through ocean boundaries and interfaces, chemical-biological interactions, marine chemistry in the context of ecosystems, carbon fluxes, oxygen demand and transport by physical processes. The issue is related to eutrophication, harmful algal blooms, hypoxia, changes in species composition and community structure as well as changes in ocean chemistry. It requires an interdisciplinary science approach involving the understanding of coupled chemical, biological – ecosystem dynamical ocean processes. Restated, it requires consideration of global and coastal ocean processes in the ecosystem context (IOC, 2000b).

Accordingly, the restructuring of the GIPME Programme proposed in 2000 (IOC, 2000b) was prepared in an attempt to align the scientific activities more closely with contemporary international policy interests and emerging scientific priorities. It proposed that the scientific components of core GIPME activities be identified within two core activity envelopes: Transport, cycling, fate and effects of contaminants; and Indicators of marine environmental condition and effects.

5.3. OCEAN SCIENCES IN RELATION TO LIVING RESOURCES

The two decades of OSLR's existence have witnessed significant advances in ocean science. In particular, recent advances in marine science make it possible to study, monitor, assess, model and in some cases manage the ocean's resources using an ecosystem approach. Studies such as JGOFS have improved understanding of the factors controlling spatial and temporal variability of ocean primary production. GLOBEC has identified many of the critical processes controlling the variability in zooplankton abundance and distribution and their relationship to fish recruitment. Programmes such as GLOBEC SPACC and Bering Sea FOCI are establishing clear linkages between physical ocean variability and fish abundance and distribution for some populations, to the point where environmental indices (e.g. wind stress, upwelling) are routinely observed for incorporating into fish stock assessments. Taken together, these advances permit improved understanding and prediction of the ocean environment and the way that it influences fishery production.

Significant scientific challenges remain before an ecosystem approach to living marine resource management can be fully realized. The SCOR Workshop on the Future of Global Ocean Biogeochemistry (Plymouth UK, 23-26 September 2000) listed among its chief information needs for fisheries: 1. how changes in higher trophic levels feedback to affect primary and secondary production; 2. how physical and chemical variability at different scales affect community structure in the ocean; and 3. how physical and chemical and trophic processes associated with mesoscale features respond to environmental variability or anthropogenic influences and how these affect fisheries.

The IOC's role in an ecosystem approach must be similar to that established for the OSLR programme at its inception by the 11th IOC Assembly in 1979 with one important difference. The IOC must now be active in interdisciplinary ocean science not just related to living marine resources, but to ecosystems and the resources that they contain, in response to the new knowledge on ecosystem effects of fisheries. This greatly expands the range of potential scientific endeavors for the IOC, and creates for the IOC a unique role among the UN specialized agencies attempting to define and implement an ecosystem approach to marine resource management, in keeping with the call for responsible fisheries.

HAB/GEOHAB Programmes of the Ocean Science Section already constitute successful activities that are interdisciplinary and take into account the need for the knowledge of the related ocean ecosystem dynamics. Consideration of other scientific issues are needed, though, in order to be effective, the IOC cannot focus on all relevant scientific issues at once. Instead, several key scientific

issues central to marine ecosystems and their resources have been identified for study, including: the role of environmental variability in the abundance and distribution of fishes; the use of environmental indices in the management of pelagic fish populations; the development and utility of indicators for coral bleaching; and the monitoring of coral reef ecosystems. Ocean Science Section has already initiated study groups to address carefully defined issues within each of these areas, and use data to test hypotheses. The results will be approaches that can be practically applied to improve marine resource assessment and management.

5.4 OCEAN SCIENCES IN RELATION TO NON-LIVING RESOURCES

The OSNLR programme has been less active for the last few years, with its primary activity being the preparation of guidance on defining the limits of the Continental Shelf in relation to the provisions of the United Nations Convention on the Law of the Sea (Cook and Carleton, 2000). However, with emerging issues such as deep-sea biodiversity, gas hydrates, and the possible sequestration of atmospheric CO_2 in the deep sea, the IOC must maintain the scientific expertise to respond to questions through the provision of sound scientific information.

The open ocean beyond the 200 mile limit comprises approximately 50% of the Earth's surface, and some scientific estimates suggest that there may be more biological diversity in the deep sea than in all other environments on the Earth combined. In the open ocean and deep-sea, there exists a variety of habitats and features of scientific and economic interest, including hydrothermal vents, polymetallic nodules, gas hydrates, seabirds, transboundary fish stocks, and deep-sea 'coral reefs'. Our knowledge of this life in the deep-sea environment is limited, and no complete catalogues of the species or habitats present in these environments exist. The United Nations Convention on the Law of the Sea regards the high-seas as "open-access commons", a resource type that is particularly vulnerable to over-exploitation (WWF/IUCN/WCPAS (2001). The status of natural resources on the high-seas). The rapid development of the capability to recover hydrocarbon deposits beneath the seafloor at increased water depths will mean increasing exploitation of such deposits in the next two or three decades, with heightened concerns about the effects of these activities on the marine environment. There is a critical need for interdisciplinary research to advance our understanding of the key geosphere-biosphere coupling processes that control the genesis and dynamics of deep-water habitats. Further, this work must be done soon so that potential high-seas Marine Protected Areas can be identified and monitored before damage to these fragile ecosystems occurs.

Gas hydrates are solids that consist of cages of water molecules that trap methane and other gases originating from the decomposition of organic material in ocean sediments. Gas hydrates are typically found in sediment pore spaces, distributed over thousands of kilometres on continental margins. Methane hydrates are of significant scientific and economic interest because they may comprise the largest fossil fuel reservoir on Earth. Methane is a major greenhouse gas, and release of methane stored in hydrate deposits to the atmosphere (owing to a decrease in ocean depth or increases in temperature, for example) may have significant impacts on climate. Recent studies suggest that gas hydrates may have contributed to some episodes of global warming in the past. The economic potential of gas hydrates and the technical feasibility of their extraction is unknown. Research for both scientific and economic interests must focus on understanding the geology of the system that produces hydrates, quantifying the amount of methane present, and evaluating the biogeochemical, ecological, and climatological impacts that methane hydrates may have on the marine environment.

Carbon sequestration is a potential technological solution being investigated to reduce or slow the increase of the concentration of CO_2 in the atmosphere. The ocean represents a large potential sink for atmospheric CO_2, and two principle techniques are being investigated: the enhancement of the net oceanic uptake from the atmosphere by fertilization of phytoplankton with micro- or macronutrients (eg, iron), and 2) the direct injection of a relatively pure CO_2 stream to ocean depths great than 1000 m. However, for both techniques, the long-term effectiveness and potential environmental consequences are unknown. The SCOR-IOC Advisory Panel on Ocean Carbon has as one of its principle Terms of Reference to maintain a watching brief on CO_2 sequestration issues. To date, the

Panel has compiled a bibliography of the existing ocean carbon sequestration documents and will make this available on its Web-site. A special expert group will be established by the Panel to address particular sequestration issues and produce white papers when needed.

In considering these emerging issues related to the ocean's non-living resources, it seems clear that the former structure of the OSNLR programme is inadequate to effectively address these issues, and that an interdisciplinary approach within the context of ocean ecosystems is needed.

5.5. MARINE SCIENCE FOR INTEGRATED COASTAL AREA MANAGEMENT (ICAM)

The ICAM is the most recently adopted programme within the Ocean Science Section. The existing activities within the ICAM Programme are both viable and responsive to international interests. They should be maintained in essentially their current form as a major component of the Ocean Science Section, with the understanding that the programme adapts its range and focus to future changing circumstances.

Section Summary

Examination of the IOC statutes, international policy perspectives, and emerging environmental research priorities (Section 4), and the status of IOC's Ocean Science Section activities (this section) suggests that the Oceans and Climate programmes and ICAM programmes are consistent with international research priorities and are meeting the needs of the Member States. However, the OSLR, OSNLR, and GIPME programmes should be grouped under a single integrated framework involving interdisciplinary research in the context of ecosystem dynamics.

6. THE PROPOSED STRUCTURE OF IOC'S OCEAN SCIENCE SECTION AND ACTIVITIES

As a prelude to this section, it is worth reiterating that the programmes and activities of the Ocean Science Section must be consistent with IOC Statutes requiring that IOC promote, plan and coordinate international ocean and coastal area programmes in research and the dissemination and use of their results. The Statutes also require collaboration with international organizations and especially with those UN organizations that are pertinent to the purpose and functions of the IOC as the UN focal point for Ocean Sciences. IOC is expected to continue to lead in the organization and coordination of major scientific programmes, responding to the mandates of UNCLOS, UNCED / *Agenda 21* and the Global Conventions of Climate Change and Biodiversity as well as objectives of the Global Plan of Action for the Protection of the Marine Environment from the Land Based Activities (GPA-LBA), the Regional Seas Programme and related Conventions, and the system of regional fisheries organizations of FAO. Further, the Ocean Science Section of IOC is expected to increasingly implement its activities at the regional level jointly with the other major science programmes of UNESCO and in cooperation with other UN agencies and international organizations.

The programmes and activities of the Ocean Science Section should also be consistent with emerging and existing global environmental research priorities that include climate change, marine biogeochemistry and ecosystem dynamics, biodiversity and the hydrological cycle. The Ocean Science Section should be developed further to address global interdisciplinary science issues, especially an increased understanding of the response of ocean ecosystems to human-induced and natural changes in the chemical and physical processes in the marine environment. A major challenge that needs to be met is the development of scientific mechanisms for an ecosystem approach to the management of ocean and coastal areas, including fisheries management. The development of robust, simple, and globally applicable indicators of health of marine ecosystems is an integral part of this challenge.

6.1. STRATEGY

The guiding principles of the IOC Ocean Science Section would thus include the following:

Promote, participate in and co-sponsor global programmes and their regional components that address a wide spectrum of scientific issues related to the ecosystem approach to the management of marine and coastal environments and resources;

Promote and coordinate investigations of specific scientific issues, such as those involving indicators, which require in-depth study by convening study groups, panels and small *ad hoc* groups that are sponsored either jointly with the existing or emerging global programmes or, initially, by IOC alone;

Ensure that all activities are pertinent to regional concerns and that IOC regional subsidiary bodies take an active role in them, especially in those involving capacity building; and

Further ensure that all activities respond to the scientific needs of the international global and regional conventions and programmes.

The dissemination of the scientific knowledge-base thus developed through reports, publications, symposia, internet-based web sites, workshops, and training activities would be included in all of these programme elements. In this context, close collaboration and joint actions with the five intergovernmental programmes of UNESCO would also be maintained in line with the 'Water and Ecosystems' priority.

The strategic objectives of the Ocean Science Section would thus be:

- Participation in, and co-sponsorships of, global programmes (item i) including WCRP, CLIVAR, JGOFS, LOICZ, GEOHAB, GLOBEC; and developing the institutional support for Earth System Science (IGBP);
- Investigation of specific scientific issues requiring in-depth study (item ii) and having relevance to regional concerns (item iii);
- Meeting the requirements of global and regional conventions, agreements and programmes (item iv) such as UNCLOS and the GPA.

6.2. SCIENTIFIC COMPONENTS OF A FUTURE OCEAN SCIENCE SECTION

It has been pointed out in Section 5 that the Oceans and Climate and the ICAM Programmes are well integrated with the related initiatives of other agencies and international scientific bodies. They meet the requirements of the Member States, international policy perspectives and the existing scientific research priorities. They should thus be maintained in essentially their current form as a major component of the Ocean Science Section with the understanding that, with time, the range and focus of such initiatives will change.

The structure of the other activities within the OSC must be guided by the principle that the scientific knowledge required to implement sustainable development must be integrated and interdisciplinary in nature. A crucial need exists to address significant gaps in understanding ocean processes, especially with respect to the functioning of marine ecosystems. This paradigm shift in marine science requires institutional adjustments. It is therefore appropriate that activities within the OSLR, OSNLR, and GIPME Programmes, be reformulated as interactive components of a common framework involving interdisciplinary science in the context of ocean ecosystems.

It is therefore proposed that the Ocean Science Section be restructured into three interactive principal components:

- Oceans and Climate;
- Ocean Ecosystems Science; and,
- Marine Science for Integrated Coastal Area Management

As discussed below, many programmes and activities within this proposed structure have aspects applicable to the other groupings; for example, having both coastal and global relevance, or having importance for both biogeochemical process studies and global change research. This provides a synergy within the groupings that encourages the exchange of ideas, people, and resources.

Overall scientific guidance of the Ocean Science Section should be provided by a panel of scientists with expertise in the principal disciplines and active in major international scientific programmes. Appointment to this advisory panel will be done by the Executive Secretary based on the scientific credentials of the candidates and in consultation with international scientific organizations cooperating with the Commission. This group should assess the Programme at least biennially and advise the IOC Secretariat on the direction, quality and alignment of the activities within the IOC/OSc.

6.2.1 Oceans and Climate

The primary interests relate to improving the prediction of climate change, including the buildup of carbon dioxide in the atmosphere and predicting the ocean's response to climate change. Current climate change programmes include activities aimed at improving the realism of ocean-atmosphere coupling in global climate models in terms of the exchange of heat, moisture, wind energy, and carbon dioxide between the ocean and the atmosphere. The IOC activities in this context are well integrated with the climate-related initiatives of other agencies and international scientific bodies. IOC remains a co-sponsor of the World Climate Research programme (WCRP) that is working to develop the fundamental scientific understanding of the physical climate system and processes needed to predict climate change, as well as to determine the extent of human influence on climate. The climate activities of the SCOR-IOC CO_2 Panel continue to be a mainstream complement to climate change programmes and advisory groups requiring expertise in ocean carbon issues. Of particular importance is the interaction between this component of the Ocean Science Section and GOOS requirements in relation to IOC stewardship for the GOOS-GCOS-WCRP Ocean Observations Panel on Climate (OOPC) and the GOOS-GCOS-CLIVAR Tropical Implementation Panel (TIP). No doubt, with time, the range and focus of such initiatives will change. Where these involve oceanographic questions, irrespective of discipline, the IOC can participate in new endeavors based on its institutional strengths and capacity.

In summary, the climate change activities of the existing IOC Ocean Science Section are both viable and supportive of international interests. They are proposed to be maintained in essentially their current form as a major component of the Ocean Science Section.

6.2.2 Ocean Ecosystems Science

This component of the Ocean Science Section can be regarded as restructuring of previous activities focused on marine environmental protection, living and non-living resources issues into a single component to address interdisciplinary issues related to marine biogeochemistry and ecosystem dynamics, biodiversity, indicators of health of marine ecosystems and issues concerning marine geology and geomorphology.

Justification. The scientific understanding, monitoring and forecasting of the response of ocean ecosystems to anthropogenic and natural changes in the chemical and physical environment have become crucially important. There is a need to develop scientific mechanisms that will underpin an ecosystem approach to management of the marine environment, including fisheries. Further, it is now clear that significant advances in our understanding of ocean processes will only be made through interdisciplinary studies that focus on coupled chemical, biological, physical, global and coastal ocean processes in the context of a common, interdependent ecosystem. As an integral part of these challenges, there is a strong need to address scientific issues concerned with the indicators of the health of the ocean ecosystems that are reliable in their ability to detect driving forces, powerful in their ability to discriminate between anthropogenic vs. natural sources of stress, and easy to use and broadly applicable in different parts of the world.

Ocean Science Section Activities in Ocean Ecosystems Science. In order to be effective, the IOC must prioritize needs and focus its efforts on the most relevant scientific issues. Several key interdisciplinary scientific issues central to marine ecosystems and their resources have been identified for study through programmes and study groups mostly in partnership with SCOR, GLOBEC, SCOPE, and LOICZ:

- IOC Intergovernmental Panel on HABs with the associated IOC HAB Programme including the IOC-SCOR Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) Programme and ICES-IOC Working Group on the Dynamics of Harmful Algal Blooms;
- IOC/SCOR Coastal Ocean Advanced Scientific And Technical Studies (COASTS) Programme;
- JGOFS/LOICZ/IOC Continental margins Task Team (CMTT);
- IOC/GLOBEC/SPACC *Ad Hoc* Study Group on Use of Environmental Indices in the Management of Pelagic Fish Populations;
- IOC/GLOBEC/SPACC Synthesis and Training Office;
- Joint SCOR/IOC Working Group 119 on Quantitative Ecosystem Indicators for Fisheries Management;
- IOC *Ad Hoc* Study Group on Benthic Indicators;
- IOC *Ad Hoc* Study Group on Indicators of Coral Bleaching and Subsequent Effects; and,
- The IOC *Ad Hoc* Ecotoxicology Group (in development stage).

A short description of these Programmes and Study groups for the entire Ocean Science Section is provided in the Annex V and listed in Table 1 together with their regional relevance.

Table 1

Programmes and study groups of the IOC Ocean Science Section

Investigation/Study Group/Programme	**Regional Relevance**
SCOR / IOC CO_2 Panel	All regions / global climate change
JGOFS/LOICZ/IOC Continental Margins Task Team	Regional synthesis reports and case studies; typology synthesis focusing on eastern and western boundary currents, marginal seas, polar margins, and tropical coasts.
IOC / GLOBEC / SPACC *Ad Hoc* Study Group on Use of Environmental Indices in the Management of Pelagic Fish Populations	Fish stock assessments and fisheries data for Africa, South America, North America, Iberian Peninsula, and in the region of the Kuroshio/Oyashio currents.
IOC/GLOBEC/SPACC Synthesis and Training Office	Same as above.
Joint SCOR/IOC Working Group 119 on Quantitative Ecosystem Indicators for Fisheries Management	Sustainable management of ecosystems and fisheries for coastal regions. All regions and global
IOC *Ad Hoc* Study Group on Benthic Indicators	Development of reliable and simple techniques for rapidly assessing the quality of coastal sediments. Regional and Global
IOC *Ad Hoc* Study Group on Indicators of Coral Bleaching and Subsequent Effects	Assessment and Prediction of stresses on coral reefs. Regional
IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB)	The IOC IPHAB is established to meet the scientific, managerial, implementation, and resource needs of the IOC Harmful Algal Bloom Programme. Global

Investigation/Study Group/Programme	Regional Relevance
IOC/SCOR Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) Programme	Development of the capacity to predict and prevent harmful algal blooms leading to fish kills, seafood contamination, ecosystem damage, and human health hazards. Regional and Global
ICES-IOC Working Group on the Dynamics of Harmful Algal Blooms	Development of understanding of the population dynamics of harmful algae. Collates national HAB reports and maintains the HAE-DAT database. Specific Terms of Reference revised annually by the IOC and ICES. Regional and Global
IOC/LOICZ/SCOR Study Group on the Assessment and Management Implications of Submarine Groundwater Discharge into the Coastal Zone	Provide coastal zone managers with information on the potential significance of submarine groundwater discharge into the coastal zone. Regional
IOC *Ad Hoc* Ecotoxiocology Group	Assessment of fates and effects of contaminants in the coastal ocean. Global
IOC/SCOR Coastal Ocean Advanced Scientific And Technical Studies (COASTS) Programme	Study and Synthesis of the Interdisciplinary Ocean Science of the Global Coastal Ocean. Regional and Global

This Ocean Ecosystems Science component will also take on the responsibilities of coordination and cooperation with UNEP/WB Large Marine Ecosystem initiative and GESAMP activities.

6.2.3 Marine Science for Integrated Coastal Area Management

This programme has five components: interdisciplinary approaches; monitoring, information, the development of methodology, and capacity building. The cooperation with International Geographical Union (under Oceans 21 Project), GPA-LBA and the UNESCO Water Science Division will continue.

Regarding the specific marine science activities, it will encompass IOC/LOICZ/SCOR Working Group on Submarine Groundwater Discharge into the Coastal Zone and LOICZ /IOC Basins Effort (Annex V), and the GCRMN South Asia Node which is concerned with the socio-economic aspects of coral reefs in the region. The Programme also encompasses IOC/GEF/ACOPS root-cause analysis Project for the Development and Protection of the Coastal Marine Environment in Sub-Saharan Africa. The Programme is in the process of establishing a working group on aggregated environmental-social-economic indicators for coastal areas.

In summary, the ICAM activities of the existing IOC Ocean Science Section are viable and supportive of the interests of the Member States and the International perspectives. They are proposed to be maintained in essentially their current form as a major component of the Ocean Science Section.

7. CONCLUSIONS

The scientific knowledge to implement sustainable development needs to be integrated and interdisciplinary in nature. A crucial need exists to address significant gaps in understanding ocean processes, especially with respect to the functioning of marine ecosystems. This paradigm shift in marine science requires institutional adjustments. It is therefore proposed that the Ocean Science Section reorganize the activities previously carried out under the OSLR, OSNLR, and GIPME Programmes along with new initiatives within the Ocean Science Section into a new, interdisciplinary

framework called Ocean Ecosystems Science. The Ocean Science Section would thus have the following three interactive lines of work:

- Oceans and Climate;
- Ocean Ecosystems Science; and,
- Marine Science for Integrated Coastal Area Management.

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ANNEX I

SUMMARY OF THE REPORT OF THE COMMITTEE TO REVIEW THE OCEAN SCIENCES PROGRAMME OF IOC

BACKGROUND

1. The 20th session of the IOC Assembly in 1999 adopted a resolution calling for a meeting of experts to be convened to review the IOC Ocean Science Programme. That review panel of experts met in May 2000 to

> *"review the framework of the existing ocean science programmes in the light of new developments"* and to *"identify a new paradigm for the IOC to meet evolving aspects of interdisciplinary science"*.

The report of the review panel is summarized here.

2. The review panel noted that the structure and management of the plethora of programmes has evolved over at least two decades to the point where it may not be obvious to a present-day observer how they relate to each other or to the evolving needs of the international oceanographic community of governments and scientists. Scientific research, observations and management are all interdependent. Accordingly, the panel concluded that it was not possible, as tasked, to simply review one of these three elements. The panel therefore suggested one possible rationalization of the present structure and management that might focus discussion one a way forward.

3. The report focusses entirely on a new structure for the science activities within the IOC. It proposes condensing the existing three major programme groups into two categories:

1. OSP Ocean Science Programmes; and
2. GOODS – Global Ocean Observations and Data Systems.

4. In relation to the proposed new Ocean Science Programmes group, the review proposed that there existed three natural sub-groupings. It further proposed that some of the OSLR programmes be placed within these groups and the name "OSLR" be retired.

5. The review panel also proposed that "OSLNR" be also retired and that any residual initiatives in this area be subsumed under LOICZ or COASTS or, eventually, under new developments (such as deep seabed minerals mining).

6. The proposed new Ocean Science Programme components are:

1. GOS – Global Ocean Systems (focussing on existing and new global scale research programme coordination);
2. CES – Coastal Environmental Systems; and
3. IMS – Integrated Management Systems.

7. The review panel believed that GODAE and OOPS were elements of GOOS and properly belong to the GOODS programme group. It also recognized that GCRMN and SAHFOS were elements of an observing system and should be transferred from the Ocean Science Programme to GOOS when a biologically-oriented staff member is available within GOOS to manage non-climate elements.

8. Under GOODS, the review panel proposed the combining of observing system activities with aspects of ocean services that are clearly closely involved with GOOS such as data management, data exchange and archiving.

9. The review panel also proposed that senior scientific management comprise the Executive Secretary and the Directors of OSP and GOODS. The there senior managers would be jointly responsible for cross-cutting functions. Each of the three programme groups of the Ocean Science Programme would each have designated section leaders reporting to the overall OSP Director.

10. It further recommended that a continuing external advisory group should be established for each of the three sections of the Ocean Science programme with the chairs of each group, plus additional members, forming the overall advisory group for the Ocean Science Programme.

11. The review panel made three other recommendations:

Training Education and Mutual Assistance (TEMA): The panel considered TEMA to be a very important activity which has a high visibility, and is a high priority for IOC. It should, at least, be maintained and could beneficially be further developed. The panel was surprised to find that the regular programme TEMA budget for 2000-2001 has apparently been cut by $100,000 (from $600,000 to $500,000) relative to the situation in 1998- 1999.

Public Information Communication and Outreach Activities: This activity currently includes the IOC website and newsletter, and the panel recommends that these be continued and enhanced. Further outreach should include improved information about IOC activities, particularly to ocean scientists, as well as governmental and industrial representatives and the general public. Production and widespread distribution of a small, glossy brochure about the work of the IOC should be a top priority. The IOC should also publicize by all means possible important oceanographic findings and their -implications for society . These activities will need the efforts of a dedicated publicity officer. Indeed, we view the expansion and refinement of a set of more generally accessible IOC reporting/education documents as a significant opportunity for the IOC as the U.N.'s most visible ocean sciences organization.

IOC Assembly: The panel recommends that science and the scientific community should be encouraged to play a much stronger role in IOC Assemblies. This could be achieved by, *inter alia*:

(1) having one or more consecutive "days of science" and inviting natural and social marine scientists to make presentations (both oral and poster) on issues relevant to the work of the Assembly;

(2) separating, as far as possible, much of the administrative business and scientific proceedings (this has been successfully achieved by ICES, a regional intergovernmental oceanographic organization); and

(3) increasing the participation of representatives of relevant NGOs.

ANNEX II

EXECUTIVE SUMMARY OF THE REPORT FROM THE REVIEW PANEL FOR IOC PROGRAMME ON OCEAN SCIENCES IN RELATION TO LIVING RESOURCES (OSLR)

BACKGROUND

1. The 31st session of the IOC Executive Council in 1998 adopted a resolution (EC-XXXI.2) that called for a meeting of experts to be convened to review the IOC/OSLR Programme and to assist the Programme to identify a more coherent theme for the development of future activities. That group met in July 2000 and produced a report that is summarized here.

3. The OSLR Programme was officially established by the IOC Assembly in 1982, based on an identified need to expand basic research in ocean sciences related to use of living marine resources as a priority. The Programme was planned and implemented with FAO as a co-sponsor and guided by advice from a group of four experts. The OSLR Programme had a strategic focus on physical-biological linkages and their effects on fisheries recruitment variability. Issues emerged in the late 1980s and 1990s such as harmful algal blooms (HAB) and coral reef bleaching events, and IOC responded by initiating programmes (HAB Programme and Global Coral Reef Monitoring Network (GCRMN)) which are now key elements of OSLR. IOC/OSLR has also cosponsored the Global Ocean Ecosystem Dynamics (GLOBEC) Programme and supported the Large Marine Ecosystem (LME) initiative. It has also supported the Continuous Plankton Recorder (CPR) Survey of the Sir Alistair Hardy Foundation for Ocean Science (SAHFOS), and the Convention on Biological Diversity (CBD). OSLR has also been involved in the development of the Living Marine Resources Module of GOOS (LMR-GOOS).

4. OSLR activities have been considered to be successful to various extents, however the current OSLR Programme has developed in the 1990s without a clear strategic focus and plan. This has been clearly recognised and is reflected in the need for a review to help identify a more coherent theme for the development of future activities of the OSLR Programme. The current programme is somewhat arbitrarily composed, reflecting the interest and initiatives of some member countries and key persons involved. Nevertheless, the elements of the Programme all deal with highly important and relevant issues in the context of ocean science and living marine resources. Considering the limited priority and resources allocated, the OSLR Programme has been doing well in focusing on some chosen issues and supporting other initiatives through co-operation (e.g. GLOBEC, LME, CPR).

5. The elements of the current OSLR may form the basis for the future development of activities in OSLR through evolution rather than revolution. The research activities need to be linked to the needs of society, including human welfare and environmental protection, in developing and developed countries. These needs are expressed and dealt with in management systems. The broader context of ecosystem management may provide an overall framework and theme for the future OSLR activities in IOC.

A NEW SCIENTIFIC APPROACH

The Ecosystem Approach

6. There is currently broad interest in an Ecosystem Approach (EA) to ocean management. An EA is seen as one of the guiding principles in the follow-up work on the marine environment within the framework of the Convention of Biological Diversity, and in the FAO Code of Conduct for Responsible Fishing. The Large Marine Ecosystem (LME) initiative is based on an EA, with several projects in various parts of the world. The need for an EA has also been agreed for the North Sea by the surrounding European states and the European Union.

7. The two main scientific components of an EA are Monitoring and Research, and Ecosystem Assessment. Monitoring provides updated information about the current status and trends in physical,

chemical and biological conditions. Research provides insight and understanding of relationships and mechanisms of ecosystem dynamics. Monitoring and research provide the basis for ecosystem or environmental assessments. Such assessments contain a description of the current status of environmental conditions and living resources in marine ecosystems, and an evaluation of the extent of influence from human activities. There are two main challenges in carrying out an ecosystem assessment. The first is to distinguish any influence of human activities from natural variability. The second is to distinguish between effects from different human activities.

8. Ecosystem assessments are a basis for scientific advice to managers and policy makers in the EA. The scientific basis should be clearly outlined and the advice should be clearly formulated. With more complex ecological relations to take into account in the EA, this poses a particular challenge to the scientific advisory function.

Integration of Ocean Physics and Biology

9. The review panel felt that ecological understanding needs to be strengthened by developing stronger links between biology and ocean physics. To illustrate the relationship with a metaphor: the physical-chemical environment is the stage on which organisms interact; it determines what category of play is to be enacted, but it cannot dictate the plot. The plot has been developed by natural selection of the organisms in the course of evolution. But how the stage shapes ecosystem structure needs to be elucidated. The impact of the *El Niño* and *La Niña* cycles on the ecology of the Peruvian coast is a well-known example of how the physical environment determines which type of pelagic ecosystem prevails. However, it is not known how the spring bloom of the North Atlantic is influenced by the North Atlantic Oscillation (NAO). That there must exist an ecosystem response is demonstrated by widely documented fluctuations in populations of zooplankton, fish and benthos. Indeed, even coastal ecosystems are impacted by the NAO but the mechanisms remain largely unknown. Ocean ecology, still challenged by a plethora of unknowns, needs to be firmly based on the space-time scales of the physical-chemical environment (the "stage") relevant to populations of species in order to successfully unravel the details of biological interactions between the organisms (the "actors").

10. Efforts to integrate ocean physics and biology must occur on appropriate space and time scales. It is recommended that OSLR activities be restructured along three categories of scale: global scale, LME scale and inshore coastal scale.

SUGGESTIONS FOR FUTURE DEVELOPMENT OF OSLR ACTIVITIES

11. Several general recommendations are made for future OSLR function:

- improve and increase cooperation with FAO;
- couple research and monitoring activities more closely;
- focus on three main scales of activities: global scale, LME scale and inshore coastal scale;
- continue to emphasize training and capacity building;
- clearly define the roles of the IOC regional bodies;
- expand IOC's role as a coordinator and co-sponsor of international activities such as GLOBEC and LOICZ;
- develop an IOC strategic plan for its ecosystem activities;
- allocate more resources to OSRL activities, including a dedicated staff position.

PROPOSED ACTIVITIES

12. The OSP has moved to implement the recommendations from the review. As identified in the OSP review, study groups are an effective means to focus expertise on pertinent marine science issues, without the need for significant additional staff or financial resources. Several study groups are

proposed to begin implementation of the review recommendation. Details are provided in the introduction to the revised OSP Programme.

- Ad Hoc Study Group on Use of Environmental Indices in the Management of Pelagic Fish Populations;
- SPACC Synthesis and Training Office;
- Joint SCOR/IOC Working Group 119 on Quantitative Indicators of Marine Ecosystem Change Induced by Fisheries;
- Ad Hoc Study Group on Benthic Indicators;
- Ad Hoc Study Group on Indicators of Coral Bleaching and Subsequent Effects;
- GEOHAB: Global Ecology And Oceanography Of Harmful Algal Blooms.

ANNEX III

Restricted Distribution

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INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)

Thirty-third Session of the IOC Executive Council
Paris, 20-30 June 2000

Agenda Item: 4.1.5

SUMMARY OF THE REVISED FRAMEWORK FOR SCIENTIFIC ACTIVITIES WITHIN THE IOC OCEAN SCIENCE RELATING TO GLOBAL INVESTIGATIONS OF POLLUTION IN THE MARINE ENVIRONMENT (GIPME)

This document was prepared by the Chairman of GIPME, Dr. J.M. Bewers, to provide information on progress in the restructuring of the GIPME Programme in pursuant to IOC Assembly Resolution XIX-4.

The Executive council is invited to consider the information presented and provide guidance on further work by IOC.

BACKGROUND

1. For the past 20 years, the Global Investigation of Marine Pollution in the Marine Environment (GIPME) Programme has been working on issues of marine contamination and pollution. Through method development programmes, workshops and intercomparison exercises, techniques have been developed to assess contaminant concentrations in several marine matrices and the effects of contaminants on marine organisms. GIPME is co-sponsored by the Intergovernmental Oceanographic Commission (IOC), the United Nations Environment Programme (UNEP) and the International Maritime Organization (IMO).

2. The foundation for GIPME was established in IOC Technical Series No 14 entitled *'A Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment and Baseline Study Guidelines'* (IOC, 1976). The current framework for the implementation of the GIPME Programme was outlined in IOC Technical Series No. 25 (IOC, 1984).

3. With the development of the Global Ocean Observing System (GOOS), scientists from within GIPME have also been involved in the design of the GOOS Health of the Oceans Module (HOTO). HOTO is the GOOS Module that is expected to monitor the condition of the ocean, its resources and amenities, in the context of concerns about environmental degradation. Specification of the objectives and strategic design of HOTO was completed in 1996 and appears in IOC/INF-1044 (IOC, 1996).

4. The 19th Assembly of the IOC in 1997 adopted Resolution XIX-4 that changed, in a fundamental way, the manner of implementation of the GIPME Programme and clarified the relationship between GIPME and HOTO. This decision necessitated a detailed re-evaluation of ocean science activities within GIPME, particularly the objectives and *modus operandi*, to provide guidance to those involved in GIPME and in associated IOC activities such as GOOS.

5. The previous GIPME Strategic Plan addresses solely the issue of 'pollution' in the sense of the introduction of substances into the marine environment and does not specifically cover some non-pollution issues that have become of major concern in the present decade in respect to the protection of the marine environment from the overall effects of anthropogenic activities.

6. Indeed, much has changed in the field of marine pollution during the 24-year period since the inception of GIPME and major changes in policy perspectives have taken place in recent years regarding the protection of marine environment. Specifically, reassessment of the relative importance of different pollutants has taken place because of either the advancement of science or the need to prioritize regulatory actions.

7. The most recent GESAMP Review of the State of the Marine Environment (GESAMP, 2000) highlights as the most serious compromises and threats to the marine environment, aside from possible climate change, the following: physical alteration; overfishing; sewage; eutrophication; and changes in sediment transport. Of these, only sewage constitutes a 'classical' pollution issue; the others result from new information and new perspectives on damage and threats to the marine environment on a global scale. All of the priority issues identified by GESAMP fall within the basic mandate proposed for the GIPME Programme.

8. On the other hand, new perspectives in marine environmental protection require new integrated approaches in research as well as management. The challenge for marine pollution research is now to link root causes with effects. The starting point is now *the problem* and each *problem* may be multifaceted requiring a knowledge of causes, levels, effects and potential synergism. Links invariably involve interdisciplinary research, including modelling. For example, the issue of effects of increased nutrient fluxes on ocean ecology encompasses understanding and prediction of fluxes through ocean boundaries and interfaces, chemical-biological interactions, marine chemistry in relation to transformations, carbon fluxes, oxygen demand and transport by physical processes. It

requires, in other words, interdisciplinary science approach involving the understanding of coupled chemical, biological – ecosystem dynamical ocean processes.

9. These new perspectives involve objectives that are now attainable. Scientific understanding of the oceans and the mechanisms by which contaminants enter, circulate and are removed from the marine environment, has improved substantially. In fact, after two decades of progress in studying major physical, biological and geochemical processes in the marine environment, ocean science is undergoing a major conceptual revolution. It is now feasible to undertake important interdisciplinary studies that were previously intractable (Robinson *et al.,* 1999). It is therefore desirable that the activities of the IOC regarding the protection of the marine environment should closely reflect the new interdisciplinary nature of ocean science.

10. In conclusion, there is reason to broaden the perspectives of the GIMPE Programme beyond 'classical' pollution issues to all issues dealing with the adverse effects of anthropogenic activities on the marine environment except those involving climate change, habitat destruction and fisheries which are addressed primarily by other IOC or international programmes.

THE CHALLENGE FOR GIPME

11. A document has been prepared by the Chairman of GIPME, Dr. J.M. Bewers, in consultation with several experts. It represents the results of a re-evaluation of the needs for interdisciplinary ocean science in regard to the GIPME Programme in the context of new perspectives of damage and threats to the marine environment, its resources and amenities, and scientific advances made in the last two decades.

12. The salient highlights of the review document on GIPME are as follows.

13. The overall focus of the GIPME Programme should be anthropogenic activities (aside from those involving climate change, habitat destruction and fisheries) causing, or likely to cause adverse effects in the marine environment, its resources and amenities, and associated threats to human health (*i.e.,* those arising from exposures to the marine environment or the use of resources obtained therefrom). Such a focus can respond to contemporary demands in a number of areas and programmes, to which GIPME could legitimately provide advice and information, required protocols and approaches for diagnoses and prediction of state, trends and vulnerability of marine systems and/or areas. Such a focus would enable, in principle, a good number of all current issues of concern to governments regarding damage and threats to the marine environment to be addressed within GIPME.

14. Furthermore, in order to be able to provide practical validation of hindcasts and forecasts, there is a need for the development and application of indicators of state and trends in marine systems. It is proposed that the restructured GIPME Programme devote significant emphasis to indicators, especially in relation to sediment quality and benthos, rapid assessment procedures for broad application in coastal areas, and associated modelling that is required to undertake risk assessment.

15. The priority fields of endeavour requiring primary attention within GIPME both for the purposes of satisfying contemporary marine environmental management needs and responding to scientific questions identified in associated IOC programmes such as GOOS are (without any implicit assignment of priority):

- consequences of increased nutrient influxes;
- sources and consequences of changed sediment influxes;
- sources, transport, fate of synthetic organic pesticide compounds;
- development of human health indicators in respect to risks to human health posed by the effects of anthropogenic activities on the marine environment;

- training, development and proving of techniques for rapid assessment of marine pollution; and
- study of benthic indicators of condition.

16. The necessary scientific components of core GIPME activities are thus identified within two core activity envelopes:

1. Transport, cycling, fate and effects of contaminants; and
2. Indicators of marine environmental condition and effects.

1. First Core Activity: Transport, cycling, fate and effects of contaminants

This activity should comprise three sub-activities as follows:

1.1. The consequences of increased nutrient influxes: This activity encompasses fluxes through ocean boundaries and interfaces, chemical-biological interactions and marine chemistry in relation to nutrient transformations, carbon fluxes, oxygen demand and transport by physical processes. The topic is related to eutrophication, harmful algal blooms, hypoxia, changes in species composition and community structure as well as changes in ocean chemistry. It requires an interdisciplinary science approach that includes modelling.

1.2. The sources and consequences of changed sediment influxes: This activity involves fluxes, physical transport, optical effects, sedimentary geochemistry, physical interference and benthic community responses. It also requires a multidisciplinary approach.

1.3. The sources, transport, fate of synthetic organic pesticide compounds: This activity involves agricultural, forestry and aquacultural practices, fluxes, chemical property (hazard) characterization, transformations, fate and biological effects (*i.e.*, ecotoxicology). It is a subject of keen contemporary interest in terms of the effects of human activities on the marine environment.

2. Second Core Activity: Development of indicators of marine environmental condition and effects

This activity should also comprise three sub-activities as follows:

2.1. The development of human health indicators: This topic addresses assessment of risks to human health posed by the anthropogenic mobilization of artificial and natural toxic agents in the environment. It involves the linkages between ocean and human health at the point of exposure to humans through ingestion, dermal contact and inhalation. The main concern is the ingestion of contaminated seafood and external exposures resulting from direct contact. Elements of research needed include biomarker development, modelling, informatics, training and the transfer of technology.

2.2. Training, development and proving of techniques for rapid assessment of marine pollution (RAMP): The main objective of this activity is the development of methods for rapid assessment of anthropogenic stresses on the marine environment. The emphasis should be on techniques that are simple to use, robust and inexpensive but nevertheless provide a basis for judging environmental condition and enable rapid prioritization among sites. One of the more recent tasks of GIPME has been to develop RAMP through research and training to assist in the design and implementation of the GOOS/HOTO Module. This thrust should be continued.

2.3. The study of benthic indicators of condition: This is envisioned as a science development project fronted by research activities in IOC Member States and is needed for the kinds of pollution assessments that are the responsibility of GIPME. It deals with the development of indicators for assessing the condition of marine benthic communities. It is also expected to meet the science demands for methods to be used within GOOS/HOTO.

ANNEX IV

AN ECOSYSTEM APPROACH AND FRAMEWORK FOR SCIENTIFIC ACTIVITIES WITHIN THE IOC OCEAN SCIENCE SECTION

Background

This annex provides background information on the application of an ecosystem-based approach to the study and management of marine and coastal environments. In particular, consideration is given to the IOC's role in implementing such a framework within the context of the Ocean Science Section.

The concept of an ecosystem approach to management has been addressed in detail within the international community. One example stems from ICES, whose Advisory Committee on Marine Environment (ACME) has proposed a definition of the term 'ecosystem approach' as follows:

> *Integrated management of human activities based on a knowledge of ecosystem dynamics to achieve sustainable use of ecosystem goods and services to preserve ecosystem integrity.*

Clearly, the essential issue that is pertinent to the Ocean Science Section is the requirement of the "knowledge of ecosystem dynamics as a basis" for integrated management. This requirement persists in other definitions and descriptions of the ecosystem-based approach in the sustainable management of oceans and coastal areas (see for instance, Decision V/6 of the Conference of Parties to the Convention on Biological Diversity, May 2000). Furthermore, it has been noted in Section 4.3 that, the required knowledge is not only relevant to the management but also to emerging scientific perspectives.

The Need for developing an Ecosystem Approach to management

Drivers of ecosystem change. Recent scientific advances have occurred against a background of increasing threats to the marine environment, including overfishing, global climate change, habitat alteration and destruction, introduced species, and the introduction of contaminants in coastal areas. In fisheries, the need for ecosystem approaches to management arises from the perceived failure of traditional fisheries assessment and management systems to achieve sustainable fisheries. Overfishing and its influence on the marine environment are increasingly problematic. The number of overexploited fish stocks increased by 2.5 times between 1980 and 1990 (Alverson and Larkin 1994). In addition, fishing has the ability to change the trophic structure of the oceans. Pauly *et al.* (1998) demonstrated that over the past four decades, global fish landings have gone from dominance by high trophic level, piscivorous bottom fish toward short-lived, low trophic level invertebrates and planktivorous pelagic fish. This phenomenon, called "fishing down the food web" has allowed fish catch to increase or remain constant, but is altering marine ecosystems in such a way that it is likely unsustainable.

Evidence from around the world suggests that our current scientific methods and associated data used to provide advice for resource management and knowledge about stock status are failing systematically (McGlade 1999). The main reason is that the underlying models do not address some of the most important problems outlined, i.e., the complex dynamics of marine ecosystems, the unreliable nature of prediction in any spatially extended dynamical system, the propagation of errors and uncertainties in the models as a result of imperfect information about the system and its functioning, and the long and short-term risks of overexploitation associated with over-investment, cultural dependence and technical innovation in fisheries.

Climate variability also threatens significant changes to marine ecosystems. In 1997-1998, coral reefs in the Indian and Western Pacific oceans were severely affected by higher than average water temperatures that led to coral bleaching. In some areas such as the Maldives, some 90% of coral was bleached and may not recover (GCRMN 2000). Climate variability also affects abundance and distribution of marine fish stocks. A climate shift in the North Pacific from 1977-1988 led to significant changes in marine ecosystems, reducing the carrying capacity in the Northwest Hawaiian Islands (Polovina 1999). In the Bering Sea, the period was characterized by an increase in water temperature and a shift from abundant pelagic fishes such as salmon to demersal fishes such as

pollock. The mechanisms of these climate shifts and their effects on marine ecosystems are poorly understood.

Coastal eutrophication has become a significant driver of ecosystem change. GESAMP (2001) states that eutrophication caused by excess nutrients and/or sewage discharged into coastal waters is an expanding problem and incidents are known from almost every coastal state. Natural enrichment from land and atmospheric sources is important to fisheries production, but over time, eutrophication can lead to anoxia in bottom waters, reducing and degrading available habitat and leading to species and community composition changes (Caddy 2001).

Ecosystem linkages. Marine ecosystems are not steady state systems, but exhibit continuous changes in production, species composition and inter-specific dynamics . This confounds the ability to ascribe ecosystem change to one specific cause or set of causes. The viability of many marine resources relies on the maintenance of specific trophic linkages and/or keystone organisms that are often hidden within the complex set of species assemblages and community dynamics. Unfortunately, these are often ignored or misunderstood until such time as their loss causes significant changes to the community or collapse of the trophic cascade.

Awareness of the importance of ecosystem linkages has increased significantly during the last decade, as long-term data sets on various organisms have been brought together. Striking and sudden changes are observed, quite different from those one would expect from a gradual response to human impact. For example, the algal biomass in the western Wadden Sea doubled between 1976 and 1978, followed by the macrobenthos in 1980 and an increase of several orders of magnitude in the breeding success of eider duck. In the late 1970's, sudden changes in the phytoplankton and zooplankton species composition and shifts in macrofauna assemblages and benthic respiration rates were reported in the North Sea. In the north-eastern Pacific, a major shift in the marine ecosystem in the second half of the 1970's was also recorded, hinting at a possible large-scale cause of the phenomena observed. Other examples of significant shifts in ecosystem structure have followed on from the sudden appearance of new species (e.g. following the appearance of triggerfish (*Balistes* spp.) in the 1980s in the Gulf of Guinea (Koranteng 1998)) or broad-scale environmental change (e.g. the collapse of upwelling fisheries, the mass mortality of Indian Ocean corals resulting from elevated temperatures in surface waters during the 1998 El Nino and the massive algal blooms and die-off of seagrass meadows in Florida Bay, following changes in freshwater outflow from the Everglades (Boesch 1996)).

Another phenomenon found in many data sets is cyclic change. Three-year maxima have been observed in the abundance of the dinoflagellate *Noctiluca scintillans*, at the same time as a 6 year-cycle in the amount of shrimp landed around the North Sea was found. Plankton data in the North Atlantic show evidence of 3-4, 6-7 and 10-11 year cycles, whereas benthic data suggest 6-7, 10-11 and 25-30 year cycles. And the well-known El Nino-Southern Oscillation (ENSO) cycle, which has resulted in the nearly complete failure of fisheries and many other ecological changes, occurs every 4 - 7 years. Yet despite an increasing number of documented examples from aquatic and terrestrial systems around the world, such cyclic behaviour is still considered by some as a statistical outcome of the data rather than a real phenomenon (IOC/SCOR/SCOPE 2000).

Some of the very longest data sets also indicate periods with cycles interspersed with aperiodicities, and interannual and decadal variability. Why these occur is not always clear, although links with changes in short-term or large-scale weather patterns can be made, as these lead to shifts in seasonal temperatures, changes in freshwater flows, mixing and sediment exchanges and fluxes, which are laid down as markers in sediments, corals and shellfish. However, to prove the real cause-effect relationships in such a complex system as the coastal zone is often very difficult as many different causes, including human disturbance and exploitation, can have similar effects.

The scientific needs for developing an ecosystem approach to management. Long-term data series can help to answer questions on the variability of marine ecosystems and as such any ecosystem-based management framework must have at its core a commitment to the continuous collection of data for assessment and monitoring. These long-term data sets, in combination with the results of experimental laboratory and field studies, form a necessary part of an ecosystem-based approach helping managers are to know whether the observed phenomena can be explained with clear cause-effect relationships or are more or less random and unpredictable.

The two main scientific components of an ecosystem approach are monitoring and research, and ecosystem assessment. Monitoring provides updated information about the current status and trends in physical, chemical and biological conditions. Research provides insight and understanding of relationships and mechanisms of ecosystem dynamics. Monitoring and research provide the basis for ecosystem or environmental assessments. Such assessments contain a description of the current status of environmental conditions and living resources in marine ecosystems, and an evaluation of the extent of influence from human activities. There are two main challenges in carrying out an ecosystem assessment. The first is to distinguish any influence of human activities from natural variability. The second is to distinguish between effects from different human activities.

Marine ecosystems are open systems where the different biological components are interlinked in more or less strong trophic couplings. Thus various human activities impact not only the same ecosystem but also directly or indirectly the same components of the ecosystem. This can be illustrated by some examples. Eutrophication through increased supply of nutrients leads to increased growth of plants and subsequent changes in flows of energy and composition of pelagic and benthic food webs. Fishing impacts the same food webs directly by removal and mortality of targeted and bycatch species and indirectly by altering predator-prey relationships. Contaminants that are entering the coastal zone are influenced by the same physical processes that transport nutrients, organisms and organic material stemming from eutrophication. The contaminants are taken up and transported in the pelagic and benthic food webs where they trough bioaccumulation may influence the reproduction and population dynamics of organisms at higher trophic levels. Thus it may be difficult in a given situation to distinguish between biological effects of eutrophication, fishing, and pollution.

Involvement of stakeholders is important to achieve sustainable utilization and protection of marine ecosystems. They should be involved in the various stages of an ecosystem-based approach to management. The scientific advice is the stage where scientific knowledge is translated and forwarded as an element of the basis for management and policy decisions. It is a challenge to keep scientific and political considerations separate. This is necessary, however, to improve the transparency in the decision making process and clarify the different roles and responsibilities of scientists, managers, politicians and stakeholders.

The implementation of the ecosystem approach will put a heavy demand on science in providing an improved and sound scientific basis. Further insight into the natural dynamics of marine ecosystems and the impacts of multiple human activities upon them, will be required. For fisheries systems, that information will include essential fish habitat, trophodynamics, hydrography and nutrients at appropriate temporal and spatial scales. It will also require better population assessments of non-target species, and research on how fishing changes ecosystems at genetic and population levels. For human interactions, better information will be required on, *inter alia*, the economic importance of fishery-related activities, participants in the fisheries and their activities and concerns, the public's priorities and willingness to make tradeoffs to protect and restore marine ecosystems, and the benefits and costs of management options.

IOC Contributions toward an Ecosystem Approach to management. Significant scientific challenges remain before an ecosystem approach to living marine resource management can be fully realized. The SCOR Workshop on the Future of Global Ocean Biogeochemistry (Plymouth UK, 23-26 September 2000) listed among its chief information needs for fisheries: 1. how changes in higher trophic levels feedback to affect primary and secondary production; 2. how physical and chemical variability at different scales affect community structure in the ocean; and 3. how physical and chemical and trophic processes associated with mesoscale features respond to environmental variability or anthropogenic influences and how these affect fisheries.

Better routine data collection and assessments (through e.g., GOOS) are also essential to provide the information required to implement an ecosystem approach to management. For fisheries systems, that information will include essential fish habitat, trophodynamics, hydrography and nutrients at appropriate temporal and spatial scales. It will also require better population assessments of non-target species, and research on how fishing changes ecosystems at genetic and population levels. For human interactions, better information will be required on, the economic importance of fishery-related activities, participants in the fisheries and their activities and concerns, the public's priorities and willingness to make tradeoffs to protect and restore marine ecosystems, and the benefits and costs of management options.

The IOC's role in developing an ecosystem approach to management must be similar to that established for the OSLR programme at its inception by the 11th IOC Assembly in 1979 with one important difference. The IOC must now be active in oceanographic research not just related to living marine resources, but to ecosystems and the resources that they contain. This greatly expands the range of potential scientific endeavors for the IOC, and creates for the IOC a unique role among the UN specialized agencies attempting to define and implement an ecosystem approach to marine resource management.

In order to be effective, the IOC must prioritize needs and focus its efforts on the most relevant scientific issues. Several key scientific issues central to marine ecosystems and their resources have been identified for study, including: the role of environmental variability in the abundance and distribution of fishes; the development and utility of indicators for coral bleaching and the health of benthic environments; the ecology and oceanography of harmful algal blooms; and the monitoring of coral reef ecosystems. OSC has established study groups to address carefully defined issues within each of these areas, and use data to test hypotheses. The results will be the development of approaches that can be practically applied to improve marine resource assessment and management.

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ANNEX V

STUDY GROUPS AND PROGRAMMES OF THE OCEAN SCIENCES SECTION

1. SCOR-IOC/CO_2 Panel

Overall objectives of this Panel are to advise SCOR / JGOFS, GOOS, LOICZ, and OOPC on observations, data management and modelling needed for studies of the global carbon cycle and provide an international forum for initiatives to promote high-quality observations of CO_2 in the oceans. The Specific Terms of Reference of the Panel are:

- To identify gaps and weak links in the present carbon cycle observation system that compromise the ability to understand and predict global change;
- To identify opportunities that can be used to further develop such an observing system (e.g., collaboration with other global observing systems);
- To aid the synthesis of JGOFS and IGBP results with respect to marine CO_2 observations, data management and modelling by: (i) Initiating and facilitating the assembly of CO_2 data bases; (ii) Interacting with ocean modellers to identify the weaknesses and encourage appropriate uses of CO_2 data (iii) Encouraging and facilitating the collaborative analysis of CO_2 data sets and supporting data
- To maintain a watching brief to advise IOC and SCOR on CO_2 sequestration in the ocean;
- To advise GOOS and OOPC on technology development needed to improve future capacity for carbon cycle monitoring; and
- To advise GOOS and OOPC on the observational strategies needed to assess, model, and predict global ocean CO_2 fluxes.

2. JGOFS/LOICZ/IOC Continental Margins Task Team (CMTT)

Many recent, regional studies on continental margin biogeochemistry suggest that cross-shelf transport probably influence the carbon cycle of the ocean as a whole, and that the margins constitute an important, but often neglected, link in the global carbon cycle. For this synthesis activity, JGOFS/LOICZ/IOC Continental Margins Task Team operates the following terms of reference:

- Identify relevant and appropriate data sets from continental margin studies and investigate their availability to IGBP projects;
- Develop a conceptual framework to integrate continental margin carbon, nitrogen, and phosphorus fluxes and to assess anthropogenic influence on the fluxes;
- Attempt to quantify vertical and horizontal carbon, nitrogen, and phosphorus fluxes in different types of continental margins such as Eastern boundary current, Western boundary current, Marginal seas, Polar margins, and Tropical coasts;
- Produce an overall synthesis and assessment of carbon, nitrogen, and phosphorus fluxes on and across continental margins to feed into the IGBP programme; and
- Identify major gaps and uncertainties in the current understanding of continental margin carbon, nitrogen, and phosphorus fluxes and recommend priority needs for observational and modelling efforts.

A series of products will be developed by the CMTT, including a web page, list of continental margin projects and principle investigators, a bibliography of continental margins research, regional synthesis reports and case studies, conference sessions. The CMTT will also produce a typology synthesis focusing on eastern and western boundary currents, marginal seas, polar margins, and tropical coasts. Working groups will encourage researchers in various regions to prepare regional synthesis reports and case studies. As this is a global survey of continental margins, the regional focus activities form the basis of the synthesis and will be comprehensive in scope.

3. IOC/GLOBEC/SPACC Ad Hoc Study Group on Use of Environmental Indices in the Management of Pelagic Fish Populations

The Small Pelagics and Climate Change (SPAAC) is a regional project of GLOBEC and is concerned with how climate change may influence the productivity of small pelagic fish populations. The management of these stocks are severely handicapped because the affects of the environment on population size are largely unknown. There is substantial environmental and fisheries related data available for many of the upwelling regions where they occur. It is the purpose of this Study Group to examine those data, pertinent publications and other information in terms of elucidating relationships and ultimately indices that can be reliably used for managing these important fish stocks. The Group has the following terms of reference:

- Provide a comprehensive review of the use of environmental indices as hindcasting/ nowcasting and forecasting tools of the fluctuations of pelagic fish in selected areas;
- Develop a scientific framework to understand the linkages between environmental variables and pelagic fish fluctuations, at several spatial and temporal scales;
- Investigate the requirements to incorporate environmental indices into stock assessment models and operational management procedures; and
- Propose a set of environmental variables of use in the management of pelagic fish populations to be included in local and global monitoring programmes.

Specifically targeting the very large fluctuations of clupeid fish stocks that occur in upwelling regions off the west coast of Africa, South America, North America, Iberian Peninsula, and in the Kuroshio/Oyashio currents, this study group will examine previous and recently collected environmental and related fisheries data in these regions.

4. SPACC Synthesis and Training Office (in planning stage)

IOC and GLOBEC have agreed to establish a SPACC Synthesis and Training Office at IOC Headquarters. The terms of Reference of the Office are:

- Advise, support and collaborate with SPACC research teams in developing regions;
- Establish a scientific network of SPACC scientists and facilitate the transfer of information, tools and knowledge to SPACC teams in developing regions;
- Contribute to the building of capacity in the fields of SPACC in developing regions, through training workshops, on the job training and students supervision;
- Promote and initiate SPACC synthesis activities in consultation with the SPACC Executive;
- Represent and inform the IOC of the activities of SCOR/IOC WG119 and SPACC/IOC Study Group on the "Use of Environmental Indices in the Management of Pelagic Fish Populations", and ensure adequate synergy between both groups;
- Provide relevant assistance to GLOBEC and the IOC as necessary;
- Carry out activities in co-ordination with the GLOBEC International Project Office and respond to the GLOBEC Scientific Steering Committee and the SPACC Executive, as well as the IOC; and
- Maintain a priority on Africa and South America for the SPACC Office.

5. Joint SCOR/IOC Working Group 119 on Quantitative Ecosystem Indicators for Fisheries Management

Fisheries have traditionally been assessed and managed on the basis of single species stocks or populations. Management experience and theory now suggest that ecosystem dynamics play a significant role in the maintenance of sustainable fisheries, and that assessment and management approaches which consider whole ecosystems may be required. While the need for an ecosystem approach to fisheries management is recognized, its implementation is complex and challenging. Techniques are required to bridge the gap between ecological theory and the actual management of living resources. The definition of quantitative indicators of ecosystem change may provide a means to synthesize the large amounts of multidisciplinary information required for an ecosystem approach, and

to communicate that information to resource managers. The aim of this working group is to develop a scientific approach for defining quantitative indicators to assess marine ecosystems and provide for their sustainable management. Terms of reference of the Group are to:

- Review the current state of knowledge in different marine and terrestrial disciplines relevant to the development of indicators for marine ecosystems (environmental, ecological and fisheries);
- Review theories (hierarchy, cascade...) and indicators that have been developed in terrestrial ecology and to assess their utility for marine ecosystems;
- Develop new indicators to study the functional role of species in ecosystems, exploitation and environment using output of multi-species models or available time series (fish catch statistics), and using satellites, and GIS (Geographic Information System);
- Apply these indicators in a comparative way to characterize ecosystem states, changes and functioning; and
- Assess the utility of these indicators for management purposes and for the sustainable utilization of renewable resources.

6. *Ad Hoc* Study Group on Benthic Indicators

Numerous research programmes on benthos conducted throughout the world have produced substantial data sets containing synoptic information on the abundance and diversity of the biota, environmental conditions and contaminate levels. The value of the data sets can be significantly increased by combining them into a global set and subjecting it to critical analyses that seeks to determine relationships between the benthos and selected indicators. In this way specific environmental variables may be identified that can serve as indicators of high versus low impacts of anthropogenic stress on a regional and global basis. The Terms of Reference of the Group are:

- Develop recommendations for a suite of globally applicable indicators and techniques to use in measuring the state ("health") of marine benthic communities;
- Demonstrate the effectiveness of these indicators through application in test data sets from selected coastal regions of the world; and
- Help to promote the use of these indicators, by as broad of a user community as possible, through the presentation of results of reports, publication, symposia, Internet-based web sites, or other effective forums.

7. Ad hoc study group on coral bleaching and related indicators of coral reef health

Recently reefs have experienced significant mortalities resulting from major coral bleaching events that occurred in 1997/98. Bleaching, which is the loss of the symbiotic single cell algae that live within the coral tissue, although not an unprecedented event, has caused widespread concern because of the severity of its initial impact and uncertainty of reef recovery. The development of physiological techniques which can recognize indicators of stress on corals would be a productive tool towards forecasting reef conditions and complement current methods of enumerating live and dead coral coverage, an after the fact measure of mortality. Possible indicators of stress might include both physiological and community indicators that are manifest in the corals or reef structure in response to unfavorable external environmental factors. The Group has the following terms of Reference:

- Integrate current information and establish research directions, develop techniques and studies to identify useful indicators of stress in corals leading to coral bleaching and subsequent effects
- Demonstrate the effectiveness of the indicators through application in the field at selected sites;
- Promote the use of the indicators by the user community through dissemination of results in reports, publications, symposia, web sites or other forums.

Coral reefs occur in more than 80 countries where they occupy in excess of 650,000 square kilometers of coastal regions. Development of predictive indicators for bleaching events could lessen

the societal impacts of bleached reefs by providing opportunities to seek alternative means of incomes and on information on the possibly recovery of bleached reefs.

8. *Ad Hoc* Ecotoxicology Working Group

The aim of this Group to be developed in 2001 is to provide guidance on the development of ecotoxicological techniques for determining the nature and magnitude of effects on marine biological communities and structure caused by human activities, particularly the release of contaminants to the environment. The Group will provide an advisory function to the IOC Ocean Science Programme and will design and conduct field and scientific evaluation studies as required to fulfil its responsibilities. It will also maintain liaison with activities within the IOC and International Maritime Organization relating to the application of ecotoxicological criteria and methods to the protection of the marine environment from the effects of activities such as ocean dumping and land based discharges of wastes and other matter. Specific terms of reference are to:

- Keep under review, developments in the field of ecotoxicology pertaining to the effects on biota of substances in the marine and coastal environments;
- Provide expert advice on initiatives to develop the application of ecotoxicological techniques suitable for application to marine environmental protection;
- Develop schemes for the protection of the marine environment from the effects of substances introduced to the marine environmental from anthropogenic activities;
- Design studies and experiments needed to test ecotoxicological techniques having potential application to marine environmental protection;
- Assist in ensuring the conduct of appropriate experiments and field tests for testing and refining ecotoxicological techniques suitable for application in environmental protection; and
- Provide periodic reviews of the state of technology regarding the measurement of effects on marine biological organisms, populations and communities having potential for practical application.

9. IOC/SCOR/LOICZ Study Group on the Assessment and Management Implications of Submarine Groundwater Discharge into the Coastal Zone

Submarine groundwater discharge (SGD) occurs across the land-sea interface and requires interdisciplinary research to understand its magnitude and environmental significance. Seawater intrusion into terrestrial aquifers and SGD are closely linked processes that directly affect each other. The group is charged with standardizing methodologies and undertaking measurements at selected sites, representing different topographies and soil types, to assess the implications of submarine groundwater discharge into the coastal zone. The basic approach of this project includes modelling, physical measurement and tracer techniques. The Expected Outcomes include: (1) Improved methods for making groundwater discharge assessments; (2) Development and testing of groundwater and seawater interaction models under different hydrological and hydrogeological conditions; (3) Provision of information for broad dissemination; (4) increased awareness of local stakeholders; and (5) Preparation of a methodology for information transfer and training programmes.

While five sites have been selected for intercomparison, the first test area being Cockburn Sound, Australia, the other sites may be reconsidered as the data from the first site is analysed.

10. Harmful Algal Bloom (HAB) Programme

The term 'harmful algal blooms' (HABs) covers a heterogeneous set of events that share two characteristics: they are caused by microalgae and they have a negative impact on human activities, including human health, fisheries, aqua-culture, tourism.. Despite these common features, HABs are very diverse in terms of causative organisms, dynamics of blooms and type of impact. There has over the last 30 years been an increase of HAB records in coastal waters around the world. The list of new HAB species has also increased remarkably in recent years because of new cases of harmful events, the development of scientific research in the field, and enhanced human interactions with the coastal zone. The central research problem and a challenge is to understand and predict the critical features

and interdiscplinary mechanisms underlying the population dynamics of HAB species. Predictive capabilities are essential for an efficient management and mitigation procedure.

The IOC Harmful Algal Bloom Programme is based on a Programme Plan which was developed by an interdisciplinary group of experts. The overall goal of the Programme is to foster the effective management of, and scientific research on, harmful algal blooms in order to understand their causes, predict their occurrences, and mitigate their effects. There is an Intergovernmental Panel on HAB (IPHAB) attached to the Programme. The IPHAB functions as the overall coordinating body for most international and regional HAB initiatives. It sets priorities, revises and updates the HAB Programme Plan, and is responsible for interaction with other relevant organizations and programmes. The HAB programme includes permanent regional working groups in South America (COI-FANSA), the Caribbean (COI-ANCA), and the Western pacific WESTPAC/HAB.

Training and capacity building is a main component of the IOC HAB Programme is composed of modules on taxonomy, toxin chemistry/toxicology, ecology, management and mitigation. The Programme has established IOC Science and Communication Centres on Harmful Algae to help implement the Programme maintains an number of HAB related data-bases.

The main science component of the HAB Programme is the IOC-SCOR research initiative on the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) and the ICES-IOC Working Group on the Dynamics of Harmful Algal Blooms plays a key role in the development and implementation of GEOHAB (see below).

11. Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) Programme:

GEOHAB is a joint IOC/SCOR programme of scientific research that has been established to address the need for broad-based advancement in the understanding of HABs. The mission of GEOHAB is to foster international co-operative research on harmful algal blooms in the context of their ecological systems and the oceanographic processes which influence them. The scientific goal of GEOHAB is to: determine ecological and oceanographic mechanisms underlying the population dynamics of harmful algae, by the integration of biological and ecological studies with chemical and physical oceanography, supported by improved observation systems. The scientific goal of GEOHAB will be approached by addressing these major research questions:

1. What are the unique adaptations of HAB species that determine when and where they occur and the extent to which they produce harmful effects?
2. How do HAB species and their community interactions respond to environmental forcings?
3. What are the effects of human activities (e.g., eutrophication) and interannual and decadal climate variability (e.g., El Niño, North Atlantic Oscillation) on the occurrence of HABs?

A better understanding of the factors that regulate the dynamics of HABs in the context of physical and chemical forcing, ecosystem dynamics, and human influences will be used to improve strategies for monitoring and prediction of HABs. In addition, GEOHAB will identify targeted studies on organisms, processes, methods, and observation technologies that are needed to support the interdisciplinary research. Improved global observation systems will be required to resolve influences of environmental factors (anthropogenic and climate-related) on distributions and trends in HAB occurrence. This will be greatly facilitated through strong links between GEOHAB and the Global Ocean Observing System (GOOS). Through links to national agencies and international organizations responsible for protecting coastal resources and public health, the knowledge gained from GEOHAB will be used to develop international capabilities for more effective management and mitigation of HAB problems. This linking of basic scientific research directly to societal needs should result in an effective contribution of science to the protection of the intrinsic and economic value of coastal marine ecosystems.

12. The ICES-IOC Working Group on the Dynamics of Harmful Algal Blooms

This Group's overall objective is to enhance our understanding of the population dynamics of harmful algae. Furthermore it collates national HAB reports and maintains the IOC-ICES-PICES

HAE-DAT database on HAB events in cooperation with the IOC Science and Communication Centres on HAB in Copenhagen and Vigo. Specific Terms of Reference are given annually by the IOC (via IPHAB and the GEOHAB SSC) and ICES.

The current tasks of the Group are: examine possible ways of analyzing historical data and fossil HAB records; evaluate and assess the use of remote sensing and *in situ* optical sensing technology in HAB dynamics studies; discuss the potential sensitivity of HABs to climate changes; review the implementation of the GEOHAB research programme in the ICES area; and prepare for a workshop, co-sponsored by GEOHAB, GLOBEC and GOOS, on 'Real-time observation systems applied to Harmful Algal Bloom Dynamics studies and global ecosystem functioning'.

The future tasks of the Group will include: a) review existing data on the identification, distribution and toxicological significance of new and emerging phycotoxins and the causative organisms, in terms of human health significance, HAB population dynamics and effects on marine food webs; b) evaluate progress in the application of molecular probe technologies to: i) taxonomical and genetic studies, ii) the detection and enumeration of HAB species; and iii) investigation of their physiological condition.

13. IOC/SCOR Coastal Ocean Advanced Scientific And Technical Studies Programme (COASTS)

Recent rapid advances in ocean and related sciences and associated technologies, serve to focus research issues and to make feasible definitive studies. The efficient and effective management both of multiuse exclusive economic zones and naturally linked regional segments of the coastal ocean requires a substantial scientific and technical base. Regional issues include: marine and maritime operations; exploitation and conservation of living and nonliving resources; aquaculture; recreation; and pollution control. Integrated issues in a global change context include contributions of the global coastal ocean to: the planetary scale thermohaline circulation; sea-level change; whole earth biogeochemical cycles; and the global ecosystem. Some coastal phenomena are poorly understood at best or remain to be identified, but are now recognized to be of substantial practical importance. Some regions, notably offshore of the technically most developed nations, are relatively well explored and in part, relatively well understood. Other regions, offshore of developing countries or located in remote and hostile environments, essentially await exploration. Techniques and knowledge from better-studied regions can contribute to the efficiency of research for less well-studied regions.

The fundamental goal of the COASTS programme is to develop the scientific and technical basis necessary for the management and health of the coastal seas. The overall objectives of the Programme are: (1) to encourage and facilitate coastal and shelf ocean sciences and technology on a global basis, in order to promote and improve capabilities to carry out such studies; to increase scientific understanding; and to provide scientific inputs to an effective coastal zone management; (2) to achieve this, promote understanding of physical and dynamical processes as the basis of multi disciplinary processes and to enhance and interact with comprehensive studies; (3) to assess on a global basis the major features of various physical mechanisms and their application to biological and chemical processes; and assess major interactive processes; (4) to provide, on the basis of knowledge, enhanced and synthesized by this programme, an improved and possibly adequate scientific foundation for the management of the coastal and shelf areas; and (5) to develop community modelling for coastal regimes.