Global
Ocean
Observing
System

Intergovernmental Oceanographic Commission

A Strategic Plan for the Assessment and Prediction of the Health of the Ocean: A Module of the Global Ocean Observing System

Prepared by the Health of the Ocean Panel of the Joint Scientific and Technical Committee for the Global Ocean Observing System

May 1996

IOC/INF-1044

UNESCO

IOC/INF-1044
Paris, 26 August 1996
English only

TABLE OF CONTENTS

FOREWORD

In February 1993 an *ad hoc* Panel was convened under the chairmanship of Dr. Neil Andersen to develop a scientific and technical design for the Health of the Ocean module of the Global Ocean Observing System (GOOS). A list of Panels Members is provided in Annex 1. The ad hoc Panel met twice under the co-sponsorship of the Intergovernmental Oceanographic Commission (IOC) of UNESCO and the United Nations Environment Programme. In 1994 a Joint Scientific and Technical Committee for GOOS (J-GOOS) was established and the *ad hoc* Panel became a subsidiary body of this Committee, which is co-sponsored by the IOC, World Meteorological Organization (WMO), and the International Council of Scientific Unions (ICSU). The Panel met again in 1995, when the following document was finalized. The document was endorsed by J-GOOS at its meeting in April 1996,

The Panel is now being re-formulated to further pursue remaining questions concerning human health, to address scientific aspects of implementation, and to develop specific system designs for several regions. It is anticipated that pilot projects will be implemented in the near future to test the validity and comprehensiveness of the Strategic Plan.

EXECUTIVE SUMMARY

Pollution in the marine environment has become an issue of grave concern to all coastal states. The oceans cannot provide an infinite sink for anthropogenic wastes but little attention has been given to evaluating the limits of capacity of coastal areas for waste assimilation. Consequently, instances of fisheries closures, spoiled beaches, destroyed coral reefs and wildlife habitat, toxic blooms and lost coastal ecological communities are widespread.

In crude terms, about 80% of contamination reaching the oceans stems from land-based sources through the pathways of atmospheric, direct transport discharges, rivers and run-off. The problem is amplified by the fact that contamination mostly occurs in the relatively fragile coastal zone. Ocean disposal of wastes and the discharges from marine shipping and offshore activities and natural sources make up the remaining 20% This situation was recognized as a major issue by UNCED in Agenda 21, Chapter 17,

The Health of the Oceans Module of GOOS is intended to provide a basis for determining prevailing conditions and trends in the marine environment in relation to the effects of anthropogenic activities, particularly those resulting in the release of contaminants to the environment. Its primary objective is to provide information on the nature and extent of adverse effects, including increased risks, on human health, marine resources, natural change and ocean health. Data collection, bio-monitoring and biological effects assessment will be carried out on both global and regional scales using commonly-agreed standards and methodologies. Areas of initial emphasis will be: 1) The development of a set of reliable, relatively easily applicable biological distress indices of the health of the marine environment; 2) Monitoring concentrations and trends of contaminant loading in coastal zones in relation to community responses; 3) Development of methodologies for the evaluation of assimilative capacities of coastal zones for contaminant introductions; and 4) Reclamation of available data/information on contaminant levels/community responses at regional and national levels as baseline information for HOTO monitoring activities.

The term “Health of the Oceans” is operationally defined for the purposes of the HOTO Module of GOOS as a reflection of the condition of the marine environment from the perspective of adverse effects caused by anthropogenic activities, in particular the mobilization of contaminants. Such condition refers to the contemporary status of the ocean and the prognosis for improvement or deterioration in its quality.

The Panel first identified a number of issues that, in global terms, are of contemporary concern in respect to the current health of the oceans on impending threats. These include: climate change; endangered species; biodiversity; human health; tourism; and eutrophication. All of these issues are reflected in UNCED Agenda 21 and relate collectively to the following classes of contaminants or analytes chosen for attention within the HOTO Module:

Aquatic Toxins	Artificial Radionuclides
Pesticides/Herbicides	Litter
Pathogens	Nutrients
Oxygen	Synthetic Organic Compounds
Petroleum Hydrocarbons	Polycyclic Aromatic Hydrocarbons
Suspended Particulate Matter	Trace Metals
Phytoplankton Pigments	Pharmaceuticals

The measurement of contaminant loads cannot, however, alone, provide comprehensive quality criteria, Accordingly, the HOTO Module of GOOS must balance information on levels and trends in contamination with information on associated biological effects in order to permit global and regional assessments of pollution (i.e., adverse effects on the marine environment, its resources and amenities). Indices will have to be identified at four levels of biological structure: sub-organismal; individual; population; and community.

The Panel identified the range of anthropogenic activities that significantly mobilize the contaminants in the classes of concern listed above, These include: Aquiculture, Forestry/Logging, Coastal Development, Marine Transportation, Industrial Discharge, Sea Dumping, Agricultural Practices, Mineral Extraction Processes and Municipal and Urban Waste Discharge. There are also physical disturbances caused by these practices that have a direct effect on the marine environment and these must also being taken into account in the development of the HOTO Module.

The Panel further examined the factors that bear on the selection of time and space scales for HOTO measurements. The first category of these involve managerial considerations that reflect the requirements of customers for interpretative products from the HOTO module. The second category includes scientific considerations relating to the scales of change following changes in the locations and rates of the introduction of substances and of physical disturbances of the marine environment. The third category involves considerations relating to the scales of natural variability in the marine environment for substances that are derived from both natural and anthropogenic sources.

The Panel evaluated the major data reporting requirement for the HOTO Module. It based its evaluation on the assumption that all data, whether derived from research projects, regional monitoring activities, fisheries research or classified military activities, needs to be made readily available. Past and present data management practices need to be changed for the HOTO Module to have the required impact.

GOOS will foster and exploit the development of new technology to increase the cost efficiency of marine observations and improve the users' ability to access quality data and new technology. The Panel identified various needs for new technology and noted that these technologies must not only apply to chemical and physical measurements but also to biological ones extending, for example, to devices to improve the determination of the community structure of ecosystems as an important element of this module.

A major commitment needs to be made by all countries to implement effectively GOOS. Governments must be encouraged to:

(i) Make existing data available;
(ii) Distribute data products;
(iii) Facilitate data exchange;
(iv) Develop data networks;
(v) Support the collection of satellite and *in situ* data;
(vi) Support data collection by volunteer ships and data buoys; and
(vii) Encourage person-to-person networking.

The Panel made the following recommendations to J-GOOS, its parent body, in April 1995. These were subsequently forwarded to I-GOOS for action at its second Session:

- Have conducted, through relevant bodies (e.g., GIPME), a global inventory of measurement capabilities and existing national, regional and international programmes and data bases, relevant to HOTO;

- Initiate quality assurance procedures, through appropriate channels (e.g., contracts), for those measurements the Panel considers to be of the highest priority;

- Request relevant bodies (e.g., GIPME) to reevaluate methods for Category 2 parameters in Figure 4 of this report, with a view toward stimulating their inclusion in national and regional plans;

- Request relevant bodies (e.g., GEEP) and urge the scientific community at large to define reliable measures of biological response, which can be applied globally, and develop techniques for their widespread application;

- Urge completion of the current IOC/UNEP International Mussel Watch Program. The evaluation of its results should be facilitated and urgent consideration should be given of its extension to other matrices (e.g., sediments) and to the inclusion of histopathology;

- Take steps to strengthen existing national and regional analytical centers and, where appropriate, create new ones, in order to provide technical focal points for training, data evaluation, capacity building and the introduction of new techniques. The capacity building needs to be developed nationally and in the long term become self sustaining. It also needs to be based in the short term on current international, regional and bilateral collaboration to ensure accelerated development, technology transfer and economies of scale;

- Provide PC optical disc based ocean color interpretation for satellite remotely sensed data and requisite training;

- Undertake a comprehensive operational demonstration of HOTO as an integral part of the overall GOOS implementation;

- Develop a mechanism for the delivery of regional assessments to the GESAMP “State of the Marine Environment” reporting system;

- Initiate an effort, in close collaboration with the IOC/TEMA Programme, to create regional self-sustaining capacity as appropriate for the implementation of the HOTO Module of GOOS; and

- Identify the requisite resources to have the Strategic Plan of the HOTO Module of GOOS implemented.

1. BACKGROUND

At the present time there are unprecedented pressures on natural resources. Sustainable development of these resources is hindered by an inability to detect emerging environmental problems at an early stage when remedial measures can still be effective. Nowhere is this inadequacy so pronounced as in the marine environment. Global energy cycles and the biological processes upon which all life depend are critically influenced by the ocean. Knowledge of the ocean and humanity's impact on it is only now beginning to reveal the complexity and interdependence of all aspects of the system. Improved knowledge and predictive capabilities are required for more effective and sustained development of the marine environment to reap associated economic benefits and to preserve marine resources.

The two conventions signed at the United Nations Conference on Environment and Development (UNCED), The Framework Convention on Climate Change and The Convention on Biological Diversity, and the recommendations of Agenda 21, Chapter 17, require the establishment of an adequate observing system to help develop understanding and to monitor change. Many of the processes which control the variability and change of global climate are themselves controlled by processes in the ocean. Public perceptions of risk are only eased when governments are seen to be keeping the environment, including the ocean, under close observation. If the UNCED goals of global sustainable development and integrated oceans management are to be achieved, a much more integrated data management system and a biological distress detection programme must be developed and implemented globally.

The major oceanographic processes that regulate the ocean's role in determining how the Earth System functions have variabilities over decadal time scales. These time scales exceed the anticipated lifetimes of the various global research programs that have been, and are being, implemented to study ocean circulation (e.g., WOCE), chemical fluxes (e.g., JGOFS), land/ocean interactions (e.g., LOICZ) and the dynamics of ecosystems (e.g., GLOBEC). These long term variations are associated with, *inter alia,* issues of climate change, the state of health of the ocean, biological diversity, human health protection, coastal zone management and their socio-economic impacts. Thus, it is essential that, as the coordinated research endeavors presently investigating the role of the ocean in the Earth System draw to a close, the relevant variables continue to be measured. To do this, continuing systematic, long term, global observations of marine physical, chemical and biological conditions are required, analogous to those under the World Weather Watch, operating under the auspices of the World Meteorological Organization (WMO).

The observations that are made must have the character of being long term (i.e., time-series), systematic, relevant to the role the ocean plays in changes occurring in the Earth System, cost effective and routine. Furthermore, the data that are obtained must be intercomparable. Data collected from such an ocean observing system must be provided to the world community in a timely fashion and be systematically managed and archived.

The purpose of this document is to put forth the strategy for and detailed scientific and technical design of the Assessment and Prediction of the Health of the Ocean (HOTO) Module of the Global Ocean Observing System (GOOS).

2. THE CONCEPT OF THE GLOBAL OCEAN OBSERVING SYSTEM (GOOS)

The objective of the GOOS is to ensure the establishment of a permanent system of global and systematic observations adequate for forecasting climate variability and change; for assessing the health or state of the marine environment and its resources, including the coastal zone; and for supporting an improved decision-making and management process, which takes into account potential natural and man-made changes in the environment and their effects on human health and marine resources. GOOS will provide a mechanism and infrastructure for data and information to be made available on various time scales to participating nations. As a result, individual national observing capabilities will be strengthened.

The GOOS is an internationally coordinated system for systematic operational data collection (measurements), data analysis, exchange of data and data products, technology development and transfer. GOOS will use a globally coordinated, scientifically based strategy to allow for monitoring and subsequent prediction of environmental changes globally, regionally and nationally. Data will be generated by repeat sampling and remote sensing using sea-surface and sub-surface instrumentation in the open sea and coastal regions worldwide, including enclosed and semi-enclosed areas. Major physical, chemical and biological variables need to be identified that can be used to provide an integrated assessment of the current health of the oceans and early warning of deterioration.

The GOOS will be established by Member States and implemented through nationally owned and operated facilities and services. Coordination will be provided by the IOC in cooperation with WMO, UNEP and ICSU. The GOOS is to be based on the principle that all countries should participate and that participants should make certain commitments, according to their capabilities, so that all countries can both contribute and benefit.

The GOOS will be developed from operational and scientific data gathering systems and activities already in place, such as in the first instance, IGOSS, MARPOLMON, IODE AND GLOSS, and in the latter, JGOFS, WOCE and TOGA.

Observations should be:

- Long term: Measurements once begun should continue into the indefinite future; continuity in the observed quantity is to be sought, rather than in the method, as it is anticipated that more effective methods may become available in the future.

- Systematic: Measurements should be made in a rational fashion, with the spatial and temporal sampling frequencies, as well as the precision and accuracy, tuned to address the specific deliverables of the GOOS,

- Relevant to the global system: Measurements should be made either to address ocean variables important to the issues underlying the objectives of the GOOS, or to provide data needed to initialize and validate models that describe and predict these variables a seasonal to decadal time scales and beyond.

- Measurements should be cost effective. Efforts should be made to maximize the return on available resources (financial as well as human) by applying observational methods that are economical and efficient.

- Measurements should be routine. The observations should be considered as part of the normal workload, with routine data acquisition, processing, archiving quality control, and the dissemination of products to carried out on a regular basis.

The GOOS will be comprised, *inter alia,* of:

- Activities assisting in providing those long term global ocean observations needed for research activities concerned with understanding the topics covered by each module.

- Existing global, regional and national monitoring activities, including those sponsored by international organizations (e.g. the Global Sea Level Observing System (GLOSS), the Global Investigation of Pollution in the Marine Environment (GIPME) and its Marine Pollution Monitoring System (MARPOLMON), the Integrated Global Ocean Services System (IGOSS) and improved World Weather Watch (WWW) Systems).

- Data communication and other infrastructures necessary to support operational ocean forecasting.

The sponsors have agreed that GOOS will comprise the following five “application modules”, whose objectives may overlap and which will share some of the same data (e.g., the data and information generated from all modules will contribute to the needs of Coastal Zone Management and Development), but which will have individually distinct purposes:

- Climate, Monitoring, Assessment and Prediction, including seasonal and interannual variability;

- Monitoring and Assessment of Living Marine Resources;

- Monitoring of the Coastal Zone Environment and its Changes;
- Assessment and Prediction of the Health of the Ocean; and
- Marine Meteorological and Oceanographic Services.

3. PURPOSES AND BENEFITS OF THE HOTO MODULE

The objectives of the HOTO Module of GOOS are to provide a basis for the assessment of the state and trends in the marine environment regarding the effects of anthropogenic activities, including, *inter alia,* increased risks to human health, harm to marine resources, alterations of natural change and general ocean health.

Two principles were endorsed at UNCED: marine resources should be used sustainably; and a precautionary approach should be adopted for the prevention of adverse effects of anthropogenic activities on the environment The adoption of a precautionary approach is primarily a managerial issue since in the conventions where it has been adopted, decisions can be made on the basis of circumstantial evidence,

However, there are elements of precaution that have commonly been applied in the formulation of scientific responses to management questions such as the adoption of conservative approaches that take account of scientific uncertainties. A good example of such conservatism was the procedure used for the definition of radioactive wastes unsuitable for dumping at sea under the London Convention (1972). This procedure used pessimistic characterization of the oceanographic transport and human exposure pathways to define the limit for releases of radioactive wastes to the ocean.

Some other aspects of precaution have been inadequately applied by the scientific community in dealing with management questions that have been insufficiently specific. For example, the assumption that there are no effects of a given contaminant on a marine organism may be due to the inability of the sampling design to detect change with the given design. The inclusion of such considerations is essential to the application of a precautionary approach.

The following terms of reference for the Health of the Oceans Panel have been defined to meet the requirement to develop the HOTO module of GOOS:

The HOTO Panel will be responsible for:

The strategic development and detailed scientific and technical design of the HOTO module of GOOS;

Maintaining liaison with research and monitoring activities to ensure that assessments and predictions of the health of the oceans are based on sound and contemporary scientific knowledge; and

Coordination with other modules of GOOS for the purposes of ensuring compatible strategic and scientific development of all GOOS modules.

Central to the objectives and terms of reference of the HOTO Module and Panel is a definition of the term “Health of the Oceans” and identification of environmental health criteria, or biological indices, that can provide early warning of change in the quality of the marine environment.

The term “Health of the Oceans” is operationally defined for the purposes of the HOTO Module of GOOS as a reflection of the condition of the marine environment from the perspective of adverse effects caused by anthropogenic activities, in particular habitat destruction, changed sedimentation rates and the mobilization of contaminants. Such condition refers to the contemporary state of the ocean, prevailing trends and the prognosis for improvement or deterioration in its quality.

The measurement of contaminant loads alone cannot provide comprehensive quality criteria. Biological indices will have to be identified at four levels: sub-organismal, individual, population, and community. Molecular, cellular, physiological and behavioral disturbances and pathological manifestations will be needed to reflect responses at the individual organism level, At the population and community levels, effects might manifest themselves in changes in the reproductive success of species, the disruption of the dynamic balance between producers and consumers, or deviations from the natural range of biomass variability leading to abnormal phytoplankton blooms or mono-specific swarms. Regional critical habitats, such as coral reefs, estuaries, temperate and tropical wetlands including mangroves, submerged macrophyte communities and other spawning and nursery areas will require identification of more specific biological indices, In all cases, biological indices will have to be assessed against the background of natural variability. The monitoring of HOTO analytes, environmental variables and biological effects will provide critical insights into the level and extent of public health effects associated with marine areas and resources. The direct assessment of contaminant loads and pathogenic exposure will assist national decision makers in efforts to ensure the sustained protection of human health,

The areas of initial emphasis will be :

1. Development of a set of reliable, relatively easily applicable biological distress indices of the health of the marine environment;

2. Monitoring of the extent of habitat loses in coastal zones;

3. Monitoring of the effects of altered sediment loads on the coastal zones;

4. Monitoring concentrations and trends of contaminant loadings in coastal zones in relation to marine community responses and public health effects;

5. Development of methodologies for the evaluation of assimilative capacities of coastal marine areas for contaminant introductions;

6. Reclamation of available data/information on contaminant levels/community responses at regional and national levels as baseline information for HOTO monitoring activities; and

7. Development of monitoring/assessment protocols directed at public health protection from marine environmental protection and marine resource use.

It is assumed that each module will make its data accessible to HOTO users and HOTO users can implicitly benefit from data collected within other modules (Figure 1). It is further recognized that there may be significant overlaps (i.e. partial duplication) among the measurements required by individual modules and that, given the correct type and level of coordination, these can be minimized while at the same time offering increased economy and effectiveness. Similarly, there will be components of the interpretative products of individual modules that will be relevant to meeting the objectives and providing contributions to the interpretative products of other modules. Again, appropriate coordination within GOOS should ensure both economy and effectiveness in the aggregate operational activities of GOOS.

These considerations emphasize the need for, and benefits of, coordination among the modules. It is essential that the designs of each GOOS module specify data and interpretation required by other modules.

The scientific output of the HOTO Module is meant to optimize the socio-economic benefits of the marine environment by providing the decision makers with a sound scientific basis for the sustained development of its resources. This issue will be dealt with in the following section of this report.

4. GLOBAL OCEAN HEALTH, SUSTAINABLE DEVELOPMENT AND HOTO BENEFITS

Sustainable development is intrinsically dependent upon conserving the health of the global ocean. The Health of the Ocean Module is designed to assess the status and likely trends in global ocean health and to contribute directly to the development of strategies for maximizing the economic benefits derived from the intelligent use of marine environments and resources. Figure 2 illustrates the relationship between marine resources, human uses and the HOTO indicators of global ocean health. The recognition of the interrelationships and interdependencies of sector-based engagement strategies is necessary for the sustainable development of the worlds ocean and coastal areas, Our contemporary ability to maximize such benefits and to achieve a more globally sustainable level of development is, in fact, limited by an inadequate understanding of human influences on the environment.

FIGURE 1.
DATA DELIVERY PATHWAYS

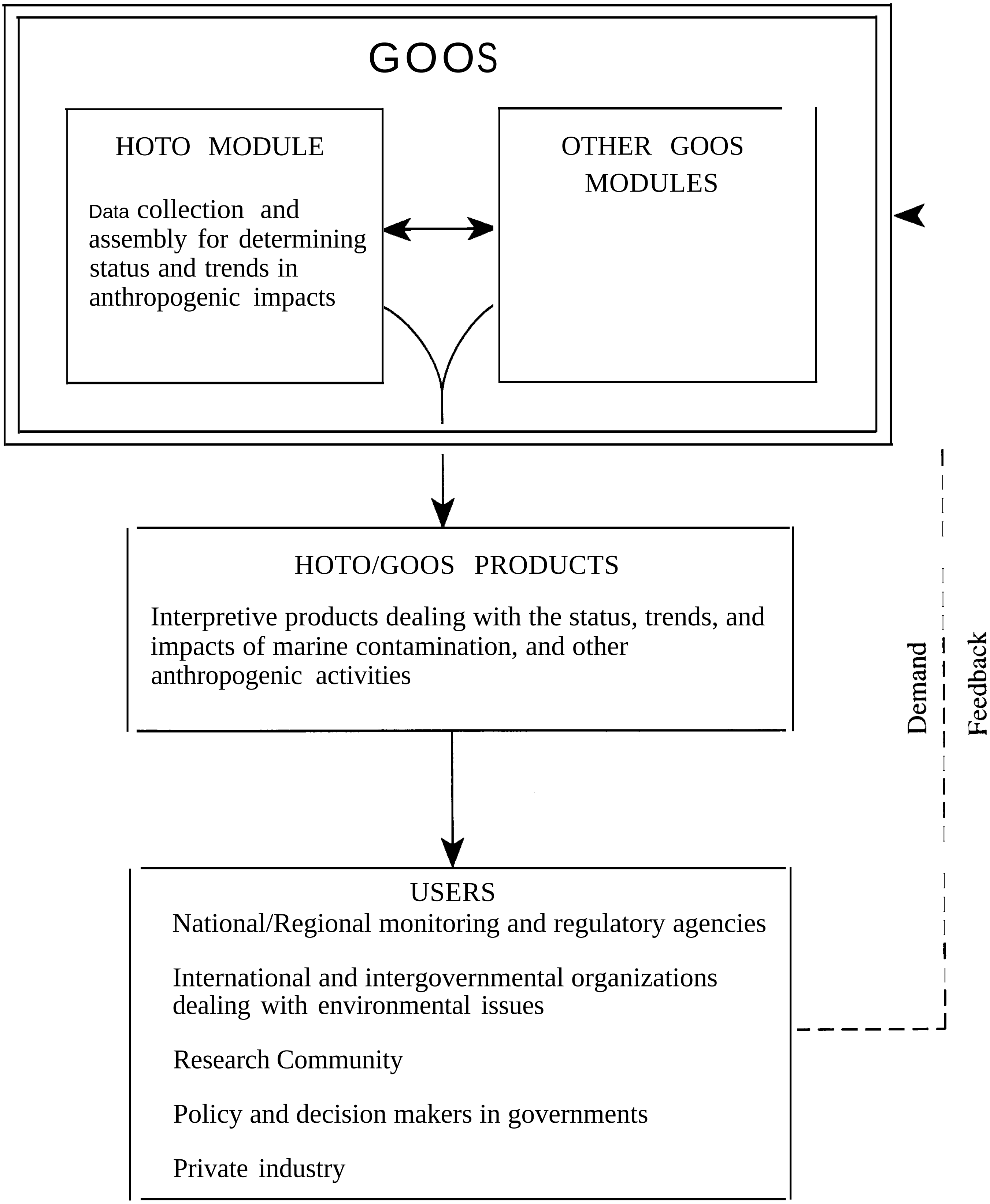
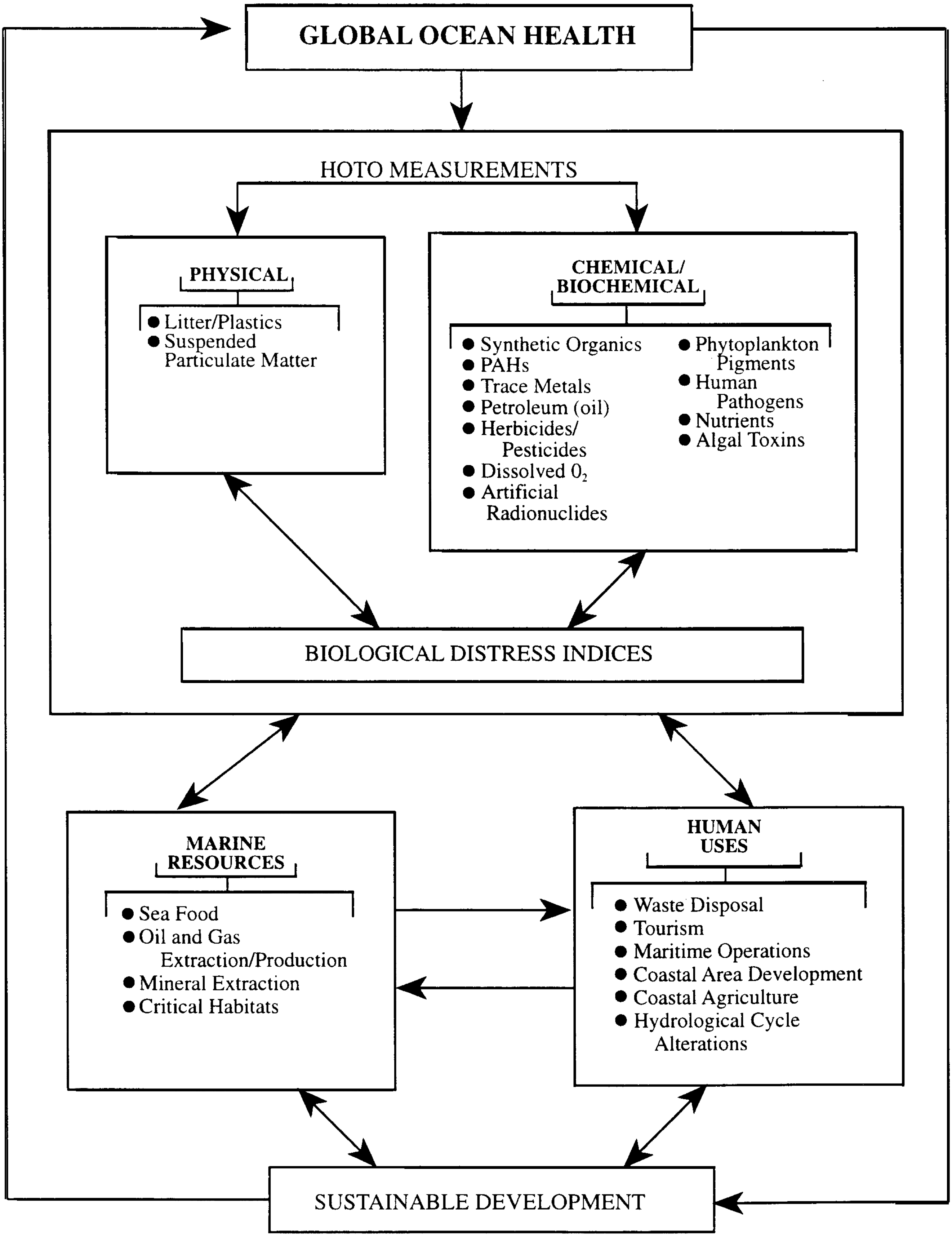


FIGURE 2.
RELATIONSHIP BETWEEN GLOBAL OCEAN HEALTH AND SUSTAINABLE DEVELOPMENT



The extent of present pollution in the marine environment is not quantitatively and precisely delineated because of the absence of comprehensive information on the presence of contaminants and particularly of their effects. This, in turn, is due to inefficiencies and lack of uniformity in monitoring and assessment programs in many parts of the world's oceans. Accordingly, there are many problems that are poorly documented, many for which the impact is not recognized and certainly some that are not even yet appreciated. In addition, the incidence of cholera outbreaks, may be deliberately under reported due to the sensitivity of the political and economic implications, exacerbates this situation. This lack of comprehension has resulted in such extreme events as the deaths from mercury poisoning in Japan many years ago to more recent events such as deaths caused by algal blooms and seafood poisoning, and extensive hypoxia occurring in coastal waters such as the Middle Atlantic Bight and the Louisiana Inner Shelf.

The HOTO Module will aim at providing basic information on key ecosystems and on the levels of contamination and pollution in the marine environment. Preliminary emphasis will be on measurements being made in coastal regions and on associated biological effects including population and community changes. The results will be useful in considerations of, *inter alia,* threats to human health, seafood safety, and coastal and river/estuarine drainage basin and estuarine land use and development. Regional elements will include observational networks focusing on specific regional problems presently being identified by GIPME, as well as elements allowing equitable comparison among regions as to the effects of more ubiquitously distributed contaminants. This will allow catastrophic events (e.g., fish kills and outbreaks of harmful algal blooms) to be evaluated within the background of climatology derived from the Climate Module of the GOOS.

Data collection and analysis in the HOTO Module must be based on the use of methods, standards and collection strategies producing globally comparable data, archived in common formats, that are readily accessible to users (e.g., modelers). Sampling must also be sufficiently intensive and of sufficient duration to determine the long-term mean (climatology) and deviations from that² mean and anomalies. It is also argued by some that, often, the effect of an increased contaminant load on biological systems is to increase variance, while the mean stays the same. Unfortunately, this is not generally appreciated and monitoring systems seldom take this into consideration. Sampling designs must take account of such possibilities. Power analysis, the assessment of the ability of a monitoring design to detect a change, should also be routinely applied. Often, power analysis reveals that the monitoring design is unable to detect even large changes and radical improvements are needed to satisfy management objectives/requirements. Nevertheless, it will never be possible to sample the ocean densely enough in space and time to provide a comprehensive description by measurement alone. Ideally, the monitoring programmes will include efforts to understand processes to the point that conceptual and numerical models can be developed so that they, combined with reasonable real time data inputs, can predict the impacts of increased inputs and/or controls. Only by assimilating the data into suitable models will maximum advantage be taken of the data. Thus, the design of the Health of the Oceans Module should include considerations of which data are most desirable for assimilation into models.

The regional elements, which are to cover all geographic areas, will in turn, be linked to a less dense network of oceanic observations to provide a global oceanic perspective, detect broad trends, and provide early warning capability. Retrospective studies for variables to be monitored (e.g., by using sediment records) should be developed to allow establishment of an initial climatology and allow interpretation of present day levels of these variables in terms of previous conditions. The products will also serve the needs of effective national and international implementation of several aspects of the UN Convention on the Law of the Sea and the provisions of the Global Action Program for the Protection of the Marine Environment against pollution from Land-Based Activities as well as other agreements and conventions dealing with the prevention of pollution of the marine environment.

Difficulties cannot be overstated in determining the sources and effects of marine contaminants. A study in the United States (National Research Council, 1990) concluded that many environmental monitoring programs have failed to provide the information needed to understand the condition of the marine environment or the effects of human activity on it. Three reasons were cited: a) monitoring programs may be poorly designed and the technology inappropriately applied; b) information is rarely presented in a form that is useful for developing broad public policy or for evaluating specific control strategies; and c) there is presently limited scientific knowledge and predictive capability about complex chemical, biological and physical interactions. A consideration that exacerbates the latter situation is that it is not clear that adequate effort has been devoted to evaluating the results of all existing monitoring programs to determine if they are meeting their goals or require revision in order to improve their overall effectiveness, including cost, Power analyses should be applied retrospectively since they can aid in the interpretation of results.

Effective and universal contribution/participation in the HOTO programme will provide direct and measurable benefits to Member States of the sponsoring organizations. Sound marine environmental and resource management requires an adequate, reliable and comparable (in both spatial and temporal terms) data base. While the access to such data may not result in reasoned and effective management, achievement of the latter is clearly not possible in the absence of valid and appropriate data. The HOTO Module aims to assist Member States in the organization, collection and analysis of such data. HOTO is also designed to serve as a vehicle to develop new, simple, reliable and inexpensive monitoring technologies. The programme will also provide for the development of a series of methods and measures for the early detection of environmental stress and ecosystem change, thereby allowing appropriate remedial action to be taken. With these data and methods in hand, coastal managers will be in a significantly stronger position to maximize the economic benefits of the sustainable use of marine resources and coastal environments.

4.1 RELATIONSHIPS BETWEEN HOTO INDICATORS, GLOBAL OCEAN HEALTH AND SUSTAINABLE DEVELOPMENT

The kind of systematic and global monitoring to be carried out under HOTO will provide a broad-range of critical benefits in two broad, but clearly inter-related categories. Tables 1 and 2 illustrate the ways in which the HOTO programme can contribute directly to: (i) our general understanding of the present status and future trends in global ocean health; and, (ii) the ability of State governments to maximize socio-economic benefits derived from sustainable development and the use of ocean/coastal areas.

A primary contribution of the HOTO programme is to develop a global perspective of the impact of human activities on ocean health. This kind of long-term monitoring strategy would contribute directly to a more basic understanding of marine ecosystem health, human health implications of regional and global deterioration of the oceans, the ability of States to achieve goals in sustainable development, and the influence of the oceans on global climate change. A general characterization of the relationships between the variables to be monitored under the HOTO programme and measures of global ocean health is presented in Table 1. The respective assignments of the entries “3”, “2” and “1” signify increasing strengths in the relationships among the variables and the issues. Blank cells represent either of weak relationship or one in which current scientific information is too limited to make an assignment.

Although not specifically indicated in Table 1, the increase of radiatively active, or so-called “greenhouse” gases in the atmosphere could lead to a change in climate. This topic is within the purview of the Climate Module of GOOS but some effects of climate change will need to be considered in the development of the HOTO module, These effects include changes in the frequency and diversity of toxic algal blooms, changes in nutrient influxes and oxygen conditions in coastal areas, altered influxes of suspended matter and changes in atmospheric precipitation patterns. The role of carbon dioxide, is being addressed by major research programs addressing climate change such as WOCE, JGOFS, LOICZ and Globec.

4.1.1 Biological Health

Key objectives of the HOTO programme are to provide the information necessary to ensure the maintenance of biodiversity and the integrity of marine communities, minimize the loss of species, limit human influences on living marine resources (including genetic richness), protect critical habitats, and safeguard human health. All of these are vital to ensuring sustainable development of coastal and marine resources.

4.1.1.1 *Ecosystem Processes*

Biological systems are structured by the interactions among components (e.g., different populations, different physical compartments) as well as by the state of the components themselves. Productivity, energy flow, and nutrient fluxes are examples of processes that determine the nature of ecosystems. Alteration of these by direct intervention (e.g., anthropogenic nutrient input) or by contamination can fundamentally alter the environment. The links between ecosystem processes and impacts at the individual and population levels are often poorly understood.

TABLE 1.
RELATIONSHIP BETWEEN GLOBAL OCEAN HEALTH, CONTAMINANTS/ANALYTES, AND SUSTAINABLE DEVELOPMENT

VARIABLES	Biological Health: Ecosystem Processes	Biodiversity	Endangered/Threatened Species	Change in Community Structure	Genetic Loss	Habitat Loss	Human Health	Seafood Consump.	Direct Contact	Sustainable Development
CHEMICAL/BIOCHEMICAL										
Synthetic Organics	3		3		3			3		*
PAHs	3			2	3			3		*
Trace Metals	3			2	3			2		*
Petroleum (Oil)	3	3	3	2	3	1		3		*
Herbicides/Pesticides	3	3	3	2	2	3		3	3	*
Dissolved O_2	2	3		2						*
Artificial Radionuclides								3		*
Pharmaceuticals								3		*
Phytoplankton Pigments+	*			*		*				*
Human Pathogens								1	1	*
Nutrients	2	3		1						*
Algal Toxins			3					1	3	*
PHYSICAL										
Litter/Plastic	3		3						3	*
Suspended Particulate Matter	2	3		2		2				*

1 - Strong 2 - Moderate 3 - Low * Directly Related

+ Phytoplankton pigments may serve as indicators of global ocean health.

4.1.1.2 *Biodiversity*

There is global concern regarding reductions in biodiversity. Loss of biodiversity in coastal zones is largely due to habitat losses such as disturbances associated with direct physical disturbance by sediment mobilization, fishing activities, mineral exploitation, coastal reclamation, etc. A number of marine contaminants may affect biodiversity, both locally and globally. Changes in nutrient fluxes can alter primary production, the species composition of plankton, dissolved oxygen concentrations, and thereby, biodiversity. Also, the change in oxidation state of some metals may alter their toxicity potential. Similarly, the chronic release of contaminants, such as oil and suspended particulate matter, may impact biological communities such as coral reefs and mangroves. The use of pharmaceuticals in aquiculture can alter bacterial assemblages and thereby affect the vulnerability of natural biota to resistant pathogens.

4.1.1.3 *Endangered and Threatened Species*

Marine mammals, birds and other wildlife are affected by habitat destruction and natural and anthropogenic toxins, especially by compounds that reduce reproductive success (e.g. organochlorines), by litter that results in strangulation or drowning, by hydrocarbons from oil spills that result in narcosis, smothering or hypothermia and by the use of explosives in fishing operations.

4.1.1.4 *Changes in Community Structure*

A major concern of the HOTO Programme is the health of biological communities which, if safeguarded, will protect system functions. Detection of alterations in the structure and/or function of communities associated with contaminant exposure, physical disturbance and nutrient inputs is a primary objective. Measurement of biological effect signals (biomarker responses, abnormal physiological, behavioral and pathological reactions, etc.) will provide both early warning and predictive components to the programme.

4.1.1.5 *Genetic Loss*

Insidious degradation of biotic communities may result in the loss of unique genetic sequences that can be used to identify products of potential economic and biomedical importance. Equally, the preservation of genetic diversity is vital to the maintenance of adaptive capabilities to future environmental change. Conservation of genetic richness of marine organisms will therefore be an important concern in the development of the HOTO module.

4.1.1.6 *Habitat Loss-Biological Dependency*

Habitat degradation, fragmentation and loss probably pose the most serious global threat to biodiversity. The HOTO Module of GOOS will monitor changes in the quality, distribution and extent of critical habitats reflecting the health of the oceans, and provide information needed to determine the cause of habitat loss. The integrity of kelp and sea grass beds, coral reefs, mangroves and other coastal communities depends on habitats constructed by organisms. These communities also provide large social and economic benefits. These systems are particularly vulnerable to environmental stress compared with purely physical habitats.

4.1.2 Human Health

Contaminants can impose direct risks to human health in two ways ; through seafood consumption and through direct contact. To a great extent, the degree to which human health consequences are of concern relates to the nature of the contaminant and its toxicological properties. Many marine contaminants, such as radionuclides and some organic compounds, are assumed to impose increasing risk of adverse effects with increasing exposure. Thus, knowing the levels of exposure becomes important to estimating and comparing risks to the health of those consuming seafood and otherwise exposed to the marine environment. Other substances, such as essential elements, are considered to have exposure thresholds for the induction of toxic effects and it then only becomes necessary to ensure that exposures are kept below these thresholds. Several contaminant categories contribute directly to human health risk from marine sources. Four general categories of human health hazard are associated with the marine environment: 1) the presence of residual chemicals such as industrial organics, trace metals, agricultural chemicals and pharmaceuticals; 2) naturally occurring toxins associated with marine organisms; 3) human enteric pathogens, primarily from sewage disposal; and 4) pathogens indigenous to the environment including *V. parahaemolyticus, V. vulnificus* and V. *cholerae.* Sampling for indicator organisms, such as fecal coleforms, in harvesting waters and shellfish stocks is an established public health protection method. However, to reduce human exposure to natural toxins such as saxitoxin, ciguatoxins and domoic acid, requires a more effective understanding and assessment of a complex set of environmental variables affecting the occurrence, duration and frequency of harmful algal blooms (HABs). The environmental measurements provided by the HOTO Module will be beneficial in providing base environmental data to further investigate such ecologically based public health threats.

The use of chemicals in aquiculture remains a concern of an unknown magnitude. Human consumption of aquiculture products exposed to a complex suite of chemicals is one area of concern; another is the possibility of creating resistant pests and pathogens as a result of the use and discharge of pharmaceuticals.

4.1.3 Sustainable Development

Because all the columns in Table 1 are components of sustainable development, any entries in these columns are denoted as having significance to sustainable development by the assignment of an asterisk.

4.2 RELATIONSHIPS BETWEEN HOTO INDICATORS, HUMAN USES AND SOCIO-ECONOMIC FACTORS

In addition to making a fundamental contribution to our global, long-term understanding of trends in global ocean health, the GOOS Programme can provide critical insights into the development of management strategies designed to maximize the benefits of sustainable marine resource use. Table 2 provides a general assessment of the nature and scope of the relationship between marine resource/use benefits and certain contaminant/analyte classes. As in Table 1, the numbers “3”, “2” and “1” denote increasing importance and the arrows signify the direction of impact. Blank cells represent either a weak relationship or one in which current scientific information is inadequate to make an assignment.

4.2.1 Seafood

The ability to achieve maximum economic benefit from seafood production (both wild harvest and aquiculture) is critically dependent on water quality. One effective way to describe the manner and scope of this relationship is to consider the ways in which contaminant/analyte loads affect finfish, shellfish, and cultured organisms. Notwithstanding the admittedly important influences of over-fishing, fleet capitalization and inadequate fishery management practices, anthropogenic contaminants affect the economic value of seafood products and reduce their sustainable production. These influences include effects on the level of harvest, distribution of commercially exploitable stocks and the safety, and therefore the economic value, of the product.

An important contribution of the HOTO module of GOOS is that it can contribute directly to the ability of Member States to ensure that globally uniform conditions of production are followed. As nations become increasingly assertive that imported seafood products are as safe as those domestically produced, it is likely that disruptions in the terms, conditions and direction of seafood trade will occur. One way to minimize the effects of these anticipated disruptions is for the international community to adopt more universally acceptable bases for judging seafood acceptability and to move increasingly towards criteria based on acceptable levels and distribution of contaminant loads in seafood harvesting areas. The latter offers improved cost-efficiency over traditional lot inspection approaches.

4.2.2 Waste Disposal

One of the environmental services provided by the oceans is its capacity to assimilate or absorb wastes, a capacity which is being exceeded in many coastal areas. Wastes from municipal, industrial and agroforestry sources, particularly in near shore areas and semi-enclosed seas, have clearly begun to have widespread impact on the ability of the ocean to provide critical environmental benefits. Of these wastes, possibly the most important single source of concern is untreated, or minimally treated sewage, which increases the levels of nutrients, suspended particulate matter and human pathogens in coastal waters. One

TABLE 2.
IMPACT ON SOCIO/ECONOMIC BENEFITS IN THE COASTAL ZONE

VARIABLES	SEAFOOD	Finfish	Shellfish	Aquaculture	WASTE DISPOSAL	Municipal	Industrial	Agroforestry	TOURISM	MARITIME OPERATIONS	FISHING PRACTICES	OIL/GAS EXTRACTION/ PRODUCTION	MINERAL EXTRACTION	CRITICAL HABITATS	Coral Reef Ecosystems	Estuaries	Temperate and Tropical Wetlands including Mangroves	Submerged Macrophyte Communities	Other Spawning and Nursery Areas	COASTAL AREA DEVELOPMENT	COASTAL AGRICULTURE	HYDROLOGICAL CYCLE ALTERATIONS
CHEMICAL/BIOCHEMICAL																						
Synthetic Organics		↑3	↑2	↑3		←3	←1	←2		←3					↑3	↑2 / ←2	↑3			←3		
PAHs		↑3	↑2	↑3		←2	←2	←3		←3		←1				↑2 / ←2				←3	←3	
Trace Metals		↑1	↑2	↑3		←2	←1	←2		←3			←1			↑2 / ←2				←2	←2	
Petroleum (Oil)		↑3	↑1	↑3		←1	←2	←3	↑1	↑2 / ←1		←1			↑3	↑2	↑1	↑3	↑1			
Herbicides/Pesticides		↑2	↑2	↑2 / ←3		←2	←3	←1	←2	←3					↑2	↑2 / ←3	↑2	↑2	↑2		←1	
Dissolved O_2		↑1	↑1	↑1 / ←3		←1	←1	←2	↑3	←3		←3				↑1	↑3	↑3	↑2	←2	←3	←3
Artificial Radionuclides							←1			←3												
Pharmaceuticals				←2		←3	←2	←3														
Phytoplankton Pigments						←2	←3	←1	↑3 / ←2						↑2			↑3		↑3	↑1	↑1
Human Pathogens		↑1	↑1	↑1		←1			↑1 / ←2	←3												
Nutrients				↑3 / ←2		←1	←3	←1	↑3 / ←2	←3					↑2					↑3	↑1	↑1
Algal Toxins		↑1	↑1	↑1					↑1						←3							
PHYSICAL																						
Litter/Plastic		↑3		←3		←1	←1	←3	↑1 / ←2	↑3 / ←2	←3										←3	
Suspended Particulate Matter			↑3	↑3 / ←3		←1	←2	←1	↑2 / ←3	←1	←3	←3	←2		↑1	↑2 / ←2		↑3	↑3	←2	←2	←1

area of particular concern is the apparent increase in frequency in toxic algal blooms which may be related to changes in nutrient inputs from anthropogenic activities. Another area of concern is the eutrophication caused by inputs of nutrients from anthropogenic activities into waters of poor circulation (e.g., some bays). It should also be noted that the wastes under consideration here may also contain one or more of the analytes discussed in Section 5.2. This underscores the importance of industrial pretreatment of wastewater before discharging into municipal wastewater treatment facilities. This module will provide the essential data required to elucidate this problem.

4.2.3 Tourism

In many areas of the world the most important economic benefit derived from coastal areas is tourism. The quality of the marine environment is of direct concern to sustainable tourism incomes. Conversely, it should also be recognized that poorly managed tourist centers contribute to significant environmental degradation of the coastal zone. For example, a significant source of agrochemicals in Southeast Asia is the large-scale development of golf courses. Similarly, the litter resulting from discarded solid wastes, especially of a non-destructive nature such as glass and plastic, has a deleterious effect on the aesthetics of beaches and coastal areas. Also, the development of resort complexes in close proximity to coral reefs can result in significant degradation of these sensitive habitats through excessive nutrient enrichment or physical damage to corals.

4.2.4 Maritime Operations

Although it has been stated by GESAMP that the impact on the global ocean of maritime activities contributes only around 10% of total marine pollution, local environments can be severely impacted. Marine activities, such as dredging, carried out in support of shipping and port and harbor development/maintenance, may cause locally severe problems through the mobilization of contaminated sediments. Similarly, the unregulated discharge of ballast water can and has created problems in local waters, Also, the noise created by propellers in shallow waters such as lakes and estuaries has the potential of leading to the disruption of marine communities.

4.2.5 Fishing Activities

Apart from the direct impact on target populations, such as changed species composition and altered size structure, fishing activities can have other direct and indirect impacts on the marine environment through the discarding of litter, such as nets, fishtraps etc., discharges of waste, and through physical disruption of the benthos (e.g., by trawling and dynamite fishing).

4.2.6 Oil/Gas Extraction and Production

Despite the controversy over the long-term impacts of oil spills, it is clear that the short-term effects of accidental introductions of petroleum hydrocarbons into the coastal environment can be locally severe, highly visible, and have major economic impacts on coastal communities. Further, in areas of offshore oil extraction, contaminated drilling muds do significantly alter benthic community structure and marine species distribution.

4.2.7 Mineral Extraction

At present, the marine mineral extraction is primarily in the form of sand and gravel operation and near shore placer deposits. These extraction processes disturb the marine environment by resuspending fine sediment and some instances mobilizing trace metals and other contaminants. In some cases (e.g., beach and reef mining), mineral extraction destroys habitats directly. These activities can result in severe disruption of marine communities and lead to habitat loss.

4.2.8 Critical Habitats

Critical coastal habitats, such as coral reefs, estuaries, wetlands (including mangroves), submerged macrophyte communities (e.g., sea grasses and kelp beds) and other spawning and nursery areas are among the most productive and diverse marine habitats. They provide environmental resources, goods and services of considerable economic benefit at local, national and global levels. These benefits include their contribution as critical spawning environments, major sources of food protein to marine communities and to humans, sources of commercially important materials and as areas for flood control and coastal protection. One should also be aware of the critical role such habitats play in the way in which people define their history, culture and communities. These contributory benefits are clear and well-recognized but are often difficult to measure quantitatively. This lack of ability to measure directly, in economic terms, their value should not, however, result in neglect of their overall contribution to human culture and welfare.

4.2.9 Coastal Area Development

Population stresses in the coastal zone are primarily due to human migration toward the coast. The growth of human population in the coastal zone is approximately twice that of the global population growth rate. This settlement pattern has exacerbated rates of change in coastal systems. Excessive rates of coastal area development have placed the goal of truly sustainable development beyond reach in some areas. Of particular importance is the need to more effectively manage waste disposal practices and future coastal development projects.

4.2.10 Coastal Agriculture

Appreciable agricultural production in the developing world is located in low-lying coastal plains. These practices, if poorly managed, can introduce excessive loads of agrochemicals into coastal environments. Again, of particular importance is the contribution of agricultural fertilizers to the total coastal nutrient flux. The addition of such nutrients can be of singular significance in altering the productivity and amenity value of coastal environments.

4.2.11 Hydrological Cycle Alterations

Freshwater management practices, including, *inter alia,* extraction of groundwater, damming of rivers and diversion of river flow for irrigation have significant impacts on coastal water quality. Such practices alter coastal salinities, change nutrient levels, disrupt sediment fluxes, destroy coastal habitats, disrupt marine community structures, cause saline water intrusion into inland areas and can lead to localized subsidence.

5. SPECIFIC HOTO MEASUREMENTS REQUIRED

The problem areas identified in the preceding section can be best addressed through the use of appropriate suites of physical, chemical and biological measurements. In this section, the measurements selected for inclusion in the HOTO module are specified in two categories: 1) chemical, biochemical and physical analytes; and 2) biological effects measurements and indicators of ecosystem health.

5.1 HABITAT STUDIES

Such acute impacts as contaminant spills and direct physical destruction (e.g., coastal development, land reclamation, mangrove logging, etc.) occur on short time scales and often result in the death of entire populations and communities. The global impact of these events is determined by their temporal and spatial distribution and is best monitored at the community/ecosystem level. The early-warning advantages of individual-level biomarkers are of little use here. However, biomarkers can be used during bioremediation following acute impact to assess the health of individuals for signs of recovery.

The economic value of some biological systems derive from their intact organization as whole communities or physical structures (e.g., the value of coral reefs in tourism and shoreline protection or mangroves in shoreline protection, supply of nutrients through the decomposition of leaf litter and trapping of pollutants). In terms of biodiversity, the basic integrity of kelp beds, coral reefs, mangroves, and other critical coastal communities depends upon physical habitats that are themselves constructed by organisms. Reduction of the areal extent of a given habitat inevitably results in a loss of biodiversity through species extinction. Loss of habitat is probably the most serious global threat to coastal marine biodiversity. Loss of habitat also reduces genetic diversity within species due to lower population size and the resultant genetic bottleneck effect.

In some cases, loss of critical habitats is caused by contaminants (e.g., sediment damage to coral reefs, pesticide effects on recruitment to macrophyte communities). Perhaps more widespread is direct physical destruction such as clearing of mangroves and land reclamation. GOOS will monitor changes in the extent and distribution of critical habitats, essential to assessing the health of the oceans. This information can also be used in determining the cause of habitat loss, the effectiveness of management, etc.

This component is probably most suited to remote sensing studies. Changes in the extent and distribution of sea grass beds, coral reefs, salt marshes, mangrove forests, kelp beds, and other critical coastal communities can be monitored via satellite imagery (probably preferable) and aerial photography. Techniques (color scanning) to monitor the frequency, distribution and extent of phytoplankton blooms, and patterns of phytoplanktonic standing stock, are well developed. Appropriate ground truthing will be required.

5.2 CHEMICAL, BIOCHEMICAL AND PHYSICAL ANALYTES

The following set of basic variables, which have been selected for inclusion in HOTO, correspond both to the variables identified in the analyses depicted in Tables 1 and 2 above and those identified as priority contaminants within the GIPME Programme and in the UNEP Regional Seas Action Plans.

5.2.1 Synthetic Organic Compounds

This is a loosely defined group of substances which includes all synthetic substances, but excluding pesticides, petroleum hydrocarbons and polyaromatic hydrocarbons, introduced to the sea as a result of human activities. The major portion of these substances result from industrial activities but their introduction to the marine environment may arise from direct discharge (point sources), discharge to municipal sewage systems or rivers and venting to the atmosphere. The substances are best classified in terms of their (a) toxicity, (b) persistence, (c) tendency to bioaccumulate, (d) bibavailability, and (e) source functions (size and nature of the land-based sources). Substances of particular concern include chlorobiphenyls, chlorinated dioxin and some industrial solvents. Current scientific knowledge of the behavior, fate and effects level of these substances is limited and new priority substances are likely to be identified in the future. Some synthetic organic compounds of concern are also produced within the marine environment particularly as a result of the practice of chlorination of sewage and by the introduction of free chlorine into the cooling waters of power stations.

5.2.2 Polycyclic Aromatic Hydrocarbons (PAHs)

This group of substances are all derived from thermal transformation of fossil fuels, particularly petroleum. PAHs constitute natural components of oil formed as a result of relatively low temperature metamorphic processes. More importantly they are also produced as combustion products of oil and coal. PAHs are introduced to the marine environment as a constituent of municipal or industrial effluents or via atmospheric pathways from industrial emissions, exhaust fumes of internal combustion engines or domestic heating systems. Human health concerns primarily relate to the carcinogenic properties of some individual PAH compounds.

5.2.3 Trace Metals

Trace metals comprise all metals and metalloids and their compounds in the marine environment. It is important to distinguish between the introduction of trace metals from anthropogenic activities and natural weathering processes. In practice, such a distinction requires the measurement of a set of metals which includes elements representative of weathering and unlikely to have major anthropogenic sources. Although trace metals in the marine environment have large and very diverse sources (elevated trace metal levels accompany almost every type of effluent), there is little evidence of widespread adverse biological effects as distinct from risks to human health posed by metals in seafoods. Elevated levels of dissolved trace metals are unlikely in seawater (other than in the immediate vicinity of sources) due in most cases to their rapid removal by adsorption to suspended particulate material. In the special case of certain organo-metallic complexes/compounds the situation is quite different. Tributyl tin (used as a constituent in anti-fouling paints on boats) and methyl mercury (formed by the microbiological methylation of mercury) are two highly toxic compounds which have been responsible for well recorded marine pollution incidents. The basis of their toxicity lies in their forms of speciation. Thus, special attention may be required to other specific forms of trace metals in the future.

5.2.4 Petroleum Hydrocarbons (Oil)

Petroleum hydrocarbons comprise ail constituents of crude oil and its refined derivatives. Pathways of the introduction of oil to the marine environment include ship deballasting operations, refinery effluent discharge, the discharge of lubricating oils to municipal sewage systems, introductions from oil production platforms and natural seepage. Marine accidents have the potential to introduce massive amounts of oil into the marine environment having locally catastrophic effects on marine ecosystems although there is sufficient evidence to suggest that recovery occurs within a decadal time scale. Chronic releases of oil to the marine environment may lead to the long term exposure of marine organisms to the toxic constituents of oil.

5.2.5 Herbicides/Pesticides

This group includes all the insecticides, herbicides and fungicides. The environmental half-life of the several hundred individual compounds in these categories varies from days (e.g. Malathion) to decades (primary degradation products of DDT). The group thus embodies a wide range of chemical properties (partitioning, volubility, volatility, etc.) and effects. Because these compounds are specifically designed to modify biological systems, there exists concern about their effects on marine ecosystems although the modes and severity of such effects on the marine environment have yet to be adequately investigated. Additional concerns involve human exposure to these compounds through the consumption of contaminated seafood products.

5.2.6 Dissolved Oxygen

The level of dissolved oxygen in surface and near surface seawater is an important measure of the state of the health of the aquatic marine environment. Dissolved oxygen levels become depressed as a result of the inability of natural processes (physical diffusion and primary production) to supply oxygen at the rate demanded for the oxidation of organic matter or reduced chemical substances. Dissolved oxygen deficiency may be particularly acute in the case of eutrophication, discharge of sewage (and the disposal of sewage sludge) and the discharge of organic industrial, agricultural and aquacultural effluents (e.g., pulp mill wastes, food processing plants, etc.). Extreme oxygen deficiencies (e.g., anoxia) can result in the elimination of all higher life forms. Anoxic conditions can also lead to the liberation of toxic forms of metals through redox mechanisms,

5.2.7 Artificial Radionuclides

This group consists of radionuclides produced as a consequence of artificial activation, nuclear fission and fusion. These radionuclides largely consist of direct products of fission (e.g. Cs^{137}, Sr^{90}, 1^{131}) and activation products of the nuclear fuel cladding or weapons casings containing the reaction. Historically, major sources of radionuclides are from nuclear weapons testing but currently, significant quantities of these contaminants are restricted to releases of effluents from nuclear power reactors and fuel reprocessing plants. The primary concerns about these substances relate to potential risks to human consumers of contaminated seafoods.

5.2.8 Pharmaceuticals

Pharmaceuticals include all substances used in preventing and treating human and animal diseases. The mode of introduction of these bioactive compounds is via municipal sewerage systems or, in the specific case of aquiculture, by their direct and intentional introduction into fish enclosures. Except in this latter case, there is no conclusive evidence of significant adverse effects in coastal waters but research on this topic is continuing.

5.2.9 Phytoplankton Pigments

The presence of abnormally dense blooms of phytoplankton is frequently a direct consequence of eutrophication (although, of course, they occur naturally). The composition, intensity and frequency of such blooms reflects the state of the marine environment. Some blooms may in themselves represent a hazard to the marine environment (e.g., foaming associated with *Phaeocystis* destroys some fisheries resources and lowers aesthetic values, red tide blooms of dinoflagellates are often toxic). There is evidence that the global frequency and severity of algal blooms is increasing. In addition to abnormal blooms and red tides, eutrophication can cause long-term changes in productivity, phytoplankton species composition, etc. Measurements of phytoplankton populations, either directly or via the quantification of pigments (i.e., by direct measurement or through satellite imagery), allow these processes to be quantified. Proper coordination of these efforts is needed if trends are to be elucidated.

5.2.10 Human Pathogens

Human pathogens are organisms that cause disease in humans. This category includes bacterial pathogens (e.g., Streptococcus, Vibrio), viruses (e.g., hepatitis virus) and enteric parasites, There is currently considerable concern and uncertainty regarding the persistence and viability of pathogens and viruses particularly and their passage though the marine food chain. Major sources of such materials are human sewage, inappropriate disposal of hospital wastes, uncontrolled discarding of the wastes of pathology and microbiology research laboratories and indigenous reservoirs of pathogens.

5.2.11 Nutrients

Nutrients include all the bioavailable forms of nitrogen, phosphorous and silicon introduced to the sea partly as a result of human activities. Though the major nutrients are relatively simple variables to quantify, it is difficult to distinguish between natural and anthropogenic sources and also to identify and quantify non-point sources of these substances. Point sources include sewage, plant outfalls and fertilizer factories. Non-point sources comprise run-off from agriculture, deposition of atmospheric contaminants, upland municipal sources, etc. Nutrients recycled from sedimentary reservoirs may also have anthropogenic origins. The major effect of excessive nutrient inputs is the promotion of eutrophication and disturbance of the structure of marine ecosystems.

5.2.12 Algal Toxins

This group of organic compounds comprise toxic substances produced by marine organisms on a sufficiently large scale to induce adverse effects on communities of higher marine organisms and/or pose threats to human consumers of seafood. Examples are toxins causing Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP), Amnesic Shellfish Poisoning (ASP), and Ciguatera poisoning and fish kills (e.g., Gymnodinium toxins). There is strong evidence to suggest that certain blooms of phytoplankton producing these toxins are induced or sustained as a result of anthropogenic destabilization of marine ecosystems (e.g., eutrophication).

5.2.13 Litter including Plastic Materials

Litter arises principally from the improper disposal of solid waste as well as the accidental, but common, introduction of such materials as fishing gear (including drift nets). Also included are degraded petroleum products (i.e., tar balls) and solid hospital wastes. This category of contaminants have riverine, coastal (garbage disposal at coastal sites or beach littering) and marine sources (ships or platforms).

5.2.14 Suspended Particulate Matter

Suspended particulate matter (SPM), in the context of the present document, is defined as all living and non-living particulate material in the water column at a given site. Increased levels of SPM can have serious effects such as inhibition of coral reef growth and, in extreme cases, blanketing of benthos. Deforestation and inappropriate agricultural practices result in increased particle mobilization causing deleterious effects on entire ecosystems. Dredging operations, sea dumping, etc. also results in increased SPM. Impovishments in the supply of suspended particulate matter to coastal areas can also result in adverse results, such as beach and shoreline erosion.

5.2.15 Other Considerations

The Panel also considered sewage as a potential substance of concern. However, it is a complex mixture of chemical, biological and physical constituents that varies in composition as a function of the degree of separation of storm, industrial and municipal sewage and the diversity of industrial and human activities in the catchment basin. Sewage is of concern in relation to pathogen content, nutrient content and oxygen demand resulting from the oxidation of organic matter. All these concerns are addressed separately in other elements of this section rather than being specifically addressed in Tables 1 and 2.

5.3 BIOLOGICAL EFFECTS MEASUREMENTS

The HOTO Module will employ simultaneous monitoring at different levels of biological organization to provide a better understanding of the mechanistic links among changes at each level (Figure 3; Table 3). This will also aid in the assessment of the effectiveness of management and mitigation measures for dealing with contaminant disposal and physical degradation.

Changes at the population/community/ecosystem levels of biological organization are of ultimate concern, However, such high-level responses are generally complex and far removed from causative events and are manifestations of damage rather than predictive indices. Detection of lower level changes (molecular, cellular, physiological and behavioral responses) which underlie higher level effects and for which causality can be established, may provide early warning of impending environmental damage. Individual and sub-individual responses may also be more amenable to detection by automated monitoring systems.

It must be pointed out here that to ensure global applicability of methodology in different regions of the world and ensure uniform interpretation of results, the use of biological techniques at the organismic and sub-organismic levels (e.g., biomarkers, physiological techniques, etc.) requires the prior identification of related/analogous members of a given biological group (not necessarily the same species) considering climatic/geographical variations and differences, but corresponding in genera, family or biological class. Such use of analogous members would provide a uniform and more reliable global picture of the combined effects of particular analytes/contaminants/situations under consideration. Furthermore, this will also enhance the global relevance of such techniques.

5.3.1 Molecular and Cellular Biomarkers.

The underlying basis of all stress-induced pathological/physiological changes is damage to, or perturbations of, life processes at the molecular and subcellular levels of biological organization. Consequently, detection of changes at these basic levels should, in theory, provide early warning distress signals of damage to the health of individuals if adverse reactions are sustained. Such molecular and cellular alterations will frequently reflect exposure to particular types of causative agents, thereby offering advantages over non-specific responses at higher biological levels (Table 3; Figure 3).

Our knowledge of distress signals has grown substantially in the past decade, often drawing on the reservoir of understanding of these processes in humans and rodents. The use of biomarkers in marine environmental toxicology is increasing and their potential power is probably considerable. Not only do they hold out the prospect of diagnostic predictors of pathological change, but biomarkers of exposure for various classes of toxic organic chemicals (xenobiotics) and certain trace metals have now been identified. This latter type of marker has the potential to provide rapid and less costly alternatives to routine chemical analytical screening which would allow the chemical analytical efforts to be focussed on more specific fingerprinting, thereby helping to link cause and effect.

Potential biomarkers include alterations in intracellular membranes (e.g., endoplasmic reticulum, lysosomes, endosomes, transport vesicles), genotoxicity (e.g., oxidative adducts, hydrophobic adducts, micronuclei), specific proteins or enzymes (e.g., metal-binding proteins, stress proteins, oncoproteins, cytochromes P-450, multi-drug resistance protein) and inhibition of cholinesterase by neurotoxins (e.g., organophosphates, carbamates). Some of these biomarkers, such as membrane changes and stress proteins, are indicative of cell injury and potential damage to health while others, such as DNA adducts, cytochromes P-450 (e.g., CYP1A and Ethoxyresorufin O-Deethylase (EROD)), multi-drug resistance (MDR) protein and metal-binding proteins, can be indicative of exposure to certain classes of xenobiotic and certain metals respectively. Molecular techniques should also be explored which detect biological damage associated with increased exposure to UV-B radiation.

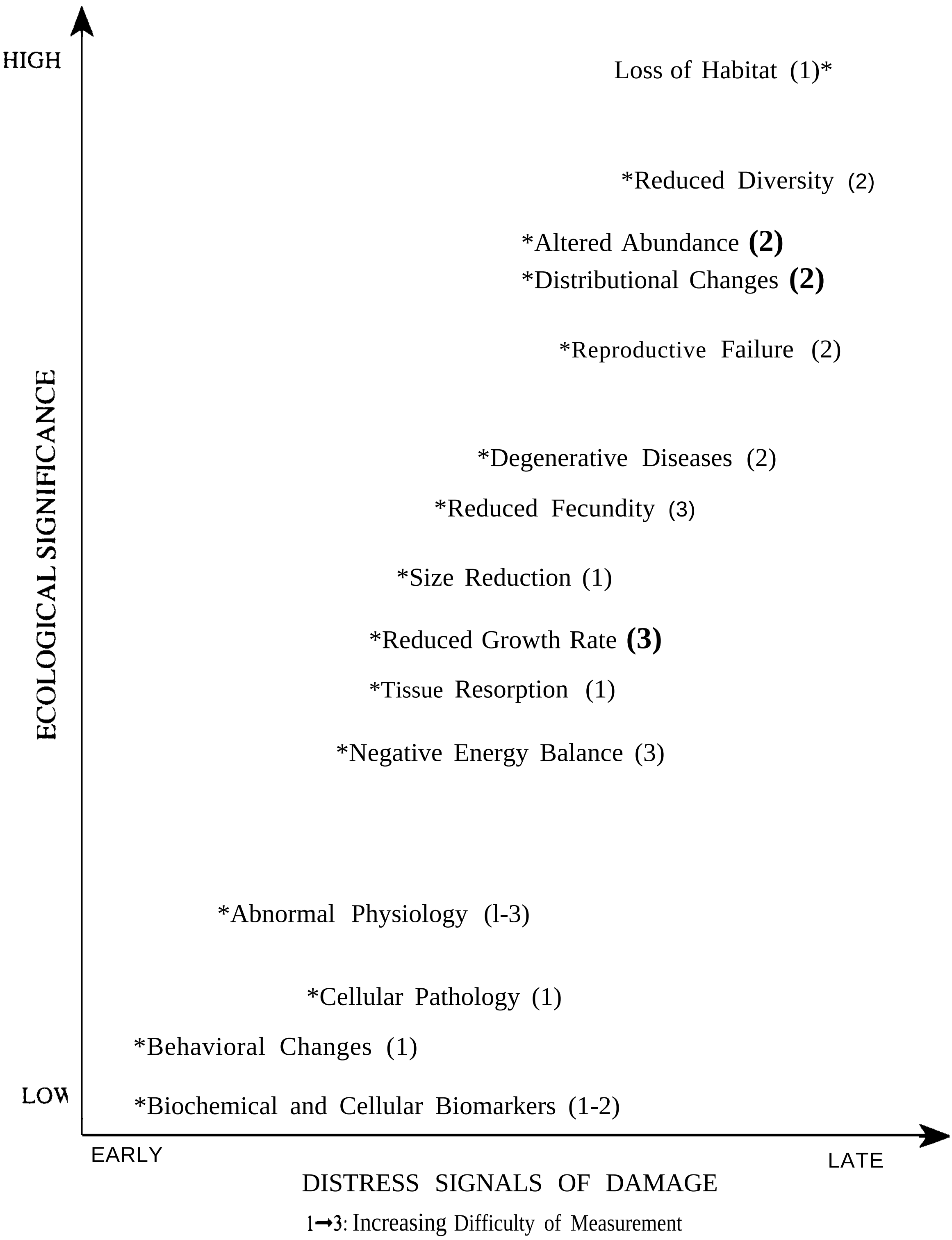
The main advantage to be gained from the use of biomarker tests is that early biochemical and subcellular changes in cells can hopefully be linked to pathological endpoints through an integrated multi-tiered approach rather than using single isolated tests. This strategy not only has the potential for detection of early warning distress signals that will be diagnostic for both exposure and injury, but will also

TABLE 3.
CONTAMINANT AND STRESS-RELATED SIGNALS OF HARMFUL BIOLOGICAL EFFECTS IN INDIVIDUALS

Levels of Biological Organization: Molecular (Membrane Alterations – Compound-Specific Biomarkers); Cell/Tissue (Neurotoxicity – Tissue Hypoxia); Organism (General Toxicity – Pathology)

VARIABLES	Membrane Alterations	Genotoxicity	Photosensitisation	Stress Proteins	Metal-Binding Proteins	Compound-Specific Biomarkers	Neurotoxicity	Cellular Granules	Cell Injury	Tissue Hypoxia	General Toxicity	Abnormal Physiological Behavior	Pathology
Synthetic Organics	●	●	●			●	●		●		●	●	●
PAHs	●	●	●	●		●			●			●	.
Trace Metals	●	●		●	●		●	●	●		●	●	●
Petroleum (Oil)	●	●	●			●	●		●		●	●	●
Herbicides/Pesticides		●				●	●		●		●	●	●
Dissolved Oxygen													
Artificial Radionuclides		●							●			●	●
Pharmaceuticals											●		
Phytoplankton Pigments							●		●	●	●	●	●
Human Pathogens													
Nutrients									●	●		●	●
Algal Toxins							●		●		●	●	●
Litter/Plastic										●		●	
Suspended Particulate Matter										●			

FIGURE 3.
BIOLOGICAL DISTRESS SIGNALS OF DAMAGE TO OCEAN HEALTH



provide a prognostic capability for predicting the likely consequences for the health of individuals in a population if the stress is sustained.

Biomarker tests are in general relatively easy to use, require routine preparative and measuring equipment, and the resulting data can be readily interpreted. However, users need to be aware of environmental factors which can interact to produce false negatives or positives. This problem will be minimized by the use of batteries of tests. Certain tests use cells in body fluids, for example blood; these can be used non-destructively and involve pathological changes in intracellular membranes of Iysosomes, as well as other effects. In fact, Iysosomal membrane damage appears to be a universal marker for effects of stresses in most if not all nucleated cells.

5.3.2 Cellular Pathology

The use of molecular and cellular biomarkers coupled with cellular pathology (or histopathology) has the potential to reveal significant differences between impacted and unimpacted (or reference) organisms. Furthermore, the compilation of tests used will indicate whether some differences result from exposure to xenobiotics, metals or other causative agents. it is important to note that by relating biomarkers of cell injury to significant pathological consequences for the individual, their diagnostic value and predictive capability for providing early warning of further damage at higher organizational levels will be strengthened (Table 3; Figure 3).

Many antibody-based recognition tests for specific proteins (e.g., cytochromes P-450, stress proteins, oncoproteins, etc.) can now be applied directly to histological samples. This can provide useful information on the spatial distributions of such proteins in relation to stress-induced structural and organizational alterations in cells and tissues.

Histopathological changes can be easily and accurately quantified using microstereological procedures applied to tissue sections, and this data can be correlated with both cell injury processes and abnormal physiology. Such techniques are relatively simple, low cost, and rapid, yet are capable of providing information of a very high level of biological/pathological sophistication. Histopathological samples can be archived indefinitely and yet can be made readily available for subsequent application of advanced molecular recognition tests for specific proteins and other products (“epitomes”).

5.3.3 Physiological and Behavioral Responses

Community level changes following exposure to anthropogenic stress arise in part from the differential effects of the stresses on individuals in component populations. Abnormal physiological and behavioral responses of individuals are therefore potentially valuable early warning signals of impending population and community level changes. Most physiological and behavioral responses to contaminants are non-specific. Consequently, they must be carried out in conjunction with the lower level biomarkers measurements mentioned above, and with appropriate chemical residue analyses, if causal relationships are to be established. Examples of the variables that can be measured include energy balance, circulatory and respiratory rates, feeding and locomotor activity, growth, reproductive condition and fecundity. The ecological significance of these variables is’ shown in context in Table 3. Clearly, the ease with which particular measurements can be made will vary greatly depending on the species in question and its habitat. For example, simple determination of the presence or absence of species, individual feeding behavior, growth rates, reproductive status, can be made quite readily in coastal areas with many macroinvertebrates (crustaceans, molluscs, polychaetes and echinoderms) and macroalgae. However, in many localities and with species from other phyla, such measurements are impractical. More sophisticated automated, on-line physiological and behavioral monitoring systems are also now available for recording cardiac, ventilator and feeding activity in crabs, barnacles, bivalves, and polychaetes. These can be augmented by, and related to laboratory based measurements of energy balance and behavioral changes (for examples, altered turning frequency and angle; velocity and velocity distribution). Application of such techniques is only restricted by equipment availability as they are relatively straightforward to carry out.

5.3.4 Population and Community Monitoring

Relationships between anthropogenic stresses and their adverse biological effects are more difficult to establish at the population and community levels. Nonetheless, a key objective of HOTO is to determine the extent of global biological change.

Population and community changes may result from stresses not amenable to lower level monitoring. For example, contaminants might affect larval recruitment and settlement patterns without stressing adult populations, either because adults are less sensitive to the contaminant or because of physical separation of larval and adult populations. As another example, species can be removed by direct human intervention (e.g., fisheries), and this would not be addressed by biomarker studies.

Continuing qualitative and quantitative surveys of selected communities, especially coastal ones, will be required to assess changes in diversity, abundance, and distribution of organisms within communities. At the simplest level these will involve simple, standardized, field measurements (e.g., transects, surveys). For some communities (e.g., coral reefs), standardized methods already exist or are being developed. For other communities, the development of new methodology will be required; this will primarily involve standardization and application of existing procedures.

Recruitment to key populations will be monitored through analysis of data collected during community surveys (e.g., size-frequency data) and through direct measurement (e.g., settling plates). HOTO will focus on recruitment of benthic populations; it is assumed that recruitment of economically valuable species will be monitored as part of the Living Marine Resources Module of GOOS.

Considerable progress has been made in developing automated systems for counting and identifying phytoplankters, thereby providing information on abundance, diversity, and community structure. There is potential to develop these into self-contained instruments; it might be possible, for example, to place these on merchant ships, as is done with Hardy Plankton Recorders (CPRs), to obtain broad spatial coverage.

Community structure studies can be facilitated by further technological development and application. Further development and dissemination of PC-based species identification keys, data management and statistical procedures, etc., will be emphasized in GOOS. Sophisticated technologies such as fully automated ROV devices and GIS systems should be developed for some, components of GOOS; in some cases (e.g., deep-sea benthos) such technologies may be the only suitable method.

For some communities, remote sensing applications may allow broad-scale assessment of changes in community structure. Techniques are being developed for coral reefs and mangrove forests, for example. One goal of HOTO will be to develop remote sensing applications through coordination of *in situ* community structure studies with the “whole community” remote sensing studies, described below.

The procedures described above have not been applied over regional or global scales to date. However, there are numerous reports of their successful application in the assessment of the extent of contamination and biological effects on smaller scales. For example, metallothionein has been used effectively in the detection of trace metal exposure *in situ* in molluscs and fish (Rock and McCarter, 1984; Olsson and Haux, 1986; Couillard et al, 1993; Benson et al, 1990). Similarly, EROD assays provide an indication of exposure to PAHs and other xenobiotics. In the Venice lagoon region and along the UK coast, suites of biomarkers have been used to great effect to define contaminant and effect gradients (Lowe et al, 1995). On the basis of these studies sites at which detailed residue analyses in seawater, sediment and biota should be carried out have been identified with a view to establishing exposure-response relationships prior to taking appropriate bioremedial action. *In situ* monitoring of physiological status using automated recording equipment has also been shown to be feasible (Aagaard et al, 1995). Only modest technological developments are necessary to permit long term deployment of recording equipment in estuarine and coastal areas. With regard to higher level (i.e., population and community) measures of biological effect, there are several studies which confirm the utility of the measurement procedures. For example, the influence of drilling muds on benthic communities and disturbances in coral reef fish communities by trace metals have been characterized using multi-dimensional scaling (Warwick and Clarke, 1992; Olsgard and Gray, 1995). It only remains to evaluate the utility of these approaches when implemented over wider spatial and temporal scales.

6. MONITORING CONSIDERATIONS

The HOTO Panel agreed that it is absolutely essential that the goals and objectives of any monitoring program be clearly stated from the outset. The entire design of the program should flow from these goals; no monitoring program can measure every variable or address all management issues. Once the goals and objectives are clear, the sampling design must be tailored to meet them. In particular, it is imperative to specify the level of change anticipated or directed by policy objectives, in quantitative terms, the minimum magnitude of change or effect that the program must be able to detect, and to ensure that the design has adequate statistical power to accomplish this.

The Panel also acknowledged that the statistical design must allow assessment of both the spatial and temporal scales of environmental effects. In relation to the monitoring of chemicals: 1) the relationship between measurements and matrices; 2) the relationships between difficulty of measurement and the importance of the measurement; and 3) temporal and spatial aspects of contaminant monitoring have all been considered. In addition, this approach was tested by an evaluation of the variables in the context of their relative regional importance.

In making decisions regarding sampling in new localities, ordination techniques can be used to rank the status of study sites relative to one another and with respect to conditions at sites considered to represent background conditions. However, for successful managerial action, temporal (i.e., longitudinal) sampling series are advisable so that patterns and trends in anthropogenic stressors, contaminant levels and associated biological effects can be monitored. Such sampling permits the consequences of managerial actions adopted to ameliorate adverse environmental consequences of anthropogenic activities to be evaluated. Usually, a significant proportion of study sites should be located in the vicinity of expected contaminant sources (e.g., in the vicinity of river discharges and urban harbors) to maximize the signal-to-noise ratio of measurements, In cases where atmospheric transport is the primary agent of contaminant delivery to the area concerned, measurements should be made of this input directly through measurement of both the air and precipitation. Recognizing relationships between anthropogenic stressors, contaminant levels and associated biological responses is a prerequisite to the prediction of future environmental changes.

6.1 STATISTICAL DESIGN CRITERIA

Once the objectives of the implementation plan in a given region have been formulated, attention must be given to sampling design, If no data are available, pilot studies will be needed to assess the scales of spatial and temporal variability in the analytes measured. These data are needed so that the monitoring program can be designed to meet the objectives.

In the past, sampling designs have concentrated on reducing statistical type-1 errors (i.e., the risk of rejecting a null hypothesis when it is true). This is done by setting the probability of rejecting the null hypothesis at a value of p=0.05. Yet, if one reduces a type-1 error, one increases the risk of committing a type-II error (i.e., the risk of accepting a null hypothesis when it is false). This is particularly relevant for HOTO considerations. For example, if one does a statistical test, such as a 't-test", on mean concentrations of two samples of heavy metals in fish consumed by man and finds no significant difference, this may simply be due to the sampling design being too low power ever to detect such a difference. In such cases, one must quote the power of a particular test to detect a change (Peterman, 1990; Fairweather, 1991). Power analyses are highly relevant to management issues where managers can decide *a priori* what magnitude of change they are concerned with. Then it is possible, using power analyses, to design a sampling program to detect such changes.

In addition to the incorporation of power analyses in the design of sampling programs, there is a need to consider other new approaches such as Beyond Before-After Control-Impact (Underwood, 1991, 1993). Here, emphasis is placed on multiple controls and random sampling over time in order to distinguish effects of impacts over natural variability.

Feed-back monitoring (Gray and Jensen, 1993), which tests predictions made in monitoring programs, can play an important role in the management of the marine environment.

6.2 MEASUREMENTS VERSUS MATRICES

The Panel identified the matrices where many of the analytes/contaminants are measured and presented an evaluation of the present state of measurement in these matrices (Table 4). Three categories of difficulty were determined. The first are relatively easy measurements that can be carried out with individuals with training using routine technology. These have been assigned a '1 The second group were defined by the Panel as those requiring more specialized equipment or training but could be analyzed by

TABLE 40
MEASUREMENT PHASES FOR CONTAMINANTS/ANALYTES

Contaminant/Analyte	Seawater	Fresh Water	Suspended Material	Tissues	Sediments	Beaches	Atmospheric Precipitation
Algal Toxins	3			3			
Artificial Radionuclides	3		3	3	2		3
Herbicides/Pesticides	3	3	2	2	2		3
Litter/Plastics			*			1	
Human Pathogens	2	2	1	1		1	
Nutrients	1	1					2
Dissolved Oxygen	1	1					
Synthetic Organics	3	3	2	2	2		3
Petroleum (Oil)	1	1	1	2	2	1	3
PAHs		2	2	2	2		3
Suspended Particulate Matter	1	1	*				
Trace Metals	2	2	2	2	2		3
Phytoplankton Pigments	1		1		3		
Pharmaceuticals	3	3		3	3		

The numerical entries in this table represent the relative simplicity of the measurement of the relevant analyte/matrix combination. An assignment of 1 signifies that the measurement is routinely made and there is widespread competence. An assignment of 2 signifies a somewhat more difficult measurement but one that can be made by marine or public health laboratories in essentially all regions of the world. An assignment of 3 signifies a relatively difficult and complex measurement for which there are a limited number of laboratories worldwide able to make it. A * denotes that the analyte and the matrix are synonymous.

monitoring laboratories within most nations. These have been assigned a “2”. The third group require more sophisticated measurements that would most probably be made by experienced research laboratories but perhaps do not exist in all countries. These have been assigned a “3”. The matrices chosen were seawater, groundwater and freshwater, suspended particulate matter, biological tissues (i.e., fish/seafood) and sediments. The Panel also added beaches - to represent the fact that litter and oil spills (petroleum) impact these areas. Precipitation was also added as this is a mode of entry to the marine environment of some of the analytes discussed above.

6.3 DIFFICULTY OF MEASUREMENT VERSUS IMPACT

The Panel evaluated the analytes/contaminants for degree of impact versus difficulty of measurement. This evaluation drew on an analysis of regional concerns conducted during the Seventh Session of GIPME in 1991 which took advantage of the considerable experience gained by GIPME Expert Groups in relation to both measurement capabilities and issues of concern within regional marine areas. As discussed in the previous section, different matrices present different challenges. However, the analysis is represented in Figure 4. The analytes fall into three distinct categories.

Category 1 analytes are those judged both to have high impact and be relatively easy to measure, such as nutrients, pathogens, suspended particulate matter and plant pigments. Also included in this category are ancillary properties for the characterization of the sampling regime such as salinity, temperature and dissolved oxygen. Litter and petroleum also have a high impact near sources (spills and dump sites) as well as at some distance from the sources. These are relatively easy to measure and also belong to Category 1. These analytes are also judged to be useful for international training programs under, for example, TEMA.

Category 2 analytes were judged to be difficult to measure and have lesser impact (i.e., trace metals, artificial radionuclides and pharmaceuticals). These analytes require sophisticated instrumentation, considerable training and specialized standards and reference materials. It is worth noting that the Panel’s result is contrary to public perceptions of the impact of these compounds. However, it is also worth noting that many non-specialists who consider this issue have a different perception because they often look only at very localized situations and not at the entire marine environment in a comprehensive manner.

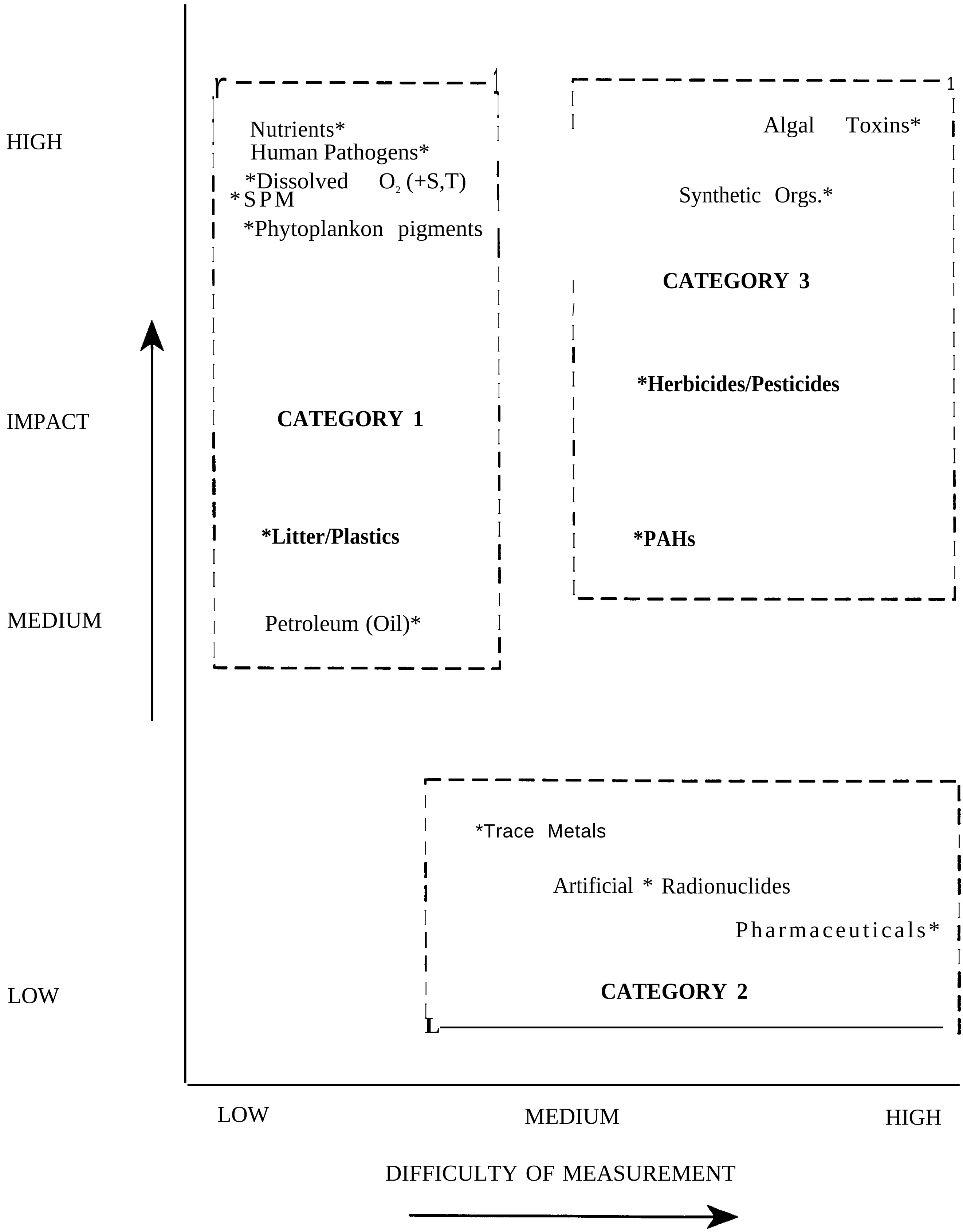
Category 3 analytes were judged to be of high impact and are presently difficult to measure. These are algal toxins, synthetic organics, herbicides and pesticides and, but to a lesser extent, PAHs. From a global monitoring perspective, it is imperative that efforts should be made to reduce the difficulty of measurement of these analytes as a priority.

Ease of measurement of biological variables is compared with their ecological significance and rate of response in Figure 3. Easy to measure indices at lower levels of the functional and organizational hierarchy offer the best means of obtaining an early warning of deterioration in ocean health. However, with regard to assessing the current extent of habitat loss, measures of community/ecosystem status offer greater potential. A further consideration in this context is that the signal-to-noise ratio will tend to be generally higher at the lower organizational levels (i.e., molecular, cellular and physiological) and will decrease as the ecological significance of the measurements increases. However, biological communities are naturally variable in both time and space; hence, any measurement strategy must take into account, for example, natural, seasonal cycles and spatial patchiness.

6.4 TIME AND SPACE SCALES

Factors that bear upon time and space scales for measurements are of three types. First are managerial considerations that involve the requirements of customers of the interpretative products from the HOTO module. Second are scientific considerations relating to the scales of change associated with changes in the locations and rates of introduction of substances and the locations and rates of physical disturbances of the marine environment. Third are the scientific considerations relating to the scales of natural variability in the marine environment of substances that have natural as well as anthropogenic sources and of natural biological communities.

FIGURE 4.
IMPACT VERSUS DIFFICULTY OF MEASUREMENT FOR CONTAMINANTS/ANALYTES



Managerial Considerations: Assessments of the state and trends in environmental conditions are required for local, regional and global purposes. For local conditions, the highest spatial and temporal resolution will be required. Such resolution is reduced for regional requirements and reduced further for global purposes.

Scientific Considerations: The scales of change resulting from anthropogenic introductions of contaminants are an important consideration in selecting spatial and temporal frequencies of measurement for the HOTO Module. The spatial and temporal resolution required to detect and understand conditions and change will be greatest near to sources and lowest furthest from the sources, This aspect of measurement frequency is further discussed below. For contaminants having natural components, it will be necessary to define the envelope of variability against which anthropogenically induced change must be detected. This will be contaminant-specific but likely to impose higher spatial and temporal measurement frequencies in coastal areas than in regional and deep ocean areas.

Figure 5 attempts to define measurement intervals (i.e., the inverse of measurement frequencies) appropriate for monitoring different contaminants in the context of distance from their sources. It has been formulated on the basis of scientific considerations relating to the likelihood and value of making measurements of change for local human health protection purposes, for example, and for detecting change at locations more remote from sources.

There is a need to stress explicitly at this point certain characteristics relating to the sophistication of methodologies employed in monitoring systems for the HOTO Module of GOOS. That is, all monitoring networks should use the simplest methods available, assuming that they offer appropriate precision and accuracies. If capability exists in a region to employ more sophisticated techniques and instrumentation, these may also be used. However, under no circumstances should the simpler techniques be forsaken because of the presence of the capability to employ more sophisticated alternatives.

6.5 REGIONAL EVALUATIONS

The Panel selected a number of geographic areas for which sufficient knowledge existed to assess the relative importance of contaminants and attempted to assign relative priorities to regions in the context of contamination and its effects (Table 5). This is by no means a complete list and is based on the expertise that was on hand within the Panel. A zero was assigned to analytes of little regional interest and low medium and high were ascribed to other analytes. In an attempt to achieve a summary, the Pane! assigned points to the rankings assigning 1 point for low, 2 points for medium and 3 points for high. The point ratings for specific regional marine areas were summed and appear at the foot of Table 5. While the precision of the assignments may not be high, it clearly reflects the necessity for primary attention to semi-enclosed marine coastal areas. Open-ocean oligotrophic areas are clearly of lesser priority within the context of the HOTO. It was noted, for example, that if the Asian Seas region were accounted for on a basin by basin basis, an entirely different picture would emerge. In the selection of areas for evaluation, it was apparent that enclosed or semi-enclosed seas having some uniformity in characteristics and concerns, such as the Mediterranean and Baltic Seas, were easier to assess than those that have long open coastlines such as West Africa. In concluding this analysis the Panel has benefitted from the results of some of long-standing regional monitoring programs.

7. REQUIREMENTS FOR TECHNOLOGY AND ITS DEVELOPMENT

Ocean measurement problems are formidable. Current technology permits systematic observation and analysis of the global oceans from a physico-chemical perspective; however, on-line, automated biological systems have only recently become available. Continued development of these techniques, together with research into how best they can be applied, is a major aim of the HOTO Module. Increasing the cost-effectiveness for making marine observations will be fostered and the production and quality of data will also be enhanced. This will, in turn, need the development rapid data handling and interpretation systems so that tangible benefits can be derived rapidly from the HOTO Programme.

FIGURE 5.
SPATIO-TEMPORAL ASPECTS OF MONITORING OF CONTAMINANTS FOR HEALTH OF THE OCEANS ASSESSMENTS

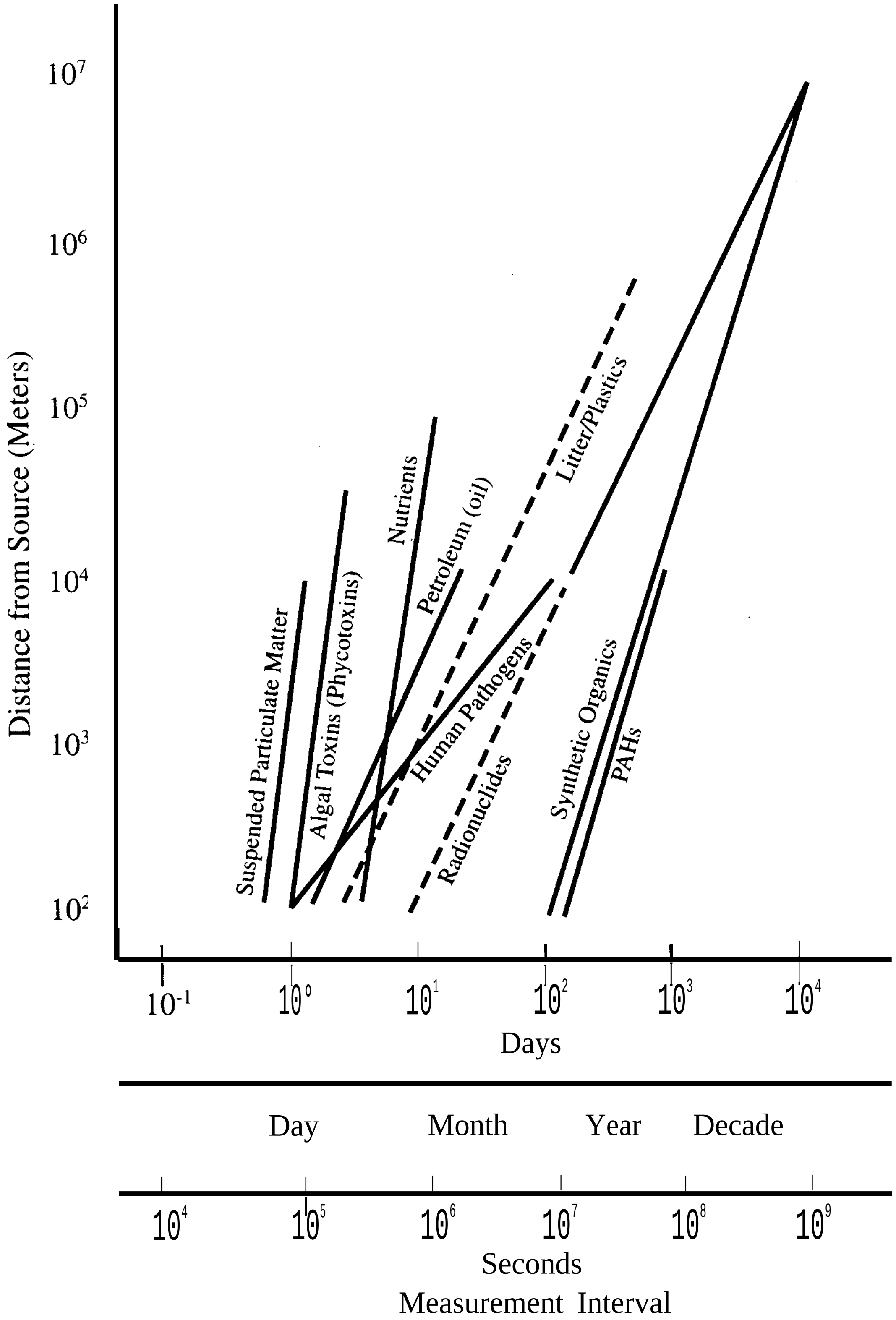


TABLE 5.

RELATIVE PRIORITIES FOR CONTAMINANTS AMONG MARINE AREAS

	Caribbean	Northern FSU	North Sea	West Africa	Baltic Sea	Mediterranean	Red Sea	The Gulf	Asian Seas	Black Sea	Oligotrophic Gyre	Great Lakes
Algal Toxins	H	–	M	–	M	M	L	L	H	M	¯	?
Artificial Radionuclides	–	H	M	¯	L	L	–	-	-	H	–	L
Herbicides/Pesticides	H	L	M	H	H	M	–	–	H	H	L	H
Litter/Plastics	M	M	L	H	M	H	M	L	M	H	L	H
Human Pathogens	H	L	H	H	M	H	M	H	H	H		H
Nutrients	H	L	H	H	H	H	L	H	H	H	H	H
Dissolved Oxygen	–	–	–	M	H	M	–	–	M	H	L	H
Synthetic Organics	L	M	M	M	M	M	L	L	L	H	L	H
Petroleum (Oil)	H	M	M	M	L	M	H	H	H	H	L	L
PAHs	L	M	M	M	M	M	H	H	M	M	L	M
Suspended Particulate Matter	H	L	L	M	M	L	L	H	H	M	–	L
Trace Metals	L	L	M	L	L	L	L	L	L	M	L	M
Phytoplankton Pigments	M	L	H	L	H	M	L	–	H	H	–	H
Pharmaceuticals	-	-	M	L	L	L	–	L	L	L	–	L
Totals	25	18	27	25	29	27	16	20	30	37	10	29

The entries in this table reflect priorities for different contaminants bearing in mind the severity of their effects (i.e., their hazards) in a selection of marine regions. The assignments and numerical weighings are:

– = Insignificant	Numerical Wieghting 0
L = Low Priority	Numerical Weighting 1
M = Medium Priority	Numerical Weighting 2
H = High Priority	Numerical Weighting 3

The numerical weighings have been summed for marine regions (bottom row).

The Great Lakes, although not a marine area, has been included in the table for illustrative purposes but excluded from the summations of weighings.

There needs to be continuous evaluation of technical developments and, where appropriate, integration of new techniques for assessing biological effects into the HOTO module. As temporal changes in the nature and quality of physical, chemical and biological measurements occur, research will be needed to provide insight into the relationships between the different types of measurements, if the continuity of monitoring is to be maintained.

Contemporary technology for contaminant measurement is largely based on sampling from platforms followed by laboratory analysis of samples. There are great opportunities for applying new technologies to overcome the limitations of this traditional approach for many contaminants. As part of GOOS, the extent of such opportunities in relation to the needs of modules requires to be aggressively evaluated. Such technologies include development of sensors, remote sensing, unattended moorings with or without real-time data telemetering and autonomous underwater vehicles.

For biological response measurements, the identification of sensitive indices that can be mechanistically linked to specific contaminant exposures is essential. This would then permit evaluations of the potential of new technologies for making more frequent, more ubiquitous and more synoptic measurements. Technologies showing most potential for biological response measurement include remote methods of assessing community structure, density and diversity, on-line, computer-aided physiological and behavioral monitoring systems, molecular and cellular biomarkers of exposure and damage. These include immunofluorescence and Polymerase Chain Reaction (PCR), for example, to detect viable but non-culturable pathogens. Currently, limitations in the measurement of biological responses in the marine environment is the most severe impediment to the development and implementation of the HOTO Module.

Systems that already exist could be improved such as networks of marine laboratories, existing time-series programmes in the coastal ocean and mussel watch activities. New camera systems for benthic surveys, remote submarines, and networks of on-line biological sensors near major point sources are just some of the tools that will be part of HOTO.

Having provided routine atmospheric observations for over two decades, satellites will carry instruments during the next decade that will provide prodigious amounts of ocean data. In the 1990s, sensors will be launched to study ocean circulation and pigment distribution; for example, variables of basic importance to considerations on the health of the oceans. The SeaWiFS (Sea-viewing Wide Field-of-View Sensor) Mission, presently scheduled to begin sometime in the indefinite future (but the launch has been delayed so many times that one can only question if it will ever be launched), includes determining the spatial and temporal distributions of phytoplankton blooms, understanding the fate of fluvial nutrients and acquiring global data on marine optical properties. This sensor replaces the Coastal Zone Color Scanner which operated experimentally from 1978 to 1986.

8. ANCILLARY PROGRAMME REQUIREMENTS

8.1 COORDINATION

It is anticipated that the day-to-day coordination of activities involving the various GOOS Modules will bean on-going responsibility of the GOOS Support Office. With regard to scientific and technical matters, individuals implementing HOTO Module activities should maintain continual liaison with scientific and technical programmes both within the UN System and outside. Maximum utilization must be made of existing mechanisms and capabilities among regions that have already been created for the execution of current IOC programmes and those of other UN Agencies. This will both expedite the implementation of the HOTO Module and ensure that regional concerns are addressed within GOOS.

8.2 QUALITY ASSURANCE

A fundamental requirement of global monitoring programs, such as those envisaged under the HOTO Module of GOOS, is that the resulting data must be comparable irrespective of the laboratory, country or region of origin. This presupposes that the data should be “true”. The production of “true” results is totally dependent on adherence to established Quality Assurance/Quality Control (QA/QC) procedures covering good field and laboratory practices.

Quality assurance refers to the total sum of activities employed by a laboratory to ensure that the data it produces meet the quality desirable for decision making. It consists usually of Quality Control defined as the set of procedures undertaken by the laboratory for continuous monitoring of operations and results in order to ensure that the results are good enough to be released and Quality Assessment, the procedures providing documented evidence that the quality control is being achieved (RM No. 57; UNEP, 1990).

A recent review of intercomparison exercises organized among European and North American laboratories in the last 20 years by the International Council for the Exploration of the Seas (ICES) revealed considerable differences in the results from measurements of a variety of contaminants in various matrices (Topping, 1992). Earlier,, Kullenberg et. al. (1986) had expressed some misgivings about the comparability, or the lack of it, of data emerging from similar exercises conducted in the context of the monitoring programs being undertaken under the IOC Marine Pollution Monitoring Programme (MARPOLMON) and the UNEP's Regional Seas Program. This has resulted in a loss of confidence in a great bulk of data produced under these programs and compromised their usefulness for the purposes for which the monitoring programs were set up. Consequently, effort, time and substantial resources have been lost.

It is, therefore, absolutely necessary that even at the planning stage, emphasis must be placed on recognition of, and insistence on adherence to, QA/QC Procedures in the monitoring programs envisaged under the HOTO Module of GOOS.

Perhaps the most critical requirement is the availability of adequately trained and properly motivated personnel and appropriate facilities for the execution of the defined tasks in the monitoring programme. This involves collective familiarity of the staff with all aspects of monitoring, from sample design to validation of data and requires that facilities (e.g., clean laboratories) and equipment are well maintained and serviced. The expendable material (e.g., glassware, solvents, gases, etc.) should also be of suitable quality.

Second, the design of sample collection would be such as to ensure the collection of representative samples which would properly labeled (e.g., sample type, location, time and date of collection, environmental characteristics, etc.) and assigned numbers for archiving purposes. Those samples which require special or particular "treatment" or preservation procedures to prevent their deterioration should be treated promptly. All aspects of transportation of samples to the laboratory, further processing of samples where necessary, and storage should follow procedures that will preserve the integrity of the samples prior to analysis. Where applicable, precise extraction procedures are employed to isolate, without contamination, alteration or loss, of the analyte of interest.

Third, instrumental analyses should follow for the accurate and precise measurement of the analytes of interest by a technique validated using relevant reference materials (RMs) and, where available, certified reference materials (CRMs). A CRM is reference material, accompanied by a certificate, one or more of whose property values are certified by a procedure which establishes traceability to a fundamental basic unit in which the property values are expressed, and for which each certified value is accompanied by an uncertainty at a stated level of confidence (ISO Guide 30, 1992). The use of reference materials has been recognized as the best available option for determination of the precision and accuracy of measured data. It is recommended that RMs be analyzed as a blind test to exclude the introduction of bias. Furthermore, the analyses of RMs should be repeated at predetermined intervals to confirm that the method remains in a state of statistical control (Wade and Cantillo, IOC, 1993).

Next is the quantification stage in which concentrations of analytes of interest in the sample are calculated using calibration curves derived from authentic standards. Often it is necessary to run confirmatory analyses to validate identification of the determinant in the sample and with certain protocols the influence of "matrix effects", which can interfere with quantification, are evaluated. Thereafter, the quality of the data produced must be validated prior to being reported. This involves verification that all the accuracy and precision criteria for the analyses have been complied with and that aberrations have not crept in, either due to human error or instrument malfunction.

In recording the validated data, it is essential to report other conditions that will allow both an evaluation of data quality and provide the necessary information to afford a reasoned interpretation of data. The data produced, which to all intents and purposes, should be 'true" are then ready to be archived. In order to maintain in-house and external confidence in the "truthfulness" of data produced, a laboratory must participate routinely in intercalibration/intercomparison exercises, and should be willing to subject its sampling and analytical procedures to external vetting.

At the global level the IOC/U NEP/lMO Committee for the Program on the Global Investigation of Pollution in the Marine Environment (GIPME), through the concerted efforts of its three groups of experts, is one of the foremost watchdogs on QA/QC procedures in marine pollution studies and will prove to be a dependable resource for the HOTO Module of GOOS in ensuring that data produced by various participating laboratories, irrespective of their country and region of origin, are comparable. It will also serve to identify and promote the development of necessary reference materials.

It must be noted that measurements made in environmental monitoring programs are becoming increasingly automated and include in-situ measurements from moored instruments or casts and remotely sensed data. It should be stressed that the QA/QC procedures involved in such cases, though different in many ways from those applied in traditional methods, should be no less rigorous and that intercalibration of equipment and methods employed should follow international protocols. For an example, in remote sensing application, “ground truthing” is an absolute necessity.

The above views are even of greater concern regarding the newly-emerging biomarker techniques and the monitoring of biological effects at the population and community levels. A prerequisite to QA in this respect will be the appropriate capacity building with regard to standardized methodology and intercalibration (e.g., through GIPME/GEEP and TEMA programmes). In effect, intensive series of evaluations, training and intercalibration exercises, tuned to the various regional/global environments are needed for this purpose. QA/QC biological procedures and protocols need to be developed.

8.3 DATA SERVICES

In giving thought to this most necessary aspect of GOOS as a whole, it was the consensus opinion of the Panel that the present status of international data management, including archiving and retrieval, is clearly inadequate to deal with the demands imposed by GOOS. As a result, GOOS should give early attention to this most crucial issue. Having said this, the Panel evaluated the major data reporting requirement for the HOTO Module and based its evaluation on the assumption that all data, whether derived from research projects, regional monitoring activities, fisheries research or classified military activities, needs to be made available. Past and present practices need to be changed for the HOTO Module to have its intended impact.

Ocean data collection is but the first step which ends with user access and application. A great deal of data exists that is not readily available, nor centrally archived, which points to the need for increased national, regional and international cooperation in data management. Protocols for data receipt, verification and validation will need to be developed in order to ensure that the GOOS data archive contains reliable data to assess the health of the ocean. In addition, the Panel feels that data should be available for no more that the cost of reproduction and distribution.

Presently, methods and standards for data archiving and exchange are in use for physical oceanographic data but are lacking for biological and chemical oceanographic and environmental data. Although some efforts have begun such as the work of GIPME’s Group of Experts on Methods, Standards and Intercalibration (GEMSI), much more attention needs to be focused on setting international policies and procedures that facilitate data access and usability, including procedures for quality assurance.

The HOTO Panel notes, however, that there may be three sources of data that may prove difficult to access. First, military organizations, and in particular, developed country navies, have collected important marine data for decades. These data are rarely made available to the marine research community. It is hoped that emphasis will be placed on developing agreements between responsible international authorities and military officials that would better guarantee access and analyses of such data. Second, significant marine monitoring activities have traditionally been carried out in private consulting companies. In certain instances, such private operations have not released into the public domain the data used to produce their contract documents. While, it is unclear how valuable such project-specific data would be to the GOOS Programme, the Panel did raise concerns over the need to access them. Third, research centers in the developed world do not generally perceive the research benefit of participating in large-scale monitoring data exchange programmes. Fourth, developing world organizations often lack the resources necessary for effective participation in global data exchange programmes. New resources and incentives must be developed to ensure the participation of such organizations.

9. RELATIONSHIPS AMONG HOTO, OTHER GOOS MODULES AND OTHER INTERNATIONAL PROGRAMMES

The Climate Monitoring, Assessment and Prediction; Monitoring and Assessment of Marine Living Resources; and Assessment and Prediction of the Health of the Oceans Modules of GOOS constitute the basic scientific elements that have both contributory and delivery responsibilities. Each should be designed from a global scientific perspective to acquire data and information as a contribution to GOOS. Each also has to have delivery responsibility in terms of assessments of state and change. The Marine Meteorological and Oceanographic Services should be developed, again from a global perspective, to provide additional data in relation to improving short and medium term weather prediction. Thus, the HOTO Module again constitutes a contributory and an evaluation role in GOOS, in this case with regard to forecasting.

Some ongoing ocean observing activities are presently underway, including the IOC-WMO Integrated Global Ocean Services System and the Global Sea Level Observing System, which presently largely serve major climate research programs. These systems are limited to measuring physical oceanographic parameters. The Marine Pollution Monitoring System (MARPOLMON) of GIPME is the combined assembly of regional operational data gathering activities for selected contaminants in the marine environment. It is intended to provide one contribution to the HOTO Module of GOOS through the delivery of marine scientific data on conditions in the marine environment relating primarily to chemical characteristics, fluxes and effects that constitute essential elements of the program as originally conceived (IOC Tech. Ser. No. 14, 1976) and strategically developed (IOC Tech. Ser. No. 25, 1984). GIPME, as jointly sponsored by the IOC, UNEP and IMO, has two major objectives as illustrated in Figure 6. These are: 1) To provide assessments of the State of the Marine Environment; and 2) To provide data and information to GOOS, to satisfy the requirements of GOOS and, indirectly, those of Earthwatch and GCOS. However, GIPME has an additional responsibility to develop improved understanding of the processes involving the sources, transport, behavior, fate and effects of contaminants in the marine environment. Such improved understanding will also provide benefits to the HOTO Module and to GOOS in improving the reliability of assessments and the modeling of GOOS data. It is considered that the experience of GIPME in regional monitoring activities place it in a unique position to deliver the regional assessments to GESAMP for its periodic reviews of the “State of the Marine Environment” at the request of its sponsoring UN Organizations along the lines defined by GESAMP for Regional Marine Assessments (GESAMP, 1994).

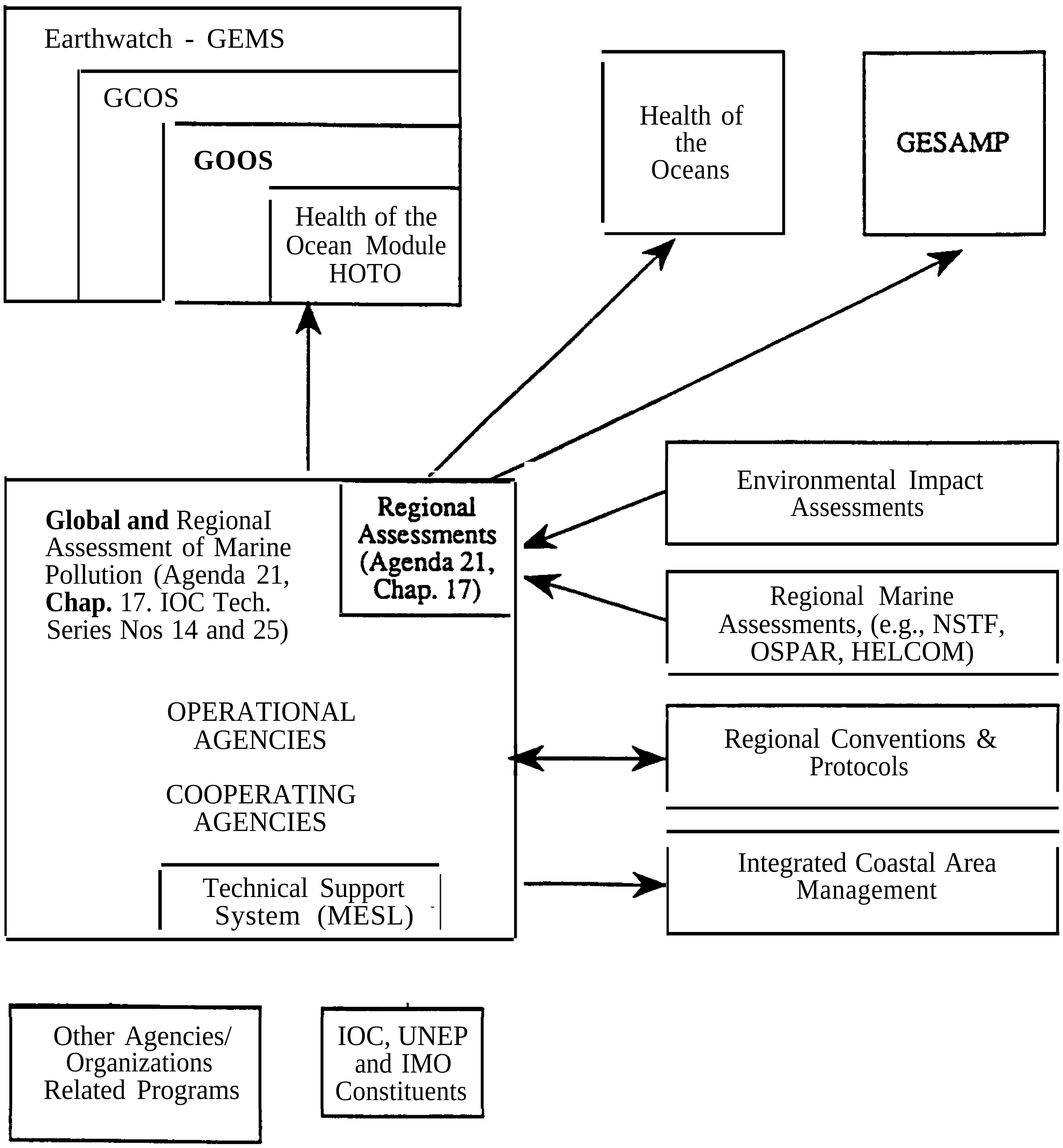
GIPME includes work not specifically directed at regional issues such as the development of methods for widespread application, preparation of reference materials and all projects addressing open ocean issues. Training workshops and intercomparison exercises are convened in the various regions to promote their monitoring effectiveness, The level of activity varies among regions.

The first test of a global chemical contaminant monitoring system was IOC’S Marine Pollution Monitoring Pilot Project (MAPMOPP) within IOC’S Integrated Global Ocean Services System (IGOSS). Petroleum contamination was the variable that was measured. MAPMOPP demonstrated that such a coordinated global measurement system could work and yield useful products.

The Regional Seas Program of UNEP was initiated in 1974 as a global program implemented through its regional components. Presently there are fourteen regions with close to 140 coastal States and Territories participating. The program is under the overall coordination of the Oceans and Coastal Areas Program Activity Center (OCA/PAC) of UNEP. OCA/PAC activities traditionally consisted of two separate categories, The Regional Seas Program and other activities (i.e., global and regional). The latter category included such subjects as climate change, global monitoring, environmental impact assessment, living marine resources and marine mammals. Recently, in order to respond effectively to the demands for integrated coastal area management on the basis of national priorities within a regional context, these two categories have been merged so that in each Regional Seas Program, as appropriate, relevant global issues and activities have been apportioned. Because UNEP is a co-sponsor of GIPME, the marine pollution programs of the IOC and UNEP are closely coordinated.

FIGURE 6.
GLOBAL INVESTIGATIONS OF POLLUTION IN THE MARINE ENVIRONMENT (GIPME)

STRATEGIC ELEMENTS OF GIPME



In order to provide a mechanism ensuring globally available data quality assurance services for contaminant measurements, the IAEA, with support from UNEP and IOC, established the Marine Environmental Studies Laboratory (MESL) in 1986 as a section of the then International Laboratory for Marine Radioactivity (ILMR) in Monaco. MESL organizes intercomparison exercises regionally and globally and acts as a center for testing and editing the UNEP Reference Methods for Marine Pollution Studies, with technical support from the GIPME Expert Groups. It organizes specialized local and regional training courses, instrument maintenance services, pilot monitoring studies and acts as the Regional Analytical Center for the Mediterranean Action Plan. The experience gained in the operation of this center can be applied in the provision of similar services for GOOS, in general, and its HOTO Module, in particular.

In view of the foreseen requirement for GIPME to contribute to GOOS, in addition to assessments of the “State of the Marine Environment”, there exists a need to reconsider the strategic requirements of GIPME in the specific context of GOOS. This should be completed before the harmonization of the respective UNEP and IOC activities relating to GIPME is undertaken to ensure that the combined programme fully anticipates its responsibilities and achieves its goals. Therefore it is imperative that HOOP and GIPME work in close collaboration to ensure all requirements of both the GOOS Module addressing the health of the ocean and the GIPME Programme are met.

Of relevance to integrated coastal area management, is the Unesco Coastal Marine Ecosystem (COMAR) Cooperation Programme with its network of regional and inter-regional projects in Africa, Asia and the Pacific, Latin America and the Caribbean. A COMAR/ International Union of Biological Science (IUBS) - International Association of Biological Oceanography (IABO) Task Force on Marine Biodiversity and Ecosystem Function and a UNEP/Unesco (COMAR) Task Team on the Impact of Expected Climate Change on Mangroves have been established.

An existing program that can be considered a prototype of continuing efforts needed internationally to monitor the health of the ocean is the IOC/UNEP-GIPME International Mussel Watch Project, being carried out by the IOC, in collaboration with UNEP. Begun in 1991 in collaboration with U.S. NOAA, this project included the collection of bivalve samples in Central and South America to quantify the sources and rates of input of wastes for the purposes of identifying the current status of ocean health in that region. With the collection of samples and subsequent analyses by the participating laboratories in participating countries, a data base was created for identifying trends. Approximately 300 samples from 80 coastal sites on both east and west coasts of the region were analyzed at two referee laboratories, the Geochemical and Environmental Research Group at Texas A&M University, College Station, Texas, U. S., and MESL in Monaco, as well as at national laboratories in the participating countries. Additional tissue samples are available for further in-country analysis and inter-laboratory comparison. The project complemented a U.S. NOAA Mussel Watch Program begun in 1984 to monitor the North American coastline, as a follow-on to a prototype program initiated by the U.S. EPA in 1976. Further, were collected and provided by Canadian participants which effectively has the Project covering the Americas. A meeting in Brazil was convened in April, 1993, at which the results of this phase of the program was discussed and is being published by the IOC. Planning for the next phase, the Asia-Pacific Section, has begun and a meeting was convened in January, 1993, at the University of Tokyo to further develop plans for closing the Pacific Rim. This was followed by a Workshop in Bali just before a WESTPAC Symposium in November, 1994, WESTPAC, at its meeting in February, 1996, in Tokyo, discussed the further development of this Second Phase of the International Mussel Watch Project. In addition to generating high quality data on chlorinated hydrocarbon, PCB and PAH concentrations and a quasi-synoptic baseline of the contamination in this global area, the International Mussel Watch Project is serving as a field test for a global chemical contaminant monitoring program.

However, the International Mussel Watch Project does not, as yet, provide data on the health of the biota, but only on the spatial distributions of contaminant residues. If such programmes are to effectively provide a framework for monitoring the health of the oceans, then they must in the future include indices of biological effects, such as histopathology. This will give an effective measure of the well-being of the mussels that can then be correlated with the contaminant distribution patterns. In addition, Mussel Watch could serve as a means of detection of the presence of human pathogens.

The details of the International Mussel Watch Project provided above should not be interpreted as implying that there are not some fairly simple measurements that could be made at the land-sea interface and within the coastal zone that would provide valuable information for assessing the relative state of coastal areas. In addition, more infrequent measurements in the offshore region would give some indication of trends in a more regional context (e.g., character of outfmows from constrained regional sea areas). Also, use should be made of shelf transects that are included in the conceptual design of the Open Ocean Baseline Study of GIPME.

The observations and measurements planned to be made within the framework of the HOTO Module of GOOS will be concentrated in the shelf seas areas of the world's oceans. That is, the density and frequency of the observations are likely to represent those areas of the ocean that are most likely at risk. Within the framework of the International Geosphere-Biosphere Program (IGBP) of the International Council of Scientific Unions (ICSU), there are three "Core Projects" that are of relevance to the HOTO Module. These are the Land-Ocean Interactions in the Coastal Zone (LOICZ); the Joint Global Ocean Flux Study (JGOFS) and the Global Ocean Ecosystem Dynamics (GLOBEC) Program. Of these, LOICZ is the most directly pertinent, while JGOFS has greater relevance for the Climate Module and GLOBEC more relevance to the Living Marine Resources Module of GOOS. It should be recognized that the "Core Projects" of the IGBP are purely research activities of limited (e.g., about 10 years) duration. Thus, they might make use of data generated through an operational GOOS, but the likelihood of the HOTO Module producing significant data outputs within the lifespan of LOICZ, for example, is limited. In contrast, the data generated through the research of LOICZ could provide significant contributions to the further elaboration and development of the HOTO Module as it reaches full global scale coverage and becomes fully operational after the turn of the century.

The LOICZ Project is as its name suggests, that component of the IGBP which focuses on the area of the earth's surface where land, ocean and atmosphere meet and interact. The overall goal of this Project is to determine at regional and global scales, the nature of that dynamic interaction; how changes in various compartments of the Earth System are affecting coastal zones and altering their role in global biogeochemical cycles; to assess how future changes in these areas will affect their use by people; and to provide a sound scientific basis for future integrated management of coastal areas on a sustainable basis.

In comparison with the relatively uniform environment of the sunlit zone of the open ocean, of the rapidly mixed environment of the atmosphere, the spatial and temporal heterogeneity of the world's coastal zone is considerable. There are, as a consequence, considerable methodological problems associated with developing global perspectives of the role of this compartment in the functioning of the total Earth System, Identifying and quantifying this role and developing scenarios of change in the coastal compartment of the Earth System under anthropogenic and geocentric driving forces of change will require a considerable body of research that is detailed in the LOICZ Implementation Plan. The approaches and methods developed by LOICZ to address these research goals may have value in the further development of the HOTO Module of GOOS and in the interpretation, at wider regional and global scales, of the information and data collected and assembled through the implementation of the HOTO Module. The implementation phase of LOICZ commenced in 1995 and the research networks established through the LOICZ Project could be used to provide practical advice and assistance in the implementation of the HOTO Module at local and regional levels.

The above examples are important because GOOS will be built, as far as possible, on existing activities and bodies as well as on the progressive implementation of new elements and capabilities. It will be updated and improved in response to results of research programs and the development of new technology. Present national and international infrastructures and mechanisms that are the result of many years of effort and cooperation will be exploited. Because the experience of those who have developed present systems is a critical requirement, representatives of present programs are being asked to help in the development and planning of GOOS - essentially forming the collective scientific advisory resource.

10. IMPLEMENTATION PROCEDURES

GOOS will foster the collection and dissemination of ocean data. It will be implemented and managed through national and regional services and facilities. Adequately funded national organizations that cooperate actively with international organizations are required. Today there are few of these, and support for them must grow if GOOS is to become a reality. Thus, efforts must be made to encourage national support while at the same time ensuring agencies that support marine environmental activities that their support will be of direct benefit to them (e.g., through data availability and interpretation) and will require the minimum (i.e., extra effort and expense) from them in order to get data collected by projects supported by them in a suitable form and of a suitable quality.

Initial emphasis must be on strengthening all relevant UN System activities. A major commitment needs to be made by all countries towards the effective implementation of GOOS. This includes the dedication of both human resources and financial support specifically to GOOS Module activities. In addition, governments must be encouraged to:

(a) Make existing data available;
(b) Distribute data products;
(c) Facilitate data exchange;
(d) Develop data networks;
(e) Support the collection of satellite and in situ data;
(9 Support data collection by volunteer ships and data buoys; and
(9) Encourage person-to person networking.

Because all countries must be involved, substantial training and assistance must be provided to developing countries. Partnerships between developed and developing countries are to be encouraged. Close collaboration is also required among relevant international organizations for proper implementation. Most countries, for example, do not have access to, or capabilities for, using the large volume of remotely-sensed data becoming available. The greatly increased availability of small, inexpensive computers will allow more users to manipulate data and prepare products, Training is needed in how to apply these kind of data to local needs,

GOOS is to be based on the principle that all countries should meet certain commitments, according to their capabilities to fulfill such commitments, in the agreed global plan, so that all countries may benefit. The UNCED process established the following criteria for capacity building:

o The capacity needs to be developed nationally and in the long term to become self-sustaining;
o It needs to be based in the short term on international, regional, and bilateral collaboration to ensure accelerated development, technology transfer and economies of scale;
o It needs to be developed only as fast as it can be used effectively; and
o It requires sustained action over a long period.

11. REFERENCES

Aagaard, A., Warman, C., Depledge, M. H. and Naylor, E., Dissociation of Heart Rate and Locomotor Activity During the Expression of Rhythmic Behavior in the Shore Crab, *Carcinus maenas* (L.), Mar. and Freshwater Behav. and Physiol., 26, 1-10, 1995.

Benson, W. H., Baer, K. N..... and Watson, C. F., Metallothionein as a Biomarker of Environmental Metal Contamination, In Biomarkers of Environmental Contamination, Ed. McCarthy, J. F. and Shugart, L., Lewis Publ., Boca Raton, FL, 255-266, 1990.

Couillard, Y., Campbell, P. G. C. and Tessier, A, Response of Metallothionein Concentrations in a Freshwater Bivalve *(Anodonta grangis)* along an Environmental Cadmium Gradient, Limnol. Oceanogr., 38,299-313, 1993.

Fairweather, P. G., Statistical Power and Design Requirements for Environmental Monitoring, Austral. J. Mar. And Fresh. Res., 42, 555-567, 1991.

GESAMP, The State of the Marine Environment, UNEP Regional Seas Reports and Studies, No. 115, UNEP, Nairobi, Kenya, 1990.

GESAMP, Guidelines for Marine Environmental Assessments. GESAMP Reports and Studies, No. 54, IMO, London, U. K., 1994.

GESAMP, Biological Indicators and their Use in the Measurement of the Condition of the Marine Environment, GESAMP Reports and Studies, No. 55, UNEP, Nairobi, Kenya, 1995.

Gray, G. S. and Jensen, K., Feedback Monitoring: A New Way of Protecting the Environment, Trends in Ecol. and Evol., 8, 267-268, 1993.

IOC, A Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment and Baseline Study Guidelines, IOC Technical Series, No. 14, Unesco, Paris, 1976.

IOC, A Framework for the Implementation of the Comprehensive Plan for the Global Investigation of pollution in the Marine Environment, IOC Technical Series, No. 25, Unesco, Paris, 1984.

IOC/UNEP Committee for the Investigation of Pollution in the Marine Environment, Seventh Session, Paris, 21-25 January 1991.

IOC-XVll/8 Annex 2 rev., The Approach to GOOS, Paris, 12 March 1993.

IOC/WMO Committee on Climatic Changes in the Ocean; Ocean Observing System Development Program, IOC Technical Series, No. 27, IOC (Unesco), Paris, 1994.

IOC/UNEP/lMO Committee for the Investigation of Pollution in the Marine Environment, Eighth Session, San Jose, Costa Rica, 18-22 April 1994.

ISO, Terms and Definitions Used in Connection with Reference Materials, ISO Guide 30, Geneva, 1992,

Kullenberg, G. (Ed.), The IOC Programme on Marine Pollution. Mar. Poll. Bul. vol. 17, 341-352, 1986.

Lowe, D. M., Fossato, V. and Depledge, M. H., Contaminant Induced Lysosomal Membrane Damage in Blood Cells of Mussels *(Mytilus galloprovincialis)* from the Venice Lagoon, Mar. Ecol. Prog. Ser. (In press), 1995.

NRC, Managing Troubled Waters, The Role of Marine Environmental Monitoring, National Research Council, U. S. A., National Academy Press, Washington, 1990,

Olsgard, F. and Gray, J. S., A Comprehensive Analysis of the Effects of Offshore Oil and Gas Exploration and Production on the Benthic Communities of the Norwegian Continental Shelf, Mar. Ecol. Ser., 122, 277-306, 1995.

Olsson, P. E. and Haux, C., Increased Heptic Metallothionein Content Correlates to Cadmium Accumulation in Environmentally Exposed Perch, Aquatic. Toxicol., 9, 231-242, 1986.

Peterman, R. M., Statistical Power Analysis can Improve Fisheries Research and Management, Can. J. Fish. Aquar. Sci., 47, 2-15, 1990.

Rock, M. and McCarter, J. A., Increased Heptic metallothionein Production and Resistance to Heavy Metals by Rainbow Trout *(Salmo gairdneri),* Comp. Biochem. Physiol,, 77C, 77-82, 1984.

SCOR, Report of the Panel on Monitoring Ocean Climate Fluctuation, Global Atmospheric Research Program, Working Group 48, WMO/lCSU, Geneva, 1977,

Topping, G.,The Role and Applications of Quality Assurance in Marine Environmental Protection. Mar. Poll. Bul. Vol. 25, 61-65, 1991.

UNEP/lOC/lAEA/FAO, Contaminant Monitoring programmes Using Marine Organisms: Quality Assurance and Good Laboratory Practice. Reference Methods for Marine Pollution Studies No. 57. UNEP Nairobi, 1990.

Underwood, A. J., Beyond BACI: Experimental Designs for Detecting Human Environmental Impacts on Temporal Variations in Natural Populations, Accst. J. Mar. Freshwater Res., 42, 569-587, 1991.

Underwood, A. J., Beyond BACI: The Detection of Environmental Impacts on Populations in the Real, but Variable, World, J. Exp. Mar. Biol. Ecol., 161, 145-178, 1992.

Wade, T. and Cantillo, A., Marine Pollution Studies Quality Assurance Workbook for the Use of Standards and

Reference Materials in the Quantification of Chlorinated Pesticides, IOC Manual and Guides, Paris, 1994.

Warwick, R. M. and Clarke, K. R., Comparing the Severity of Disturbance: A Meta-Analysis of Marine Benthic Community Data, Mar. Ecol. Prog. Ser., 92, 221-231, 1992.

12. OTHER READING

Global Marine Pollution: An Overview, IOC Technical Series, No. 18, Unesco, Paris, 1977.

Prospects for Global Ocean Pollution Monitoring, UNEP Regional Seas Reports and Studies, No. 47, UNEP, Nairobi, 1984.

Global Ocean Observing System: Status Report on Existing Ocean Elements and Related Systems (IOC-INF-833), December 1991 (IOC/INF-879).

Global Ocean Observing System, Draft Development Plan (IOC/EC-XXV/8 Annex 1) 6 January 1992.

Summary Report, Joint IOC-UNEP Intergovernmental Panel for the Global Investigation of Pollution in the Marine Environment, 1st Session, Paris, 4-7 March 1992.

Summary Report, First Meeting of the Bureau of the Joint IOC-UNEP Intergovernmental Panel for GIPME, Paris, 22-24 July 1992.

Biomarkers - Research and Application in the Assessment of Environmental Health (Eds., Peakall, D. B. and Shugart, L. R.), NATO ASI Series, Springer-Verlag, Berlin, Heidelberg, New York, 1993.

Non-destructive Biomarkers in Vertebrates (Eds., Fossi, M.C. and Leonzio, C.L.), Lewis-CRC Boca Raton, FL and, Ann Arbor, Mich, 1994.

ANNEX I

LIST OF PARTICIPANTS

HOTO PANEL

Dr. Neil **ANDERSEN** *(Chairman GIPME and HOTO Panel)*
University of Maryland
Horn Point Environmental Laboratory - CEES
2020 Horn Point Rd.
P.O. Box 775
Cambridge, MD 21613
USA
Tel: (1-410) 228-8200 Ext. 8479
Fax: (1-410) 221-8490
e-mail: (Internet): andersenr@hpel.cees.edu

Dr. Samuel **ANURIGWO**
Imo State Environmental Protection Agency
Government House
PMB 1159
Owerri
NIGERIA
Tel: (083) 234-986 or 233-703

Dr. J. Michael **BEWERS** *(Vice-Chairman GIPME and GEMSI)*
Marine Chemistry Division
Bedford Institute of Oceanography
PO Box 1006
Dartmouth, Nova Scotia B2Y 4A2
CANADA
Tel: (1-902) 426-2371
Fax: (1-902) 426-5342
e-mail (Internet): m_bewers@bionet.bio.dfo.ca

Dr. Robert E. **BOWEN**
Environment Science Programme
University of Massachusetts
Boston, Mass. 02125-3393
USA
Tel: (1-617) 2877443
Fax: (1-617) 2877474
e-mail (Internet):bowen@umbsky.cc.umb.edu

Prof. Michael H. **DEPLEDGE**
Director
Plymouth Environmental Research Center
University of Plymouth
Drake Circus
Plymouth PL4 8AA
UNITED KINGDOM
Tel: (44-1752) 233038
Fax: (44-1752) 233039
e-mail (Internet): m.depledge@plymouth.ac.uk

Prof. Edgardo **GOMEZ**
Marine Science Institute
University of the Philippines
U.P.P.O. Box 1
Diliman, Quezon City 1101
Philippines
Tel: (632) 922-3921 and 922-3959
Fax: (632) 924-7678
e-mail (Internet):admin@msi.upd.edu.ph

Dr. John **GRAY** *(Chairman GEEP)*
Section of Marine Zoology and
Marine Chemistry
Biological Institute
University of Oslo
P.O. Box 1064 Blindern
0316 Oslo, Norway
Tel: (47) 2285-4510
Fax: (47) 2285-4438
e-mail (Internet): j.s.gray@bio.uio.no

Prof. Youssef **HALIM** *(Vice-Chairman GIPME Panel)*
Department of Oceanography
Faculty of Science
Alexandria 21511
EGYPT
Tel: (203) 586.96.61
fax: (203) 545.76.11
e-mail (Internet):hummon@alex.eun.eg

Dr. Michael **HUBER**
Scientific Director
Orpheus Island Research Station
P. O. Box 4
Halifax QLD 4850
Australia
Tel: (61-77) 777336 Ext. 21
Fax: (61-77) 777336
e-mail (Internet): Michael.Huber@jcu.edu.au

Dr. Anthony **KNAP** *(Chairman GEMSI)*
Director
Bermuda Biological Station for Research
Ferry Reach 1-15
BERMUDA
Tel: (1-441) 297 18 80 Ext. 244
Fax: (1-441) 297 81 43
e-mail (Internet):knap@bbsr.edu

Dr. Michael **MOORE**
Plymouth Marine Laboratory
Citadel Hill
Plymouth PL11PB
UNITED KINGDOM
Tel: (44-1752) 222772
Fax: (44-1752) 226865
e-mail (Internet):m.moore@pml.ac.uk

Dr. Md. Sirajul **ISLAM**
Environmental Microbiology Laboratory
international Center for Diarrhoeal
Desease Research
GPO Box 128
Dhaka-1 000
Bangladesh
Tel: (880) 600171-78/2405
Fax: (880) 2-833116
e-mail (Internet): sislam%cholerar@external.ait.ac.th

Dr. Jonathan **PATZ**
Department of Molecular Microbiology
and Immunology
Johns Hopkins School of Hygiene
and Public Health
615 N. Wolfe St., Rm. 7041
Baltimore, MD 21205-2179
Tel: (1-202) 260-5874
Fax: (1-202) 260-6405
e-mail (Internet): jpatz@phnet.sph.jhu.edu

IGBP GLOBAL CLIMATE CHANGE RESEARCH PROGRAMS

NOTE: All chairmen of these programs were extended invitations not only to attend the HOTO Planning Sessions but to make comments on the various drafts that have been produced. To date, and aside from the individuals noted below, we have received communications from Dr. Brian Rothschild, Chairman of GLOBEC.

Dr. John C. **PERNETTA** *LOICZ Representative*
LOICZ Project Director
Netherlands Institute for Sea Research (NIOZ)
PO Box 59
1790 AB Den Burg
Texel
THE NETHERLANDS
Tel: (31-222) 369404
Fax: (31-222) 369430
e-mail (Internet): loicz@nioz.nl

Dr. Anthony **KNAP** *JGOFS Representative*
(See above)

GLOBAL OCEAN OBSERVING SYSTEM

Dr. Michel **GLASS** *Chairman of I-GOOS*
Directeur du Programme Géosphère-Biosphere
IFREMER
Technopolis 40
155, rue Jean-Jacques Rousseau
92138 Issy-les-Moulineaux Cédex
FRANCE
Tel: (33-1) 46482222
Fax: (33-1) 46482224
e-mail (Internet): michel.glassr@ifremer.fr

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

(To be Named)
Senior Assistant Secretary, IOC
Head, Marine Pollution Research
and Monitoring Unit
Intergovernmental Oceanographic Commission
UNESCO
1, rue Miollis
75732 Paris Cedex 15
FRANCE
Tel: (33-1) 45 68 39 92
Fax: (33-1) 40 56 93 126
e-mail (Internet): TBD

Mr. Arthur **ALEXIOU**
GOOS Support Office
(same address as above)
Tel: (33-1) 45 68 40 40
Fax: (33-1) 40 56 93 16
e-mail (Internet):a.alexiou@unesco.org

Dr. Rodger **DAWSON**
IOC/UNEP/UNU International Mussel Watch Project
University of Maryland
Chesapeake Biological Laboratory
P.O. Box 38
Solomons, MD 20688
USA
Tel: (1-410) 326-7394 (general -4281)
Fax: (1-410) 326-7210
e-mail (Internet): dawson@cbl.cees.edu

Dr. Manuwadi **HUNGSPREUGS** *(2nd Vice-Chairman, WESTPAC)*
Head, Dept. of Marine Science
Chulalongkorn University
Phya Thai Rd.
Bangkok 10330
Thailand
Tel: (66-2) 218-5409
Fax: (66-2) 255-0780/251-1951
e-mail (Internet): hmanuwad@netserv.chula.ac.th

Dr. Yihang **JIANG**
Acting Director
IOC Regional Secretariat for WESTPAC
196 Phaholyothin Rd.
Chatujak
Bangkok 10900
Thailand
Tel: (66-2) 561-5118
Fax: (66-2) 561-5119
e-mail (Internet): oijyh@chulkn.car.chula.ac.th

Dr. Jean-Paul **REBERT**
Acting Director, GOOS Support Office
Intergovernmental Oceanographic Commission
(same address as above)
Tel: (33-1) 45 68 40 42
Fax: (33-1) 40 56 93 16
e-mail (Internet):j.rebert@unesco.org

Dr. Su **JILAN** *(Chairman, WESTPAC)*
Second Institute of Oceanography
State Oceanic Administration (SOA)
Hangzhou, Zhejiang, 310012
China
Tel: (86-571) 884-0332
Fax: (86-571) 807-1539
e-mail (Internet): sujilr@bepc2.ihep.ac.cn

CORRESPONDING MEMBER

Dr. Paul **EPSTEIN**
Harvard Medical School
The Cambridge Hospital
1493 Cambridge St.
Cambridge, MA 02139
USA
Tel: (1-617) 498-1032
Fax: (1-617) 498-1671
e-mail (Internet):pepstein@igc.org

ANNEX II

LIST OF ACRONYMS

ASP	Amnesic Shellfish Poisoning
COMAR	Coastal marine Ecosystem Cooperative Programme (of UNESCO)
CRM	Certified Reference Material
DDT	Dichloro Diphenyl Trichloroethene
DNA	Deoxyribonucleic Acid
DSP	Diarrhetic Shellfish Poisoning
EROD	Ethoxyresorufin O-Deethylase
GCOS	Global Climate Observing System
GEEP	Group of Experts on the Effects of Pollution
GEMS	Global Environmental Monitoring System
GEMSI	Group of Experts on Methods, Standards and Intercalibration
GESAMP	Group of Experts on Scientific Aspects of Marine Environmental Protection
GIPME	Global Investigations of Pollution in the Marine Environment
GIS	Geographic Information system
GLOBEC	Global Ecosystem Dynamics
GLOSS	Global Sea-Level Observing System
GOOS	Global Ocean Observing System
HELCOM	Helsinki Commission
HOOP	Health of the Ocean Panel
HOTO	Health of the Ocean
IABO	international Association of Biological Oceanography
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
I-GOOS	Intergovernmental Committee for GOOS
IGOSS	Integrated Global Ocean Services System
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange
IUBS	International Union of Biological Science
JGOFS	Joint Global Ocean Flux Study
J-GOOS	Joint Scientific and Technical Committee for GOOS
LOICZ	Land-Ocean interactions in the Coastal Zone
MAPMOPP	Marine Pollution Monitoring Pilot Project
MARPOLMON	Marine Pollution Monitoring System
MDR	Multi-Drug Resistance
MESL	Marine Environmental Studies Laboratory
NSTF	North Sea Task Force
OCA/PAC	Oceans and Coastal Areas Programme Activity Center (of UNEP)
OSPAR	Oslo-Paris Commission on Environmental Pollution
PAH	Polycyclic Aromatic Hydrocarbons
PCR	Polymerase Chain Reaction
PSP	Paralytic Shellfish Poisoning
QA/QC	Quality Assurance/Quality Control
RM	Reference Material
ROV	Remotely Operated Vehicle
SeaWIFS	Sea-Viewing, Wide Field-of-view Sensor
SPM	Suspended Particulate Mater
TEMA	Training, Education and Mutual Assistance
TOGA	Tropical Ocean and Global Atmosphere
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
U-B	Ultraviolet Radiation-B

WESTPAC	Western Pacific (regional IOC body)
WMO	World Meteorological Organization of the United Nations
WOCE	World Ocean Circulation Experiment
WWW	World Weather Watch