Intergovernmental Oceanographic Commission
Workshop Report No. 80

PROGRAMME ON HARMFUL ALGAL BLOOMS

IOC-SCOR Workshop on Programme Development for Harmful Algal Blooms

Newport, Rhode Island, USA
2-3 November 1991

SC-92/WS-26

UNESCO

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1. EXECUTIVE SUMMARY

THE PROBLEM

Harmful algal blooms have occurred throughout recorded history, yet the public health and economic impacts of these phenomena have increased during the last several decades. This expansion relates in part to the increasing exploitation of coastal waters (due to waste disposal, aquaculture, maritime commerce and other anthropogenic influences), as well as to the dispersal and proliferation of algal populations associated with natural oceanographic and meteorological processes.

New species are being regularly added to the list of harmful phytoplankton, e.g. the discovery that several diatoms produce domoic acid, an excitatory amino acid, which can result in a variety of neurological disorders in humans, including memory loss and occasionally death. Other recent additions to the list of harmful events and causative species are marine fauna kills due to the silicoflagellate Dictyocha speculum and the prymnesiophyte *Chrysochromulina polylepis*.

At a number of recent international conferences and workshops, an important topic of discussion has been whether a global increase in the frequency, magnitude, and distribution of harmful blooms is occurring in coastal waters, perhaps as a result of mans' activities.

The understanding and prediction of, and management responses for, harmful algal blooms are major concerns throughout the world. The time is long overdue for an effort to coordinate and accelerate our efforts. The IOC-SCOR Workshop focused on developing an international programme and coordinating activities on harmful algal blooms.

THE PLAN

There are short-term, medium-term and long-term aspects to the problems arising from harmful algal blooms. The overall goal of the Harmful Algal Bloom Programme, as indicated below, embraces these three time scales as well as the range of related scientific and administrative problems:

To foster the effective management of, and scientific research on, Harmful Algal Blooms in order to understand their causes, predict their occurrences, and mitigate their effects.

There are two major divisions of the problem - scientific and operational. The scientific programme can be separated into three branches: ecology and oceanography; taxonomy and genetics; and toxicology and toxin chemistry. The operational problems can be divided into four branches: resource and aquaculture management; information network and training; monitoring; and public health and seafood safety. There are many interactions between the divisions, e.g. fisheries management questions benefit from knowledge of the ecology and dynamics of blooms; monitoring is based on information

about ecology, oceanography, taxonomy, and toxicity. The individual programme activities have specific goals as follows with the objectives identified in the body of the report.

Scientific Programme Elements

i) Ecology and Oceanography: to understand the population dynamics of harmful algae;
ii) Taxonomy and Genetics: to discriminate the causative organisms at the appropriate levels;
iii) Toxicology and Toxin Chemistry: to determine the physiological and biochemical mechanisnresponsible for toxin production and accumulation, and to evaluate the effect of phycotoxins on living organisms. Operational Programme Elements
iv) Resource and Aquaculture Management: to develop and improve methods to minimize the environmental and economic consequences of Harmful Algal Blooms;
v) Information, Network, and Training: to develop, maintain and co-ordinate a flow of information, technology and expertise to scientists and administrators;
vi) Monitoring: to assist and facilitate the development and implementation of appropriate monitoring programmes;
vii) Public Health and Seafood Safety: to protect public health and ensure seafood quality.

THE IMPLEMENTATION

IOC-FAO Ad hoc Intergovernmental Panel on Harmful Algal Blooms

Adequate resources are required to continue programme planning, to develop implementation plans, and to act. The IOC-FAO Ad hoc Intergovernmental Panel on Harmful Algal Blooms meets 23-25 June 1992 in Paris, France. The panel's terms of reference include reviewing the programme, promoting its implementation, and identifying the necessary resources. In the meantime, significant activities are in progress:

i) ICES Study Group to plan and propose a programme for investigating the dynamics of harmful algal blooms (IOC to co-sponsor);
ii) SCOR Working Group on the Physiological Ecology of Harmful Algal Blooms (ICES and IOC potential co-sponsors);
iii) IOC Newsletter on harmful algae;
iv) UNESCO Manual on Harmful Marine Phytoplankton (proposed with IOC, ICES, and SCOR as co sponsors);
v) International Directory of Experts on algal problems (IOC-UNESCO to publish in late 1992); vi) Discussion for the formation of an International Society on the problems of harmful algae. The IOC-FAO/OSLR Programme planning process has made a significant contribution to these activities.

2. FOREWORD

Harmful algal blooms have occurred throughout recorded history, yet the public health and economic impacts of these phenomena have been especially severe during the last several decades.

An important topic of discussion at a number of recent international conferences and workshops, has been whether a sustained global increase in the frequency, magnitude, and distribution of harmful blooms is occurring in coastal waters, perhaps as a result of mans' activities. Regardless of whether such an expansion is occurring, however, it is clear that the study and management of harmful algal bloom phenomena are major concerns throughout the world. The time is long overdue for an effort to coordinate, standardize, and accelerate these studies.

Algal blooms can take many forms, some of which have serious adverse effects due to the sheer abundance of the organisms or due to the production of toxins. Historically, this discipline originated with concerns about "red tides" in which the water was discolored by the great abundance of toxic and/or nontoxic microorganisms. Through time, the field has expanded to encompass a variety of toxic and noxious problems of large algal biomass as well as toxic algae in low concentrations which cannot be considered 'blooms'. The term ' harmful algal bloom' has thus evolved to represent a variety of phenomena and effects. As that title is well-recognized by the general public it will be used in thsi document in order to cover the multitude of problems with important societal implications.

The range of harmful effects and their economic costs has widened with increasing awareness, study, and with the growth of aquaculture. A useful review of causative species, the range of harmful effects, and their economic and public health impacts can be found in IOC Workshop Report No. 57 (Workshop on International Co-operation in the Study of Red Tides and Ocean Blooms, Takamatsu Japan, 16-17 November, 1987). Briefly, one way that blooms can affect human health is through the contamination of filter-feeding shellfish. This can result in: Paralytic Shellfish Poisoning (PSP); Neurotoxic Shellfish Poisoning (NSP); Diarrhetic Shellfish Poisoning (DSP); and Amnesic Shellfish Poisoning (ASP). Fish may be contaminated as well, causing Ciguatera Fish Poisoning (CFP). In addition, the viscera of clupeoid fish can contain PSP toxins, resulting in human illness or death following consumption of whole fish. Whales and porpoises can be victims as well, receiving toxins through the food chain via contaminated zooplankton or fish. The death and decay of masses of algae may lead to anoxia through decompositional oxygen demand, with consequent non-specific marine fauna mortalities.

New species are being regularly added to the list of harmful phytoplankton. The most recent was the discovery that several diatoms produce domoic acid, an excitatory amino acid, which can result in a variety of neurological disorders in humans, including memory loss and occasionally death. Other recent additions to the list of harmful events and causative species are marine fauna kills due to the silicoflagellate Dictyocha speculum and the prymnesiophyte Chrysochromulina polylepis.

Marine fauna may be poisoned by a variety of algal species that release toxins into the water. Problems associated with harmful algal species and farmed fish have expanded considerably in recent

years, due in part to the simultaneous expansion of the farming of salmonid fish (e.g., Norway, Scotland, Canada, Chile and New Zealand). Fish mortalities are due primarily to *Gymnodinium nagasakiense* (= *Gyrodinium aureolum*) in the North Sea region, and *Heterosigma akashiwo* in British Columbia, Chile and New Zealand. *Chattonella antique* is a major problem to fish farms in Japan. In addition, the diatoms *Chaetoceros convolutes* and *C. concavicornis* can kill through physical damage to gills. Many aquaculture operations are economically marginal at present, so losses due to fish mortalities during harmful blooms threaten to destroy this fledgling industry in certain regions. Research, both fundamental and regional, is urgently needed to assist the industry in coping with these problems.

There is no doubt that a spreading of harmful bloom species into new areas has occurred. For example, the PSP problems along the northeast coast of America or within the Indo-West Pacific clearly represent expansions of the geographic ranges of the causative species from nearby areas with prior histories of shellfish toxicity. Many natural mechanisms can be implicated in this type of dispersal, including transport of cells and dormant stages by storms and currents. In addition, dispersal by means of ship ballast water discharge or the introduction of contaminated fish or shellfish stock have been proposed as potentially important human activities which can serve as spreading mechanisms. It is difficult, however, to gauge the significance of man's accidental introductions relative to the natural processes of species dispersal through time. The biogeographic distribution of many of the phytoplankton classes involved in harmful algal blooms can be described as modified latitudinal cosmopolitanism, meaning that the same species (or morpho-species) generally occur throughout the world within certain latitudinal limits. Attempts to explain the sudden abundance of a species in a region where it had not been observed before must consider the possibility that the introduction of that species may have occurred naturally in the distant past and that its sudden appearance and proliferation could as easily be due to changes in environmental conditions that favor its growth. Nevertheless, the documentation of vast quantities of viable, dormant cysts of certain harmful species in ballast water of international cargo vessels demonstrates the potential for man-related species dispersal.

In some regions, such as the Inland Sea of Japan or Tolo Harbor in Hong Kong, there has been a clear upward trend in the annual frequency and/or magnitude of algal blooms. The heightened bloom activity has closely paralleled deterioration in water quality due to increased concentrations of essential phytoplankton nutrients such as nitrogen or phosphorus. However, to extrapolate these regional patterns to the general conclusion that there is currently a global expansion of harmful blooms is tenuous at present. Suitable quantitative data sets providing good regional coverage of all parameters relevant to harmful algal bloom phenomena are lacking, and the wide diversity of species and types of harmful effects make it difficult to compile a "total" for yearly comparisons. However, the limited data available are provocative, especially those that document long-term shifts in the phytoplankton community composition towards groups that include higher proportions of harmful species, such as in Helgoland or Narragansett Bay. Resolution of whether such bloom events are a reflection of a global expansion is a major challenge requiring both monitoring and experimental study.

In the short term the emphasis must be on mitigating effects of harmful algal events. In the medium term, the focus will be on understanding, modelling and prediction, with the eventual long-term focus of preventing or eliminating the problems.

3. ROLE OF THE WORKSHOP

The Workshop's goal was to complete the broad outline of an International Programme of sufficient scope and vision to deal with the serious and growing problem of Harmful Algal Blooms. The next steps will be to refine the programme plan and to prepare an implementation plan. As the implementation will be through a combination of national and international Programmes, the implementation plan must be developed in conjunction with national representatives who can identify national priorities and commit the necessary resources. The specific objectives for the Workshop were:

i) to identify the goals of the programme,
ii) to prepare an outline for the plan of the programme,
iii) to identify goals and objectives for the individual elements of the plan which can be refined at a later date, and iv) to identify the specific, immediate actions that can/should be taken in the near term.

Location and Timing of the Workshop

The Workshop was held in Newport, Rhode Island, USA on the 2nd and 3rd of November 1991, following the Fifth International Conference on Toxic Marine Phytoplankton. This IOC-SCOR Workshop was the third in a series designed to develop a programme on Harmful Algal Blooms (HAB). It follows the IOC Workshop on International Co-operation in the Study of Red Tides and Ocean, Takamatsu Japan, 1617 November 1987; and the Ad hoc Group of Experts on Red Tides in Paris, France, 5-9 February 1990. The agenda, circulated before the meeting, is included as Annex I.

Sponsoring Organizations

The meeting was jointly sponsored by the Intergovernmental Oceanographic Commission (IOC) and the Scientific Committee on Oceanic Research (SCOR). The meeting chairman was Prof. Robert Fournier, Secretary of SCOR. The IOC was represented by Prof. Thomas Osborn, Assistant Senior Secretary for Ocean Sciences in Relation to Living Resources, and Mr. Henrik Enevoldsen from the Harmful Algal Bloom sub-programme. Participants are listed in Annex II.

The IOC is responding to an identified need of its Member States to have a programme to assist them in dealing with noxious algal blooms. Annex lII shows the programme development and authorization history inside the IOC-FAO programme on Ocean Sciences in relation to Living Resources (OSLR). SCOR is responding to concerns of its members and to a motion brought forward at its XXth SCOR General Meeting, 1-3 October 1990, Rostock-Warnemünde Germany, to have a working group on the "Physiological ecology of atypical algal blooms." The International Council for the Exploration of the Sea (ICES) has also been active for several years in researching the problem. Documents from several member countries of ICES and IOC were available at the meeting. There are many national Programmes for approaching various aspects of the problem. An international community of active scientists has been responsible for an extensive series of international symposia, of which the Fifth was held in Newport just prior to the IOC-SCOR meeting. These international symposia are well attended (325 persons at Newport) with the proceedings published as books which form major reference volumes in the field.

4. Goals of the Programme

There was considerable discussion about the goals of the programme, realizing that there are shortterm, medium-term and long-term aspects to the problems arising from harmful algal blooms. The overall goal of the programme, as indicated below, embraces these three time scales as well as the range of scientific and administrative problems:

To foster the effective management of, and scientific research on, Harmful Algal Blooms in order to understand their causes, predict their occurrences, and mitigate their effects.

The goal of the programme is to encompass the different aspects of the entire problem in order to ensure as complete a treatment as possible. Although the goal may well exceed the mandates of potential participating organizations, it should not limit their involvement. Rather, it is designed to show that a complete treatment requires the participation of many varied organizations - national, regional and international - both governmental and non-governmental. The IOC is concerned with, and responsible for, the intergovernmental and scientific aspects of international activities. SCOR is concerned with fostering international scientific cooperation. Many organizations will be involved in different capacities and at differing levels in the overall programme.

5. Outline of the Programme

The programme outlined herein is based upon discussions at the Workshop, previous IOC reports from the Takamatsu and Paris meetings, as well as the experiences of several members in developing national Programmes to deal with harmful algae. There are two major elements of the problem: scientific and operational. The plan must cover both aspects since they are highly interrelated. Completeness of the programme is fundamental at this stage to show where the different interests fit in the global problem and to show how the operational and scientific Programmes interact.

The scientific programme can be separated into three branches: ecology and oceanography; taxonomy and genetics; and toxicology and toxin chemistry. The operational problems can be divided into four branches: resource and aquaculture management; information network and training; monitoring; and public health and seafood safety (FIGURE 1). Obviously there are many interactions among the divisions in the figure, e.g. fisheries management questions benefit from knowledge of the ecology and dynamics of blooms; monitoring is based on information about ecology, oceanography, taxonomy, and toxicity; the information network receives and disburses information from all the other programme elements.

Decisions about which portions of the programme are funded, and at what level, by different organizations will determine the rate at which progress is made on the various programme components. A complete programme can be designed and the international community can then gather support for the aspects that can be initiated immediately, subsequently seeking further resources for the remainder.

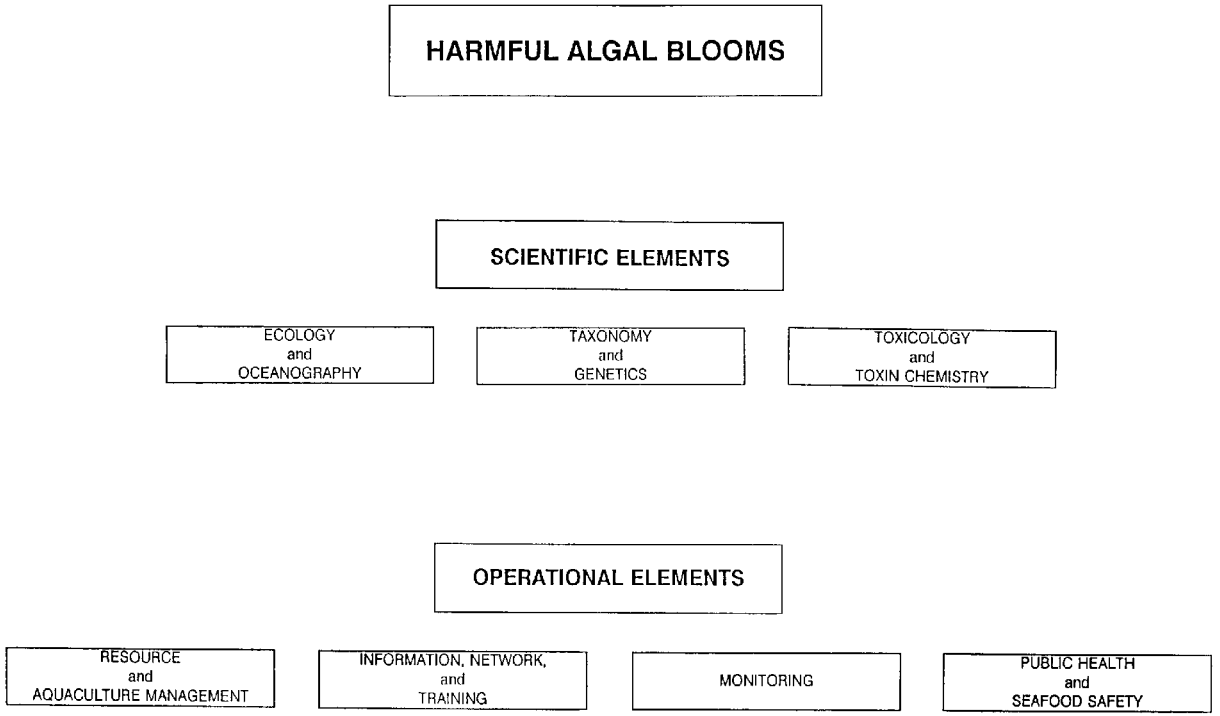

HARMFUL ALGAL BLOOMS
SCIENTIFIC ELEMENTS
ECOLOGY and OCEANOGRAPHY
TAXONOMY and GENETICS
TOXICOLOGY and TOXIN CHEMISTRY
OPERATIONAL ELEMENTS
RESOURCE and AQUACULTURE MANAGEMENT
INFORMATION, NETWORK, and TRAINING
MONITORING
PUBLIC HEALTH and SEAFOOD SAFETY

FIGURE 1

6. Goals and Objectives of the Programme Elements

Specific objectives for each programme element were developed after discussion at the present Workshop and from previous OSLR programme documents. Scientific programme elements were discussed in subgroups (Annex IV), with further discussion in plenary session. The operational elements were discussed in plenary session only. In addition to the discussion at the Workshop, ideas from many substantive documents, available on various portions of the scientific and managerial problems, are incorporated into the programme objectives. A bibliography appears at the end of the report.

6.1 SCIENTIFIC PROGRAMME ELEMENTS

6.1.1 Ecology and Oceanography

Goal: To understand the population dynamics of harmful algae.

Justification: The ability to predict or mitigate harmful events requires detailed understanding of all processes affecting population dynamics.

Objectives:

i) Develop the necessary understanding of bloom dynamics of harmful algae, which includes the phases of bloom progression (excystment or bloom initiation, exponential growth, aggregation, toxicity, as well as death, encystment or dispersal), and the succession of phytoplankton species.

ii) Determine the role of nutrients with respect to harmful algal events in areas subject to coastal enrichment.

iii) Elucidate the importance of human activities in the dispersal of certain harmful species (e.g. via ship ballast water; transfer of shellfish stock).

iv) Derive quantitative relationships among the biological, physical, and chemical parameters with respect to the bloom-forming species which can be used in a local management context through predictive models and management strategies.

v) Determine the ecological role of toxicity in the population dynamics of toxic species and the consequences of toxicity to living resources.

vi) Design appropriate experimental and field studies to develop the required understanding of the hydrography, ecology and oceanographic conditions controlling population dynamics.

vii) Develop models (and eventually reliable predictions) of toxic blooms based on the unique hydrography, chemistry, and plankton composition determined by regional research Programmes.

6.1.2. Taxonomy and Genetics

Goal: To establish the taxonomy and genetics of the causative organisms at the appropriate levels.

Justification: Research and management are suffering from the lack of reliable taxonomic and genetic understanding and information.

Objectives:

i) Develop and maintain the capability to recognize, characterize and identify harmful species in order to:
   - establish the morphological criteria needed to distinguish species and strains of harmful species from each other and from morphologically-similar harmless species; facilitate environmental monitoring;
   – conduct life cycle studies for those species where such information is lacking; and study ultrastructural and phenotypic variability.

ii) Establish a committee to make taxonomic recommendations and to develop identification standards to:

   – resolve taxonomic problems;
   – prepare manuals and reference materials, such as slides, videotapes, and other instructional material;
   – provide verification (by circulation of samples);
   – guarantee nomenclature standardization; and
   – establish training standards.

iii) Determine the genetic heterogeneity within species, populations and isolates with respect to mating compatibility and biochemical and molecular characteristics, such as:
   – general physiology;
   – pigments and sterols;
   – toxin composition;
   – viral relationships;
   – RNA, DNA sequences; and
   – cell surface antigens.

iv) Support existing, establish new regional culture collections specializing in harmful species, and create a centralized international culture collection of harmful species to provide:
   – research and reference material;
   – new isolates; and
   – training.

v) Promote the development of new, rapid, automated identification, discrimination and counting techniques such as:
   – image analysis, including computerized interactive taxonomic identification systems;
   – flow cytometry; and
   – immunolabelling for molecular and identification purposes.

vi) Encourage and enable the development of computerized taxonomic data bases of harmful species.

6.1.3. Toxicology and Toxin Chemistry

Goal: To determine the physiological and biochemical mechanisms responsible for toxin production and accumulation, and to evaluate the effect of phycotoxins on living organisms.

Justification: Detailed knowledge of toxin production and accumulation as well as the chemical and pharmacological properties of toxic metabolites is required to design effective strategies for human health protection and marine resource management.

Objectives:
With respect to physiology:

i) Determine the physiological mechanisms underlying variable toxicity among strains of species or within single strains grown under different conditions.

ii) Define the toxin accumulation and deputation processes in contaminated seafood.

iii) Determine chemical conversions of toxins within tissues of contaminated seafood.

iv) Define the role of endo- or exocellular bacteria and viruses in the production of toxins.

v) Establish the biosynthetic pathways of toxin production in algae.

vi) Determine the processes associated with toxin degradation.

With respect to chemistry:

vii) Isolate, identify and/or elucidate the structure of toxins.

viii) Prepare and supply toxin standards.

ix) Develop new chemical analytical methods for toxins, specifically:
    1. alternative assay methods to replace such tests as mouse and other bioassay organisms, while improving the sensitivity, specificity, and reproducibility of all methods; and
    2. simple field assay kits.

x) Prepare a technical manual on methods for toxin analysis (with a clear indication of where each method is appropriate, where there are potential pitfalls for each technique, etc.), and a list of chemistry experts for each of the various toxins.

With respect to toxicology:

xi) Define the fate of algal toxins in the marine food web.

xii) Elucidate mechanisms of toxicity to marine animals.

xiii) Establish and recommend quarantine levels.

xiv) Establish pathological indicators to determine toxins responsible for mortalities and other impacts.

xv) Develop antidotes against seafood toxins.

6.2 OPERATIONAL PROGRAMME ELEMENTS

6.2.1. Resource and Aquaculture Management

Goal: To develop and improve methods to minimize the environmental and economic consequences of Harmful Algal Blooms.

Objectives:
i) Assist managers in designing, evaluating and improving cost-effective procedures for selecting and protecting aquaculture sites; applying methods for early warning of toxicity; and developing management strategies.
ii) Assist managers in applying scientific results as quickly and effectively as possible to resolve management, mitigation, public safety, public education, and public relations problems.

6.2.2. Information Network and Training

Goal: To develop, encourage, and maintain the flow of information, technology and expertise to scientists and administrators.

Objectives:
With respect to information network:
i) Produce a regular newsletter for reporting bloom occurrences, recent publications, meetings, new techniques, requests for assistance, and general information.

ii) Prepare and publish a manual containing standardized methodology for the study of harmful algae (this book could be modelled after the Unesco Phytoplankton Manual).

iii) Prepare identification sheets and reference slides for harmful species, preserved material, and video documentation, updated as necessary.

iv) Compile lists of experts grouped according to areas of expertise, updated as necessary.

v) Ensure rapid communication of new problem species, methodologies, and other common information to researchers, administrators, and doctors.

vi) Ensure the development and distribution of appropriate medical information sheets.

vii) Facilitate worldwide distribution of reference books, conference proceedings, and equipment.

With respect to training:

viii) Facilitate workshops and training programmes on taxonomy, ecology, toxin extraction and analysis, management strategies, public health and safety, and mitigation techniques. ix) Ensure access to equipment grants and extensive training of selected individuals in regions that lack adequate facilities and properly trained personnel for toxin analysis.

6.2.3. Monitoring

Goal: To assist and facilitate the development and implementation of appropriate monitoring programmes.

Objectives:

i) Provide a source of information and guidance on design and implementation of monitoring programmes.

ii) Interact with regional, national and international monitoring plans and programmes to:
- identify long-term trends in the frequency of harmful algal blooms;
- identify cyclical patterns in shellfish toxicity as a result of climatic or Hydrographic features;
- delineate trends associated with coastal enrichment due to domestic and agro-industrial chemical discharges;
- identify sources and rates of macronutrient inputs including riverine, ground-water, and atmospheric; and
- ensure standardization of data and archiving methods for harmful algal events.

iii) Encourage analysis of sediments, especially from anoxic basins, that can provide evidence (cysts, frustules, etc.) for the prior occurrence of harmful species in regions where recent introductions are suspected.

iv) Ensure the compatibility (e.g. techniques, type of data collected) of plankton and toxin monitoring programmes with basic studies of algal bloom dynamics and ecology.

6.2.4. Public Health and Seafood Safety

Goal: To protect public health and ensure seafood quality.

Objectives:

i) Facilitate monitoring for toxic species and seafood toxins.

ii) Encourage standardization of methods for toxin detection and levels for market closure.

iii) Facilitate testing of techniques for the mitigation of noxious blooms: (e.g. forced sedimentation, aeration, sea surface scum collection).

iv) Where appropriate, assist with regulatory measures to reduce nutrient input.

v) Facilitate and encourage public education on both prevention and treatment of fish/shellfish poisonings through literature such as first aid manuals.

vi) Facilitate more rapid and accurate information transfer to researchers, administrators, and doctors involved in harmful algal phenomena.

vii) Prepare, distribute, and maintain fact sheets on toxins for the medical community.

7. Implementation

7.1 IOC-FAO Ad hoc Intergovernmental Panel on Harmful Algal Blooms

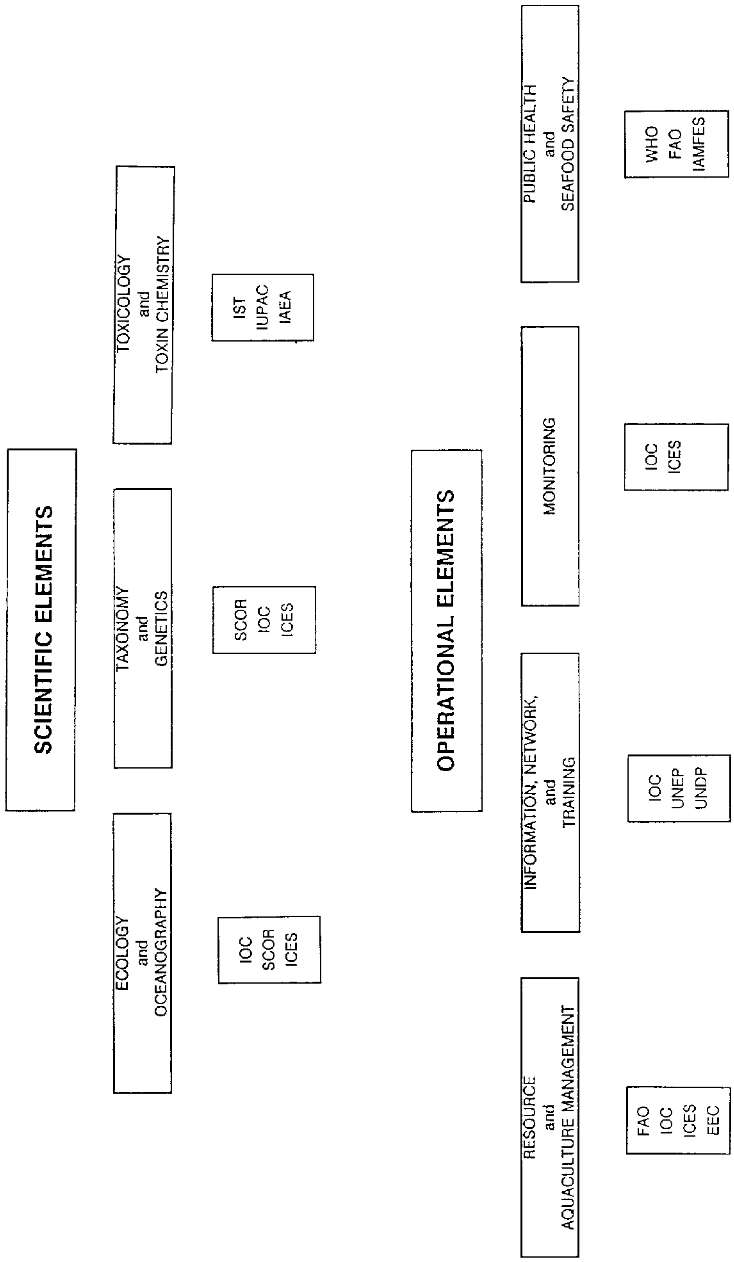
Adequate resources are required to continue programme planning, to develop implementation plans, and to institute the programme. The IOC-FAO Ad hoc Intergovernmental Panel on Harmful Algal Blooms first meeting in Paris, France, 23-25 June 1992, is charged with reviewing and identifying programme requirements, promoting implementation, and identifying the necessary resources (see Annex lil). A further programme planning meeting will be held 10-11 April in Vigo, Spain specifically to prepare material for consideration by the Intergovernmental Panel.

Activities in Progress

As noted earlier, the goal of the Workshop was to design a programme and not to prepare an implementation plan. However, some activities are occurring that naturally fall. into the implementation category and it is worth cataloging these. Given the magnitude and diversity of problems arising from harmful algae, many organizations are naturally involved. These different groups operate in numerous geographical and technical areas and their actions are complimentary. The programme as outlined in FIGURE 1 can be related to different international organizations as shown in a preliminary fashion in FIGURE 2.

7.2. ICES Study Group on Plankton Dynamics

A Study Group on the 'Dynamics of Algal Blooms' was authorized (Annex V), at the 79th statutory meeting of ICES, in La Rochelle, France, October 1991, under the chairmanship of Ms. B. Reguera (Spain) and will meet in Vigo, Spain 7-9 April 1992 to plan and propose a programme for investigating the dynamics of harmful algal blooms in the coastal environment. IOC was asked to co-sponsor this Study Group. This Study Group addresses the first objective in the Ecology and Oceanography portion of the programme outline. ICES as an organization is uniquely qualified to take the lead in this aspect of the work. It represents many of the developed countries most concerned with the problem and that possess, in conjunction with Japan, the necessary technology to perform the experiments and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IOC UNEP UNDP
MONITORING
IOC ICES
PUBLIC HEALTH and SEAFOOD SAFETY
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FIGURE 2

observations. This work is a major aspect of the scientific programme that can only be approached with a coordinated international programme. Documentation by previous ICES groups is listed in the bibliography.

7.3. SCOR Working Group on the Physiological Ecology of Harmful Algal Blooms

SCOR established a Working Group, at the SCOR Executive Council meeting 12-14 November 1991, in Hamilton New Zealand, to examine the historical data on the physiological ecology of harmful blooms (Annex VI). The terms of reference are:

1. To review and analyze data on the physiological ecology and biochemical aspects of harmful algal blooms, especially those resulting in toxic episodes and paying particular attention to nutritional, environmental and physiological factors.
2. To assemble within two years the Working Groups findings and submit for publication a report, summarizing the state of knowledge and identifying the areas of future research

This activity reinforces the discussion in Newport on the need for a review of the historical data with respect to the ecology and physiology of blooms and will perform that review on a timely basis with a group of international experts. It offers the background support for the ICES Study Group described above, using the strength of SCOR's operating technique of appointing Working Groups on well-focused, significant problems and giving them a finite time to achieve their objectives. ICES and IOC are being asked to co-sponsor this Working Group.

7.4 IOC Secretariat Actions

The workshop participants agreed that in addition to continuing the planning process, the IOC could contribute substantially by operating a newsletter, supporting the continued publication of a directory of experts for harmful algae, publishing a manual on harmful algae, and developing support for a permanent secretariat for the programme.

7.4. 1. Newsletter

HARMFUL ALGAE NEWS

An IOC newsletter on toxic algae and algal blooms

The IOC is publishing a "newsletter" on Harmful Algal blooms. The initial issues will be incorporated into the quarterly International Marine Sciences (IMS) Newsletter which has a distribution of 6000 copies. An additional 1500 copies will be sent to persons on the mailing list for the Fifth International Conference on Toxic Marine Phytoplankton who are not on the present IMS mailing list. Tim Wyatt volunteered at Newport, and IOC has requested him to be responsible for the first two editions. An editorial committee should be formed by the ad hoc steering committee to support his efforts and to review the situation in the fall of 1992. The first issue will be in early 1992.

7.4.2. Phytoplankton Manual

The suggestion by Gustaaf Hallegraeff for a manual on harmful phytoplankton species was favorably received and pending some minor administrative agreements on editorial committee, format, etc. will proceed quickly. To date, the UNESCO Monographs on Oceanographic Methodology have been produced/coordinated/edited by working groups. In this case, an editorial steering group with an editor could be co-sponsored by IOC, SCOR and ICES. The IOC will coordinate the formal establishment of the editorial group and the sponsorship with SCOR and ICES. In the past the monographs have been freely distributed to official institutions in developing countries.

7.4.3. Directory

An updated international directory of experts and interested parties will be published from IOCUNESCO, and will continue to be edited by Alan White. It seems appropriate to plan for 2000 copies of approximately 400 pages which will contain information on 800 individuals. This new book will represent a substantial expansion from the previous directory of White (1990).

7.4.4. Ad hoc Planning Committee

Suggestions were accepted for membership on an ad hoc planning committee to review the Workshop report and to sustain activities pending more complete establishment of the programme activities. A complete list of those names proffered is: Donald ANDERSON, Alan CEMBELLA, Einar DAHL, Yasuwo FUKUYO, Gustaaf HALLEGRAEFF, Ivona MARASOVIC, Theodore SMAYDA, Max TAYLOR, Alan WHITE, and Timothy WYATT. These people will be called upon to assist with the initial stages of the programme development.

7.5. International Society

Long-Term Overall Programme Guidance

The scientific and managerial community has been active in organizing the International Conferences on Toxic Marine Phytoplankton. While there is no international society, the work has been accomplished on an informal basis across a wide range of disciplines. The Fifth International Conference in Newport from 28 October to 1 November had 325 participants from 44 countries with 80 papers and 139 posters presented in the 5 days.

It would now be appropriate to form an international society that would be independent of any one country, but attached to an international body such as the International Council of Scientific Unions (ICSU). This society would provide a formal organization from which to draw programmatic input and expert representation on technical matters. The scientific community has been functioning on an informal basis as a multi-disciplinary society. Witness the increasing frequency of the international meetings, which are also growing in attendance:

Bates, S.S., Worms, J., eds, 1989. Proceedings of the First Canadian Workshop on Harmful Algae, Fisheries Centre, Moncton, N.B., September 27-28, 1989. Canadian Technical Report of Fish and Aquatic Sciences No. 1712.

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ANNEX I

AGENDA

1.0 Opening

2.0 Administrative arrangements

3.0 Review of objectives of the meeting
- 3.1 Establishment and support of a long-term international programme
- 3.2 Outline of IOC-SCOR organizations and their role in an international programme
- 3.3 Identification of the specific output (i.e. document) of the meeting

4.0 Discussion of the potential programme outline
- 4.1 Discussion on outline of programme
- 4.2 Identification of deficiencies

5.0 Discussion of the elements of the accepted programme outline
- 5.1 Scientific
  - a. ecology
  - b. taxonomy
  - c. toxin chemistry/pharmacology
  - d. other sections?
- 5.2 Operational
  - a. resource and aquaculture management
  - b. information network and training
  - c. monitoring
  - d. other sections

6.0 Identification of sub-groups to prepare portions of the document

7.0 Discussion and writing in small groups

8.0 Corporate discussion of the document portions prepared in point 7.0
- -is the document correct?
- -is the document complete?
- -what are the appropriate groups to work on the portions to delineate as completely as possible?

9.0 Discussion of concrete steps to be given high priority

10.0 Discussion of establishing a steering group

11.0 Timetable for future activities

ANNEX II

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ANNEX III

PROGRAMME AUTHORIZATION

In view of the global interest in problems of phytoplankton blooms, red tides and associated mass mortality of marine organisms expressed through various recommendations of major IOC scientific and regional subsidiary bodies, the XIV Session of the IOC Assembly, Paris, 17 March - 1st April 1987, endorsed the development of a new sub-programme on phytoplankton blooms, red tides and associated mass mortality of marine organisms, as a second major thrust of joint IOC-FAO Ocean Sciences in relation to Living Resources (OSLR) Programme in addition to the International Recruitment Project (IREP).

I. INITIATION

On its Second Session, the IOC-FAO Guiding Group of Experts on OSLR, Rome, 8-12 June 1987, agreed that a sub-programme on Red Tides and Ocean Blooms should be included within OSLR and recommended widening the expertise of the Guiding Group to cover red tides and related toxic and anoxic phenomena.

IOC-FAO Guiding Group
of Experts on the Programme of Ocean Science
in Relation to Living Resources

SECOND SESSION ROME, 8-12 JUNE 1987

3.2 PHYTOPLANKTON BLOOMS, RED TIDES AND ASSOCIATED MASS MORTALITY ORGANISMS.

3.2.2 The Guiding Group recognized the importance of red tide phenomena and oceans blooms, in particular in connection with mass mortality of marine organisms, affecting natural populations and cultures.

The Guiding Group agreed that a special Sub-Programme on red tides and ocean blooms should be included within OSLR at the same level as the ongoing IREP.

II. FIRST ACTION BY EXECUTIVE COUNCIL AT ITS 21ST MEETING

Following the International Symposium on Red Tides-Biology, Environmental Science and Toxicology, Takamatsu, Japan, 10-14 November 1987, the IOC Workshop on International Co-operation

in the Study of Red Tides and Ocean Blooms, Takamatsu, 16-17 November 1987, reviewed the global occurrences and studies of plankton blooms and proposed components for a global programme on ocean blooms and red tides.

The XXI Session of the IOC Executive Council, Paris, 7-15 March 1988, welcomed the progress made in developing Red Tides and Ocean Blooms as a new sub-programme of OSLR and the relationships with relevant elements of the GIPME Programme and recommended appropriate interaction between OSLR and GIPME.

III. PROGRAMME DELINEATION AND ACCEPTANCE BY 23RD EXECUTIVE COUNCIL

From January 31 to February 2, 1990 an IOC-FAO OSLR sponsored a meeting of an Ad hoc Group of Experts on Harmful Algal Blooms in Paris. The recommendations were endorsed by the OSLR Guiding Group of Experts and forwarded to the XXIII Session of the Executive Council, which also endorsed (Resolution EC-XX111.1) the recommendations.

TWENTY-THIRD SESSION OF THE EXECUTIVE COUNCIL
Paris, 7-14 March 1990

The Executive council adopted Resolution EC-XX111.1
Resolution EC-XXIII.1

OCEAN SCIENCE IN RELATION TO LIVING RESOURCES (OSLR)

The Executive Council,

A. General

Having received with appreciation the presentation on the activities of the joint IOC-FAO OSLR programme, over the last twelve months,

Having considered the Executive Summary and Recommendations of the Third Session of the IOC-FAO Guiding Group of Experts on OSLR, including the Recommendations of the ad hoc Group of Experts on Harmful Algal Blooms,

Recognizes the considerable progress achieved in the implementation of OSLR;

Accepts the Executive Summary of the Third Session of the Guiding Group of Experts and approves the Recommendations thereof, subject to the observations made below;

Urges Member States and interested organizations to take up specific OSLR projects in different regions;

C. Algal Blooms and Related Processes

Being aware of the increasing concern over algal blooms, especially those that are harmful to man, fishery resources or other marine organisms, and the understanding of their socio-economic impacts,

Endorses the Recommendations of the ad hoc Group of Experts on Harmful Algal Blooms, which were also endorsed by the Guiding Group of Experts (Recommendations OSLR-111.7);

Agrees that this Sub-Programme on Algal Blooms and Related Processes focus initially on taxonomy, ecology and toxicology

IV. ACTION BY THE XVITH IOC ASSEMBLY

The XVlth Session of the IOC Assembly, Paris 7 to 21 March 1991, adopted the following resolution with respect to the formation of an Ad hoc Intergovernmental Panel on Harmful Algal Blooms in order to identify adequate resources for a sufficiently broad programme to solve some of the real problems caused by algal blooms.

Resolution XVI-4 of the IOC Assembly

AD HOC INTERGOVERNMENTAL PANEL ON HARMFUL ALGAL BLOOMS

The Intergovernmental Oceanographic Commission,

Recalling that the IOC, at the Fourteenth Session of its Assembly, endorsed the development of the subprogramme on Harmful Algal Blooms, and that the Twenty-third Executive Council, through its Resolution EC-XX111.1, endorsed the programme development so far,

Being aware of the increasing socio-economic risks posed by toxic algae and harmful algal blooms to marine organisms, fisheries, aquaculture, human health and the coastal environment,

Approves the formation of an Ad hoc Intergovernmental Panel on Harmful Algal Blooms, with the Terms of Reference shown in the Annex hereto;

Invites FAO to co-sponsor the Ad hoc Panel;

Invites Member States which intend to be involved in the implementation of a programme on Harmful Algal Blooms to nominate their representatives for the Ad hoc Panel and inform the Secretary IOC accordingly;

Decides to review, at the Seventeenth Session of the Assembly, the Terms of Reference of the Ad hoc Panel, in conjunction with the Commission's review of the overall organization of the OSLR Programme;

Instructs the Secretary to convene the First Session of the Ad hoc Panel as soon as possible.

Annex to Resolution XVI-4
Terms of Reference
of the Ad hoc Intergovernmental Panel on Harmful Algal Blooms

1. FUNCTIONS

The Ad hoc Intergovernmental Panel on Harmful Algal Blooms is established to meet the scientific, managerial, implementation, and resource needs of the Harmful Algal Blooms Programme.

The Panel will carry out the following functions:

1.1 Review and identify programme requirements;

1.2 Promote efficient and cost-effective implementation of the HAB programme and prepare recommendations on this implementation to the Assembly and Executive Council;

1.3 Identify the resources necessary to meet HAB programme needs;

1.4 Ensure effective interaction and communication with regional intergovernmental (e.g., ICES, ICSEM and GFCM) as well as regional and global non-governmental (e.g., SCOR) organizations involved in research on toxic algae and harmful algal blooms; and

1.5 Report to the Twenty-fifth Session of the Executive Council and the Seventeenth Session of the Assembly.

2 COMPOSITION

The membership of the Ad hoc Panel is open to Member States of IOC (and FAO, if it agrees to co-sponsor the Panel) which have declared to the Secretary IOC their involvement or intention to participate in the development and implementation of the Harmful Algal Bloom Programme on a global, regional, or national scale. The Panel shall include the Chairman of the OSLR Guiding Group of Experts, representatives of IOC regional and other subsidiary bodies, and of other interested international organizations, particularly SCOR. Invitations to participate in Panel activities may be extended to scientific experts at the request of the Panel and with the approval of the Secretary of the IOC.

3. ORGANIZATION OF THE SESSIONS

The Panel will, prior to the closure of each Session, elect from its members a Chairman who will serve in that capacity until the closure of the next Session. The Sessions shall, in principle, be arranged without financial costs to IOC. Sessions will be conducted, documentation will be provided, and the report of each session will be prepared in English and in other working languages of the Commission as appropriate and required. Secretariat support for the Panel will be provided by the Secretary IOC.

ANNEX IV

SUBGROUPS FOR THE DEVELOPMENT OF PROGRAMME ELEMENTS

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REGUERA, Beatriz
WYATT, Timothy

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FUKUYO, Yasuwo
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ANNEX V

ICES STUDY GROUP ON THE DYNAMICS OF ALGAL BLOOMS

Resolution 2:36 adopted at the 79th statutory meeting of ICES - La Rochelle, France - October 1991:

"A Study Group on the Dynamics of Algal Blooms will be established under the chairmanship of Ms B. Reguera (Spain) and will meet in Vigo, Spain for three days in February 1992[1] to plan and propose a programme for investigating the dynamics of harmful algal blooms in the coastal ocean. IOC will be asked to co-sponsor this Study Group."

Justification:

This Study Group is considered necessary in view of the importance and urgency regarding the problem of harmful algal species, and the fundamental necessity of clarifying their dynamics and development in order to understand and predict timing, location, intensity, and detrimental effects. IOC co-sponsorship is required in order to ensure close collaboration with the IOC (OSLR) programme on Harmful Algal Blooms.

[1] The dates were later changed to 7-9 April 1992.

ANNEX VI

SCOR WORKING GROUP ON PHYSIOLOGICAL ECOLOGY

SCOR has established a Working Group which is potentially co-sponsored by ICES and IOC. After the 30th SCOR Executive Meeting in Hamilton, New Zealand the revised title and terms of reference are as follows:

Title:

1. Physiological ecology of harmful algal blooms.

Preamble:

2. The problem of toxin-producing and otherwise harmful algae has become a world-wide phenomenon, reaching a scale which is now of major concern to both cultured and wild fisheries, and to human health. There is a need to consider the occurrences more comprehensively than at present, in the context of a large-scale environmental/biological/fisheries issue.

Marine phycotoxins are naturally-occurring toxic molecules produced by certain marine algae (primarily unicellular phytoplankton and benthic/epithytic algae). In some cases, bacteria may also be implicated. Phycotoxin production is often, but not always, associated with phytoplankton blooms. Bivalve molluscs initially concentrate the toxins by feeding on the phytoplankton. Consumers of shellfish, including humans, can then be poisoned by the accumulated toxin(s). Herring and mackerel have also been known to be affected, presumably by ingesting zooplankton in areas of toxin blooms.

Recently, the problems have not only increased, but have changed somewhat in nature by threatening the very survival of the finfish aquaculture industry in certain parts of the world. In 1988, the Chrysochromulina polylepis bloom in the North Sea, starting on the western coast of Sweden and continuing along the coast of Norway, caused extensive mortalities among natural benthic populations and a number of cage culture farms, fortunately stopping its spread before reaching the area of major concentrations of Norwegian salmon farms. The physical impacts of this major bloom were compounded by the presence of one or several toxic factors (membrane toxins similar to those from Prymnesium parvum). In 1989, a bloom of the toxin-producing Prymnesium parvum in Norway affected fish in brackish water. The same year, toxic blooms of Heterosigma akashiwo in British Columbia, coupled with non-toxic Chaetoceros convolutes and C. concavicornis blooms (phytoplankton with very long setae-like appendages which cause abrasion to gills and their clogging), resulted in extensive losses of cultured fish. Heterosigma blooms recurred in 1990, while an unprecedented non-toxic bloom of Gonyeulax spinifera (about 400 x 100 km in extent) mixed with other species was responsible for substantial shellfish mortality on the western coast of Vancouver Island.

A new development of major importance was the detection of Paralytic Shellfish Poisoning (PSP) toxins in crustaceans in both Europe and the eastern coast of North America. In 1990, the first PSP outbreak for many years in Britain affected several shellfish species. It resulted in the prohibition of the

sale of crabs to Spain. Queen scallops in Scottish inshore waters were also affected and that fishery was closed.

Lobsters from the Bay of Fundy and Quebec Region were shown to have detectable levels of PSP toxins in their hepatopancreatic tissues. Although none of these levels in the Department of Fisheries and Oceans (DFO) Inspection survey of all four Atlantic DFO Regions were above permissible limits, the presence of PSP toxins in lobsters is of serious concern to both regulators and investigators.

On the Pacific coast of Canada, significant amounts of PSP toxins were found in the abductor muscles of rock scallops. This finding and comparable data for the queen scallops in Britain introduces an extremely important new negative factor into the molluscan fishery. On the basis of tests carried out on the east coast giant scallop Placopecten magellanicus, it has generally been assumed that the abductor muscle of all scallop species remain free of toxin, even when the viscera exceeded the tolerance level by a factor of 600. Although toxins in shellfish are usually regarded as an inshore problem, queen scallops as far as 90 km off Scotland and shellfish from Georges Bank were found to have high levels of PSP toxins. What does this new information mean?

1. In addition to the toxicological effects of humans, it is now clear that fish and shellfish populations can also be negatively affected, resulting in mortalities proportionate to the toxin concentrations. Effects of phycotoxins are species-specific.

2. Animal species which have not previously been reported to accumulate toxins either in their whole body or in specific edible parts, have been shown to accumulate amounts of toxin (s) significant enough to create a human health concern.

3. The occurrence of toxic and otherwise harmful phytoplankton, benthic/epiphytic algae and/or bacteria is not confined to inshore areas but also extends well into the oceanic environment.

From the above, it is evident that the problems of marine phycotoxins and otherwise harmful algae are no longer minor or occasional. The problems encountered require a much broader approach than current descriptive work, developing or improving detection methods to manage crisis, or of adjusting monitoring systems to ensure consumer safety.

Are the changes occurring as a consequence of human activities, e.g. via modifications of environmental variables and nutrient availability, repression of competing organisms due to pollution, introduction of new species/strains or genetic (directing) factors (e.g. viruses, bacteria) through transport and release of ballast waters, or new and/or increased uses of coastal areas, or, possibly, could these changes be the result of several or all of the above to form an increasing obstacle to human use of the coastal environment and a hazard to inshore marine populations?

Much of the explanation for the occurrences of toxic episodes will be found through intensive physiological and biochemical studies of the individual biological entities and communities and their interactions with the foregoing factors. Development of a programme to define and understand the conditions and circumstances which give rise to toxin production must take account of the following in developing a focus:

a) Not all algal species produce toxins
b) Toxins are not produced by all strains known to be toxigenic nor do the toxin producing strains produce toxins at all times. Certain toxins are produced by a wide variety of organisms and, thus, are not unique metabolites, e.g. domoic acid has been shown to occur in two[2] species of macroalgae and two' diatom species. The saxitoxin/neosaxitoxin family is produced by dinoflagellates and bacteria and tetrodotoxin has been shown in its anhydrotetrodotoxin form to occur in many bacterial species.
d) The influence of nutritional, environmental, physiological and genetic factors on toxin production is insufficiently documented and understood.
e) The degree to which toxins are a product of biotic community action in contrast to single species action has not been determined.

Terms of Reference:

1. To review and analyze data on the physiological ecology and biochemical aspects of harmful algal blooms, especially those resulting in toxic episodes and paying particular attention to nutritional, environmental and physiological factors.

2. To assemble within two years the Working Groups findings and submit for publication a report, summarizing the state of knowledge and identifying the areas of future research

[2]Now 4 diatom species Nitzschia pungens, N. pseudodelicatissima, N. pseudoseriata, and Amphora coffaeiformis (S.Bates personal communication, 1992)

ANNEX VII

ACRONYMS

EEC	European Economic Community
FAO	Food and Agriculture Organization
GIPME	Global Investigation of Pollution in the Marine Environment
GFCM	General Fisheries Council for the Mediterranean (FAO)
GOOS	Global Ocean Observing System
IAEA	International Atomic Energy Agency
ICES	International Council for Exploration of the Sea
ICSEM	International Commission for the Scientific Exploration of the Mediterranean Sea
CSPRO	Inter-secretariat Committee on Scientific Programmes Relating to Oceanography
ILO	International Labor Organization
IOC	Intergovernmental Oceanographic Commission
IPCS	International Programme for Chemical Safety
IST	International Society of Toxicology
IUPAC	International Union of Pure and Applied Chemistry
SCOR	Scientific Committee on Oceanic Research
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WESTPAC	IOC Sub-Commission for the Western Pacific

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WHO	World Health Organization