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BMTC-IOC-POLARMAR International Workshop on Training Requirements in the Field of Eutrophication in Semi-Enclosed Seas and Harmful Algal Blooms

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29 September - 3 October 1992

UNESCO

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SUMMARY

Eutrophication of semi-enclosed seas and harmful algal blooms are two phenomena with high public awareness on a world-wide scale.

Semi-enclosed seas are particularly prone to serious eutrophication problems due to their often high coastal populations, their function as catchment-basins and their reduced exchange of water with the open sea. The Baltic, the Black Sea and the Adriatic Sea represent different stages of eutrophication. The main concern for fisheries is that one of the first consequences of eutrophication is a loss in suitable environmental conditions for fish production and reproduction. The Baltic and the Black Sea thus suffered severe depletions of commercially exploited fish stocks due to eutrophication.

Harmful algal blooms on the other hand are increasing in frequency, intensity and geographic spread on a global scale. In addition to the importance of poisoning of living resources on a regional scale, with the increase of exports of marine products, disastrous effects may be expected on remote markets.

The aim of the Workshop was to bring together scientists, coastal managers as well as fishery experts and managers from the fishing industry from western, eastern and developing countries for establishing a North-South-East dialogue of persons concerned, involved and responsible for identification and discussion of the two phenomena in relation to coastal living resources.

Twelve key note lectures were given by wellknown experts in the fields of eutrophication, harmful algal blooms and international co-operation and training.

The Workshop then separated into two working groups to discuss special training requirements for monitoring the two phenomena.

The final sessions ended up with the recommendation of specific training courses on improving monitoring of eutrophication and training on ecology, taxonomy and toxicity testing of harmful algal blooms, respectively.

1. OPENING

The Workshop was sponsored and hosted by the State of Bremen and co-sponsored by the IOC. It was organized by the Bremen Maritime Training Centre (BMTC) and conducted by POLARMAR GmbH, polar and marine consultants, with the co-sponsorship of the following institutions:

- Alexander von Humboldt - Stiftung, Bonn
- Carl Duisberg Gesellschaft e.V., Berlin/Köln
- Der Magistrat, Seestadt Bremerhaven
- Food and Agriculture Organization (FAO)
  (Mediterranean Action Plan Co-ordination Unit, Athens)
- Hydro Bios Apparatebau GmbH, Kiel
- World Environment Center, New York

It was held at the Parkhotel, Bremerhaven, Germany, from 29 September to 3 October 1992.

Senator Uwe Beckmeyer, the State Senator for Ports, Shipping and Foreign Trade, gave the Opening Address. He stressed the fact that Bremerhaven was a particularly appropriate place to hold the Workshop; not only is Bremerhaven the principal fishing port in Europe, but it also suffers from algal blooms and mucilage, and bans on the marketing of mussels are not unknown. On the other hand, one of the most vital needs is to ensure a supply of unpolluted water. Access to such water is becoming more and more difficult, everywhere. For many developing countries, maritime trade is vital to progress, and the need for high-quality products is ever present. To ensure these objectives, these countries need to develop relevant expertise. The State of Bremen is in a strong position to help develop such expertise through its leading marine research institutions, its long maritime experience and its policy of overseas co-operation.

Senator Beckmeyer particularly thanked the co-sponsors of the Workshop. He also expressed his country's abhorrence of the atypical pockets of xenophobia that have manifested themselves recently; nevertheless, Germany has always played its full part in international co-operation and would continue to do so.

Mr. Gunther Hilliges, Chairman of the Bremen Maritime Training Centre (BMTC) and Head of the Bremen State Office for Development Co-operation, then welcomed the participants on behalf of the State of Bremen and of the BMTC in particular. He traced the state government's long-term efforts in development co-operation, which are supporting the federal government's development co-operation policy by means of its own tax money and programmes related to its special fields of experience and interest. These concentrate on contributions in the field of north-south development co-operation - and since two years also in central and eastern Europe - in particular by supporting renewable energy programmes, support of non-governmental organizations, on the execution of various training programmes, and on ocean environment protection.

Mr. Hilliges stressed that effective and comprehensive approaches to development must include the building of awareness in the economically more advanced societies for the necessity of equal sharing of our global resources. "Without the acceptance of the need for a just and sustainable development in the South, East and North the global change towards such development will be without success", said Mr. Hilliges.

He then described the BMTC, founded only two years ago by commercial firms, scientific institutions and public authorities, as Bremen's and Bremerhaven's answer to the growing requirement for comprehensive training in the fisheries, harbour management and ocean environment fields. The Workshop is understood as the starting point for future co-operation and implementation of carefully defined training needs. The selected subject of the Workshop meets well the knowledge and experience gathered in Bremerhaven and Bremen. Follow-up training programmes will be one of the future activities of the BMTC.

He finally thanked Mrs. Ursula Nix, the deputy manager and project manager of BMTC, Dr. Wolfgang Welsch of POLARMAR, and Dr. Jürgen Alheit of the Baltic Sea Research Institute, Warnemünde, for their dedication to the preparation of the Workshop.

Dr. Chidi Ibe, Head of the Marine Pollution Unit of the Intergovernmental Oceanographic Commission (of UNESCO), also gave a welcoming address. He recalled the IOC meeting on future trends in Training, Education and Mutual Assistance in the Marine Sciences (TEMA) held in Bremerhaven in 1989. At that time he represented the developing countries; now he was representing IOC itself. He had not only been able to view such matters from the IOC side, but he was also now expected to put some of the recommendations of the IOC meeting into action.

He conveyed to the Workshop the fraternal greetings of the Secretary of the IOC, Dr. Gunnar Kullenberg. He believed that the present Workshop was timely since it addresses the persistent problems of training and implementation, but it also makes a start in giving practical meaning to the intentions of the UN Conference on Environment and Development, held recently in Rio de Janeiro, and in particular to chapter 17, on Protection of the Oceans, All Kinds of Seas, including Enclosed and Semi-enclosed Seas, Coastal Areas and the Protection, Rational Use and Development of Their Living Resources, of "Agenda 21" adopted by the Conference.

The solution to the problems posed is, he believed, international co-operation between the developed countries, the developing countries and indeed an increasing number of **non-developing** countries. Dr. Ibe thanked the organizers whole-heartedly for their effort in organizing the present Workshop and expressed the IOC's keen anticipation of the Report thereof.

To complete the opening session, Dr. Jürgen Alheit presented an introduction to the Workshop. He expressed his personal pleasure in seeing his idea (of the Workshop) become reality. He was particularly pleased to see the positive interest and support given by international organizations such as the IOC, UNEP and FAO.

Eutrophication is caused by increased input of nutrients from terrestrial sources (e.g. agriculture), such as nitrogen and phosphorus, into coastal areas. This can cause enhancement of algal productivity and accumulation of algal biomass, and might change the whole ecosystem. In recent years, there appears to have been an increase of these effects in the coastal areas of industrialized countries.

Semi-enclosed seas are particularly prone to serious eutrophication problems due to their often high coastal populations, their function as catchment basins and their reduced exchange of water with the open sea. The recognition that semi-enclosed seas constitute special environments that are much more susceptible to the impact of human activities than the open oceans calls for co-operative action for semi-enclosed seas.

An illustrative example of the negative impact of human influences is the Black Sea. There is growing scientific evidence that the Black Sea has suffered catastrophic ecological damage as a result of pollution, principally from land-based sources. This had resulted in eutrophication. As a consequence, the riparian countries are loosing their valuable fishery resources which have suffered an almost total collapse. The profound alteration of the marine ecosystem of the Black Sea, primarily as a result of eutrophication, has had an enormous impact on the fisheries.

High-value species have disappeared to be replaced by fish species of much less value. Of 26 species of commercial fish in the 1960s only 6 remain in significant exploitable quantities.

The Baltic Sea, the Black Sea and the Adriatic Sea represent different stages of eutrophication, and a comparative approach to consideration of the eutrophication problems in these three large ecosystems seems particularly appropriate. Consequently, experts from these three regions brought together have to have a fruitful interaction.

Harmful algal blooms can pose a threat to public health and tourism, can cause mass mortalities of shellfish and finfish and can result in great economic hardship to coastal fishing communities and aquaculture industry. Outbreaks of harmful algal blooms are increasing in frequency, intensity and geographic extent on a global scale. Whether or not the outbreak of harmful algal blooms is caused by increasing eutrophication is the subject of an intense debate between scientists.

Harmful algal blooms can cause, in particular, Paralytic Shellfish Poisoning (PSP), Diarrhoetic Shellfish Poisoning (DSP), Neurotoxic Shellfish Poisoning (NSP), and Amnesic Shellfish Poisoning (ASP). People eating contaminated shellfish can become seriously ill, and might even die of it. This danger also presents a great economic threat to the aquaculture industry.

Since most countries lack the required expertise to cope with the negative impact of harmful algal blooms, a degree of formal international co-operation in research and training is needed which does not exist at present.

Towards this goal, IOC and FAO are developing an International Programme on Harmful Algal Blooms (HAB) which is a component of the IOC-FAO

Programme on Ocean Science in Relation to Living Resources (OSLR) and has the following overall objective: "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."

2. OBJECTIVES OF THE WORKSHOP

Dr. Alheit recalled that the objective of the Workshop was to bring together scientists, coastal managers as well as fishery experts and managers from the fishing industry from western, eastern and developing countries with the aim of establishing a North-South-East dialogue of persons concerned, involved and responsible for the identification and treatment of common problems of protection of coastal fish resources and aquaculture. The emphasis of this Workshop was on technology transfer by training and on assistance in the implementation of appropriate projects to recognize environmental hazards in time and, if possible, to prevent harmful consequences.

Dr. Alheit explained that, after discussion of the keynote presentations (see section 3, below), the Workshop participants would be split up into two Working Groups charged with discussing and identifying training requirements and formulating appropriate recommendations on training needs, to be submitted to potential funding agencies.

The programme of the Workshop is given in Annex I hereto. The List of Participants is given in Annex II.

3. KEYNOTE PRESENTATIONS

Twelve keynote speakers then addressed particular aspects of the subjects of the Workshop. Some were supported by other participants who provided a considerable amount of supplementary information on the state of the marine environment in their respective regions.

The list of speakers and topics is as follows:

Order of Keynote Presentations:

3.1 TRAINING OF SCIENTISTS FROM DEVELOPING COUNTRIES IN THE FIELD OF MARINE POLLUTION

Dr. C. Ibe, Intergovernmental Oceanographic Commission, of UNESCO, Paris, France

3.2 COASTAL EUTROPHICATION: CAUSES AND CONSEQUENCES
Dr. E. Nöthig, Alfred Wegener Institute, Bremerhaven, Germany

3.3 EUTROPHICATION OF THE BALTIC SEA - A COMMON PROBLEM
Dr. S. Johansson, Swedish Environmental Protection Agency, Solna, Sweden

3.4 EUTROPHICATION PROBLEMS IN THE EASTERN MEDITERRANEAN
Dr. N. Friligos, National Centre for Marine Research, Athens, Greece; Dr. Y. Halim, University of Alexandria, Egypt; Dr. I. Marasovic, Institute of Oceanography and Fisheries, Split, Croatia

3.5 EUTROPHICATION PROBLEMS IN THE BLACK SEA
Dr. A. Bologa and Dr. P.A. Mihnea, Rumanian Marine Research Institute, Constanza, Rumania; Dr. C. Saydam, Middle East Technical University, Erdemli-İçel, Turkey; Dr. S. Konovalov, Institute for the Biology of the Southern Seas, Sevastopol, Ukraine

3.6 THE MEDITERRANEAN ACTION PLAN WITH SPECIAL REFERENCE TO EUTROPHICATION AND PLANKTON BLOOMS
Dr. G. Gabrielides, FAO, Co-ordinating Unit for the Mediterranean Action Plan, Athens, Greece

3.7 HARMFUL ALGAL BLOOMS: A GENERAL OVERVIEW
Dr. M. Elbrächter, Biologische Anstalt Helgoland, Sylt, Germany

3.8 PROBLEMS CAUSED BY HARMFUL ALGAL BLOOMS IN CHINA
Dr. Yu-Zao Qi, Institute of Hydrobiology, Guangzhou, People's Republic of China (paper co-authored by Hon Ying, Qiang Honling and Lu Shonhui)

3.9 HARMFUL ALGAL BLOOMS AND FISHERIES
Dr. K. Tangen, OCEANOR, Trondheim, Norway

3.10 ENVIRONMENTAL ISSUES RELATED TO AQUACULTURE DEVELOPMENT
Dr. H. Rosenthal, Fisheries Biology Department, Kiel, Germany

3.11 MONITORING THE HEALTH OF LARGE MARINE ECOSYSTEMS
Dr. K. Sherman, National Oceanographic and Atmospheric Administration (NOAA), Naragansett, RI, USA

3.12 GLOBAL CHANGE: PHYSICAL AND BIOLOGICAL ASPECTS
Dr. A. Bakun, FAO, Rome, Italy

3.1 TRAINING SCIENTISTS FROM DEVELOPING COUNTRIES IN THE FIELD OF MARINE POLLUTION

Dr. Ibe (IOC) made this presentation. He first indicated that Dr. Lawrence Mee (IAEA, Monaco) had been unavoidably prevented from participating in the Workshop but had asked him, Dr. Ibe, to incorporate in his talk some of the principal points made in the keynote talk that was to have been given by Dr. Mee on Pollution as a Constraint in the Development of the Marine Environment: Building a Capacity for Management.

Pollution of the marine environment is an increasingly worrying problem in developing countries. The main causes are: (i) human alteration of the environment - by such activities as mining, dredging, construction and inappropriate forms of land use; (ii) inadequate or improper management of human wastes - domestic, industrial and agricultural; (iii) accidental spillages of toxic chemicals and petroleum.

Regarding (i), about 60% of the human race live within 100 km of the coast. The growth of the human population is expected to exacerbate this tendency to increase coastal population density; the urge to improve life styles, implying greater energy use in industrialization to produce the physical ornaments of such styles, and in mass transportation systems, often in a context of badly managed urbanization. These developments place great strains on the environment of the coastal zone. The products of this mismanagement are often direct discharge of wastes into the sea, and the growth of a substantial poverty fringe as ever-hasty urbanization proceeds. The secondary consequences due to the increased marine pollution may be dangerously lowered food quality which contributes to illness in the human population and to economic losses.

The developed countries have acquired the means to limit the worst of such effects, but the developing countries do not have the resources or the means to prevent or mitigate them. Their capacity to deal with such problems depends on the acquisition of a firm knowledge of the problems, of appropriately trained manpower and programmes of action, and of the financial and technical resources to sustain such action so that problems do not recur as soon as remedial action ceases. The fact that the ocean knows no political boundaries but is an excellent system for the transportation and distribution of many pollutants suggests that it is very much in the interest of developed countries to help developing countries to solve their marine pollution problems on a long-term basis.

The UN Conference on Environment and Development (UNCED) held recently in Rio de Janeiro, had considered such problems. Its main conclusions in respect of the oceans were: (i) the concerns expressed at the UN Conference on the Human Environment (Stockholm, 1972) mostly remain valid today; (ii) there is a need to adjust human actions better to the relevant international conventions on the marine environment; (iii) a much greater effort should be made to approach the solutions to the main problems of marine environmental management through Integrated Coastal Zone Management (ICZM) and the analysis of Large Marine Ecosystems (LEMs); (iv) much more aggressive capacity-building; (v) much more international co-operation: through international organizations such as those of the UN system; between Member States that are the donors of financial and technical assistance and those that are in need of such assistance; and (vi) the incorporation of marine environmental studies into high-school curricula.

The definition of the problems requires monitoring of the marine environment, not only initially, to specify the nature and extent of the problems, but also later, to determine the effectiveness of measures taken to reduce or eliminate them. Monitoring programmes require, as a sound basis for decision-making, to: (i) undertake relevant research; (ii) develop appropriate methodology and analytical standard and reference materials; and (iii) carry out intercalibration exercises amongst laboratories involved in specific monitoring programmes.

Besides monitoring, there must be a much greater harmonization of economic and environmental objectives, if sustainable socio-economic development is to be achieved. The strategies to be adopted are at three levels, at each of which there can be a different thrust and where the UN system can provide specific help as follows:

National Level	Regional Level	Global Level
Specific actions	Conventions and protocols	Overall strategy
UN programmes of co-operation and technical assistance	Organizing conferences to draw up conventions	Developing action plans to implement strategy

Dr. Ibe briefly described a particularly relevant UN programme - the Global Investigation of Pollution in the Marine Environment (GIPME). It is presently co-sponsored by IOC and UNEP through a Joint Panel. It has three Groups of Experts on: the Effects of Pollutants (GEEP) co-sponsored also by UNEP and FAO; on Methods and Standards (GEMS) co-sponsored by UNEP and IMO; and on Standard and Reference Materials (GESREM) co-sponsored by UNEP and IAEA. While helping the national institutions of Member States to improve their technical capacities to deal with marine pollution problems, it seeks also, through such institutions, to increase public awareness of the main types of marine pollution: pathogenic organisms, heavy metals, pesticides, hydrocarbons, radionuclides, marine debris and beach litter, and more recently, harmful algal blooms. GIPME, through its Marine Pollution Monitoring System (MARPOLMON), is a key contributor to the UNEP Global Environment Monitoring System (GEMS) and to the new IOC Global Ocean Observing System (GOOS).

The transfer of knowledge and the provision of well directed and sustained financial support are the main means of overcoming the present impediments to technical capacity-building which are low national income and socio-economic under-development (which, respectively, limit the means available and the political will to deal with environmental pollution problems).

Discussion

In the discussion of this paper several questions were raised.

(i) Dr. Wyatt asked how can we reduce or eliminate the frequent mismatch between the training of staff and the provision of the equipment.

Dr. Ibe suggested that the solution is by sustaining financial and technical support in the context of a long-term programme of marine environmental monitoring and control at the national level.

(ii) Dr. Iddya Karunasagar asked what can be done to provide analytical standard materials for marine algal toxins.

This problem was discussed at the recent GESREM meeting in Brussels; it was recognized that such standards are, at present, largely unavailable outside the laboratories that are developing them for their own research use. Dr. Indrani Karunasagar asked the IOC-UNEP Group also to consider the establishment of a regional marine alga culture centre for the Indian Ocean.

(iii) Dr. Bologa noted that the World Bank is promoting a programme of Integrated Coastal Zone Management and asked how such a programme could be developed for the Black Sea.

Dr. Ibe explained that UNEP has developed an Action Plan for the Black Sea which would contain an ICZM component. IOC would support the Action Plan and would attend the forthcoming World Bank meeting on the financing of the proposed ICZM programme and could stress the value of it in the Black Sea.

(iv) Mr. Griffiths asked how could we hope to provide sustained financial and technical support when many donor countries were cutting back on their foreign aid programmes, not only because of the currently depressed state of the world economy but also because donor countries increasingly perceived a too weak relation between the funds provided and the results obtained.

Dr. Ibe felt that, to ensure a much better cost/benefit ratio, it was necessary to develop global and regional strategies agreed by the donor and recipient countries, in which the ocean would be the integrating factor since it cannot be dealt with successfully on a piecemeal basis. The adoption of common objectives and procedures, and the use of independent organizations (e.g., UN system technical or specialized agencies) to execute specific projects should guarantee the necessary long-term sustainability of the inputs and ensure a low cost/benefit ratio in such assistance.

3.2 COASTAL EUTROPHICATION: CAUSES AND CONSEQUENCES

Dr. Eva-Marie Nöthig (Germany) made this presentation.

(i) Whereas estuaries and many smaller, enclosed water bodies along the coast of industrialized countries are severely eutrophic, the degree of eutrophication of larger water bodies such as the North Sea, for example, is still under discussion. The main causes of eutrophication are highly developed agriculture, development of river basins, inadvertent nitrogen fixation, pollution by toxins, tourism and marine aquaculture. The input of (total) nitrogen to the sea is the most important factor contributing to eutrophication. Some examples show the increase of nutrient inputs to the sea: (i) Nitrogen fertilizer is estimated to contribute to about 28% of the annual nitrogen fixation by the entire biosphere. In the USA and western Europe, fertilizer production increased threefold from the fifties to the seventies. Of these nitrogen fertilizers a small amount is leached into rivers, almost half of it is denitrified or volatilized as ammonia. 10-90% of the nitrogen in animal wastes is discharged directly into rivers or applied to fields. Nitrate input along the northeast Atlantic coast increased 32% during 1974-1981. N and P levels in the Kattegat increased by 2- and 1.2-fold, respectively between 1971 and 1982. N and P inputs from rivers discharging into the Dutch Wadden Sea increased by 5- and 7-fold, respectively between 1962 and 1984.

(ii) Manipulation of rivers in industrialized countries has resulted in drainage of wetland, thus increasing speed of river flow. Deforestation has increased soil erosion and more nutrients have therefore leached into rivers. Owing to the increased speed of river flow, more nutrients now reach the estuaries since there is not enough time for the phytoplankton of the rivers to use all these nutrients.

(iii) Molecular nitrogen is fixed inadvertently in, for example, internal combustion engines and power plants. Reactive nitrogen exists with the exhaust gases and is transported via the atmosphere until it is deposited in precipitation (contributes < 10 - > 50% in the vicinity of a river mouth).

(iv) Heavy metals, organic compounds, such as PCBs or phenol etc., can suppress growth of some or all species and can change the structure of planktonic systems as well as that of whole marine ecosystems.

(v) Tourists tend to be located along sandy beaches of oligotrophic regions, or coral barrier reefs and islands. Ecosystems in oligotrophic waters are much more sensitive to input of nutrients or organic matter. Discharge of untreated wastes can have a serious effect on the health of oligotrophic coastal ecosystems.

(vi) It is not quite clear whether marine aquaculture is having a great impact on the coastal ecosystems. However, faeces and agglutinated food tend to collect at the bottom and could induce anoxia when there is little water exchange with the open sea. Nitrogen-rich fish food may contribute to eutrophication.

The consequences of higher nutrient inputs to coastal ecosystems are: biomass increase; shifts in nutrient ratios; shifts in species composition; higher sedimentation rates; higher oxygen demand; more anoxic regimes and changes in the whole pelagic and benthic population structures.

The biomass increase causes higher rates of sedimentation of organic matter to the benthos. The benthic organisms respond with a higher metabolism, thus using up more oxygen. This can finally cause anoxia in the sediment and deeper water layers if the exchange with oxygen-rich water is minimal. The changes in ionic ratios of essential nutrients can have a significant effect on species composition in the pelagic system and therefore an impact on the whole food web structure. Higher N and P inputs to the system can cause a shift to smaller phytoplankton organisms. The latter are eaten by protozooplankton or small zooplankton rather than by large copepods. Thus, the food chain will become longer and less efficient for consumers at higher trophic levels.

In many coastal ecosystems the N:P and Si:P ratios have decreased causing significant blooms of non-silicon-requiring organisms and species have emerged with increased frequency and persistence. Examples are: (i) increasing *Phaeocystis* blooms in Dutch coastal waters; (ii) increasing flagellate biomass near Helgoland; (iii) post-spring blooms of *Dictyocha speculum* (a new form without a skeleton, found in the Kiel Bight and adjacent waters); (iv) extensive summer blooms of the blue-green alga *Nodularia spumigena* in the Baltic; (v) more red-tide blooms in the Black Sea.

As in the case of all natural processes influenced in a chronic manner by human input, eutrophication is first evident as a shift in the range of variability inherent to the receiving ecosystem. Situations judged as extreme in the past tend to become more common, eventually leading to a more drastic or qualitative change in the structure and behaviour of the perturbed system.

Depending on the properties, buffering capacity, and resilience of the system, its response can be in the form of a gradual trend; however, it can also react with seemingly unpredictable oscillations. The feed-back loops that can buffer or amplify the impact of human activities are reflected in the seasonal cycles, the basis of which is as follows. The increased availability of nitrogen (as nitrate) and phosphorus (as phosphate) in the spring as a result of turbulent mixing in shallow seas or upwelling is first exploited mainly by diatoms. As the nitrogen is increasingly incorporated into the biomass, as "new" production, there is a tendency to create a "loop" whereby nitrogen (as ammonia) is released into the sea and exploited, mainly by flagellates; the latter undergo a shift in their species composition as the nitrogen is recycled in the "regenerated" production. By the autumn, however, the loss of nitrogen to the water promotes once more a predominance of diatoms.

At present it is difficult to diagnose to which degree the changes recorded in recent years in shelf systems are a result of excessive nutrient input, changing climate cycles, or simply an effect of improvement in observational coverage. Eutrophication is a process that has to be judged relative to an earlier, pristine state of the area investigated. If possible, historical records should be looked up.

Coastal ecosystems should first be characterized by determining the seasonal cycle and species succession in the pelagic and benthic systems. Life cycles of dominant species (resting cells, triggering factors, food web structure etc.) should be investigated. The individual physical and chemical constraints and the morphology of an estuary should be considered in the studies. A holistic approach is necessary to understand the system. Large-volume experimental systems (e.g., the MERL mesocosms) can be used to study the effects of prolonged eutrophication. Models can be developed for individual estuaries to try to calculate the carrying capacity of the ecosystem and to make relevant forecasts.

<u>Discussion</u>

(i) Dr. Alheit stressed the fact that the species composition changes often observed under eutrophic conditions were not confined to the phytoplankton but may also occur in the zooplankton and nekton; moreover, such changes could occur for other reasons than eutrophication.

Dr. Halim also pointed out that the changes were often not so much in the species composition, qualitatively, but in the proportions of producer and consumer species. He noted that jellyfish were a terminal dominant species common to several seas but not necessarily a result of eutrophication. Physical factors limiting water circulation often encouraged eutrophication.

Dr. Moncheva reminded the Workshop that phytoplankton succession was a normal process and may depend on initial conditions. Blooms may also depend on a particular succession.

Dr. Mihnea noted that flagellates tend to follow diatoms and appeared when the silicon concentration declines; she thought it was dangerous to treat flagellates as one more or less homogeneous group.

Dr. Nöthig agreed, pointing out that the first flagellates to follow diatoms in a eutrophic succession were the larger species which were later replaced by smaller ones. Also, the diatoms are not totally replaced by the flagellates. It is just that diatoms can use ammonia more rapidly than dinoflagellates can.

(ii) Dr. Ignatiades suggested that the "new" and the "regenerated" production cycles were less simple than had been indicated. Ambient temperature, for example, plays an important role.

Mr. Griffiths also felt that the production cycles had been oversimplified, since it was rarely, if ever, simply a question of increased nitrogen and phosphorus availability: pollutants were often involved and species composition changes induced by heavy fishing, for example, feed downthrough the trophic web even if such changes in the phytoplankton also feed upwards through it.

Dr. Olenin believed that the role of the biotoxins in eutrophic processes was not clear; he suggested that we are assessing them only in terms of their harmfulness to human beings, which may be a short-sighted approach.

Dr. Nöthig agreed, but stressed the greatly increased difficulty of explaining the underlying processes if too many factors had to be taken into account.

(iii) Dr. Iddya Karunasagar asked whether frontal systems played an important role in the occurrence of algal blooms. Dr. Nöthig thought they did.

(iv) Dr. Aps felt it important to assess the carrying capacity of a given ecosystem in respect of nitrogen and phosphorus in particular, and to attempt to control inputs accordingly.

Dr. Nöthig said that this is a difficult task and would require a much greater knowledge of the functioning of the system than is usually available.

3.3 EUTROPHICATION OF THE BALTIC SEA - A COMMON PROBLEM

Dr. Sif Johansson (Sweden) made this presentation.

The Baltic Sea is a semi-enclosed brackish sea of about 415 000 km^2. In the nine Baltic coastal countries about 16 million people live on the coast and about 80 million people live in the drainage basin. Present estimates indicate a total supply to the Baltic Sea of about 980 000 tons nitrogen and 50 000 tons phosphorus per year. These levels represent increases in nitrogen loading of about four times and in phosphorus loading of about eight times since the turn of the century.

In the open Baltic, significant increases in phosphorus and nitrogen were observed until the late 1980s. At present, these levels appear to have stabilized, with the exception of the Kattegat and the Gulf of Riga. However, the concentrations of phosphorus and nitrogen are still so high that the resulting eutrophication has caused further deterioration of oxygen conditions in the Baltic Sea deep water. In the Gulf of Bothnia, phosphate concentrations have remained at the same level since 1978, but nitrate concentrations have increased in surface water and deep water. No indications of eutrophication have been seen in the open waters of the Gulf of Bothnia.

In 1974, the convention on the Protection of the Marine Environment of the Baltic Sea Area (the Helsinki Convention) was signed by the coastal States of the Baltic Sea. The Convention covers the entire Baltic Sea including the Kattegat, and its aim is to protect the Baltic Sea against pollution from all possible sources. It was the first international agreement in the world covering all sources of pollution. At the Diplomatic Conference in April 1992, the Helsinki Commission (HELCOM) adopted a revised convention that also covered the internal waters of the Contracting Parties, which today are Denmark, Estonia, Finland, Germany, Lithuania, Poland, Russia and Sweden and the observer State of Latvia.

Recently, the Helsinki Commission presented the Baltic Sea joint comprehensive programme. It is an action plan to restore the Baltic Sea environment. About one hundred of the worst point-sources of pollution were identified and the cost for correcting them was estimated to be about 15 billion ECUs.

Discussion

(i) Dr. Piyakarnchana asked what was the limiting nutrient in the Baltic Sea. He also asked whether eutrophication has affected the composition of the phytoplankton.

Dr. Johansson said that the inorganic N:P ratio in the Baltic Sea is about 3 by weight; that is less than 7, hence nitrogen is the limiting nutrient in the open Baltic Sea; changes in the proportions of the species rather than in the specific (taxonomic) composition have occurred. She offered to provide information on the long-term changes in the community structure in the Baltic (i.e., from the second HELCOM assessment).

(ii) Mr. Griffiths asked how the residence time of the water varied throughout the various parts and basins of the Baltic Sea.

Dr. Johansson said she did not have the complete information; for the Baltic Sea as a whole the residence time is estimated to be about 25 years; between the Gulf of Bothnia and the rest of the Baltic the exchange takes only 5-7 years. With respect to eutrophication, however, water exchange is considered to be less important than residence times; the cycles are estimated to take about 5 years for nitrogen and 13 years for phosphorus. Recent modelling could provide further answers; it could moreover be applied to the Black Sea, although there are considerable differences: the Baltic is subject to intermittent flushing during exceptional weather events; the Black Sea is not.

(iii) Dr. Ibe asked whether the large areas of anoxic bottom water in the Baltic proper had natural rather than man-made causes.

Dr. Johansson, supported by Oleg Savchuk, agreed that this is partly so, but eutrophication has lead to increased sedimentation of oxygen-demanding matter, thus increasing oxygen consumption in bottom waters. Therefore, the present, severe, situation has natural and man-made causes.

3.4 EUTROPHICATION PROBLEMS IN THE EASTERN MEDITERRANEAN

Dr. Nicholas Friligos (Greece) gave this presentation.

After describing the general distribution of the main types of industry in the countries bordering the eastern Mediterranean, Dr. Friligos stressed the fact that rivers are the main channels for the discharge of nitrogen from the land into the sea, together with agricultural waste (excess fertilizer) via direct run-off.

Our notions of the circulation of the eastern Mediterranean have evolved since they were first comprehensively described by Nielsen in 1912, reported by Lacombe in 1975 and given their most up-to-date conformation by Robinson in 1992 as a result of the IOC-UNESCO study of Physical Oceanography in the Eastern Mediterranean (POEM).

In this region, the Aegean Sea is the most oligotrophic, followed by the Ionian Sea, in terms of nutrient (N,P) and silicate (Si) concentrations.

Also in the eastern Mediterranean, three main layers of water are distinguishable on the basis of nutrient concentration criteria: 0-200m; 200-500m; and, below 500m. Some enigmas still remain as to the formation and history of certain water masses. The N:Si:P ratios are higher than normal. Primary production is likely to be phosphate-limited, unlike the world oceans in general.

In the Aegean Sea, only Eletsis Bay (vicinity of Athens and Piraeus) in the northern part of the Saronikos Gulf, and Thessaloniki Bay are eutrophied. Secchi disc depth is at about 5m, but deepens fairly quickly to 25m towards the southern part, whereas PO_4-P values range from 0.5 to 0.1 µg at./dm^3, inversely. It should be noted that there is an important sewage outfall in the Saronikos Gulf. Here too, the level of pollution is high, as well as in Elefsis Bay.

Dissolved oxygen levels are very low (approaching 0 ml/dm^3) in Elefsis Bay between July and September; anoxia is usual below a depth of about 20m.

Numerous undesirable algal blooms have been observed since 1978 in the northern part of the Saronikos Gulf. In August 1978, a fish-killing red-brown phytoplankton bloom that occurred in the Saronikos Gulf was due to *Gymnodinium breve*. Other species that have caused red tides are: *Scrippsiella trochoidea*, *Pycaminomonas* sp., a *G. catenatum*-like species, and *Noctiluca scintillans*.

In the Bay of Izmir (on the Turkish west coast) red tides (particularly of *Alexandrium minutum*) became common after 1980.

Such events (also often due to *A. minutum*) in Alexandria Bay have been observed since the 1960s. (See information provided by Dr. Halim, herebelow).

In the Adriatic, specifically in Kastela Bay, red-tide blooms due mainly to *Lingulodinium polyedra* and *Alexandrium tamarense*, have been observed since 1980. (See intervention by Dr. Ivona Marasovic, herebelow).

Many of these events are described in the UNESCO Reports in Marine Science No. 49.

Dr. Halim (Egypt) gave a short unscheduled supporting talk on the area of the Nile Delta.

Comparing the pre-Aswan Dam era (before 1965) and the post-Dam era, he reminded participants of how the Nile discharge had a major effect on the coastal ecology in the vicinity of the delta and indeed on the south-eastern Mediterranean in general. This impact was habitually measured in terms of salinity and dissolved nutrients and silicates. Algal blooms occurred because of the loading of the river water during its passage through the Nile flood plain which forms the core of Egyptian agriculture. However, these blooms, which often extended far offshore and alongshore, were considered as being favourable to regional marine productivity, notably as reflected in sardine abundance. Diatoms predominated in such blooms. Besides sardines, which sustained a major fishery for several months of the year, shrimp abundance was also high.

After the Aswan Dam came into operation in 1965, the Nile discharge dropped from about 50 million m^3 to less than 10 million m^3 per year. The amount of suspended particulate matter discharged into the Mediterranean dropped to zero. The sardine fishery collapsed rapidly and only showed signs of recovery around 1978; this recovery was due in part to a change in fishing techniques. Shrimp abundance was both slower to decline and slower to recover. The Dam put an end to natural "beneficial" eutrophication and induced the spread of an oligotrophic regime in the eastern Mediterranean Sea; levels of primary productivity were 40-50 gC/m^2/year, although values continued to remain higher than this off the Nile Delta. The eutrophication here was man-made, with important domestic waste discharges from Alexandria and Port Said. Also, agricultural run-off is received by coastal lagoons. The Nile discharge has continued at about 3 million m^3 through the Rosetta branch only, while another 2 million m^3 is discharged via a large relief canal to the west between the Nile and the sea.

Fish diseases have also been observed to increase since the Dam was built. However, this man-made eutrophication is still considered to be more beneficial than pristine oligotrophic conditions.

Dr. Marasovic (Croatia) provided some additional information on

Kastela Bay in the central eastern Adriatic.

Eutrophication has been observed for the last forty years; however, between 1970 and 1980, no summer phytoplankton minimum has been observed, and even maxima have sometimes been observed. Primary production was around 150gC/m^2/year in 1970; it was at about 200 gC/m^2/year in 1980 and is now about 250 gC/m^2/year. Chlorophyll **a** biomass has also increased. Transparency has decreased, surface dissolved-oxygen levels have increased and bottom levels have decreased. Diatoms were dominant up to the 1970s, whereas dinoflagellates became dominant at the end of the 1970s; this is a good sign of eutrophication. Red tides due to *Lingulodinium (Gonyaulax) polyedra* started to recur in 1980, although they are often limited to a part of the Bay. Before 1980, cell counts of *L. polyedra* were about 5000/dm^3, and after, around 20 million/dm^3. Fish kills started to occur. With dissolved oxygen levels below 0.5 mg/dm^3, biotoxins were not at first suspected.

Information on nutrient and chemical discharges into Kastela Bay is reliable.

It is now believed that water temperature is the key trigger mechanism, since blooms never occur when T<20°C. Also, cell counts are clearly related with water temperature and dissolved oxygen, but less well so with N-NO_3 because nutrients are not limiting factors in Kastela Bay. Sediment particle grain size (<60µm) is good for the development of *L. polyedra* cysts.

The observed increase in primary production in the open Adriatic is regarded as natural eutrophication. Here, the production and the catch of pelagic fish increased together between 1980 and 1990.

Discussion

(i) Mr. Griffiths asked Dr. Friligos whether the strong and persistent N/S winds in the Aegean played a role that would explain some of the outstanding enigmas of the circulation.

Dr. Friligos thought this might be partially so but certainly could not explain all.

(ii) Dr. Savchuk asked Dr. Halim whether the distribution of isopleths commonly observed in the coastal waters off the Nile Delta is driven by simple dilution or by biological/chemical processes.

Dr. Halim said both actions were at work.

(iii) Dr. Olenin asked Dr. Marasovic whether something had occurred in the benthic fishes of the Adriatic similar to what had happened to the pelagic fish stocks.

Dr. Marasovic explained that there had been many observed changes in the benthic community in the northern Adriatic; also, in Kastela Bay in the past, green algae had predominated whereas, now, brown algae predominate. Also, in the northern Adriatic, with the serious depletion of bottom dissolved oxygen levels, two classes of hydroids had disappeared altogether, and in Kastela Bay some phytoplankton species had disappeared locally.

(iv) Dr. Aps asked whether there was any clear relation specifically between eutrophication and fish production.

Dr. Marasovic thought that eutrophic conditions are not suitable to fish larvae.

Dr. Andrushaitis asked whether the increase in the N:P ratio is due to biological factors or to changes in human-waste discharge.

Dr. Marasovic thought the biological factors were the more important.

(vi) Dr. Houvenaghel inquired as to whether macroalgal blooms occurred.

Dr. Marasovic thought they did not.

3.5 EUTROPHICATION PROBLEMS IN THE BLACK SEA

Dr. Bologa (Rumania) made the first of four presentations on this subject. He very much regretted that Dr. Zaitsev had been unable to come to the Workshop owing to a last-minute difficulty in his travel plans.

Increasing eutrophication as well as other human activities have considerably changed the structure and functioning of the Black Sea ecosystems, mainly in its northwest corner, affecting both the qualitative and the quantitative state of the benthic, phyto- and zoo-planktonic communities.

This change can be attributed to the more rapid acceleration of change in the interrelationships between human influence and biota in this nearly enclosed basin during the last three decades. The marked decline of the ecological health has induced marked changes, especially in the structure of littoral ecosystems.

The macrophytobenthos has shown a gradual, but continuous, decline approximately since 1945-1950 due to natural (e.g., occasional massive frosts) and human factors (e.g., silting of the rocky bottom, increased turbidity, diminution of light penetration).

The previously large belts of *Cystoseira barbata*, a perennial brown alga, along the western coast have practically disappeared, as have numerous other associated and/or epiphytic algal and animal species.

The present algal flora, which displays a reduced species diversity, is uniform. Generally, it is dominated by *Enteromorpha intestinalis*, *E. linza*, *Ceramium elegans* and *C. arborescens*. These newly dominant species with short and nearly seasonal life cycles show considerable production but, nevertheless, they do not reach the levels of *Cystoseira* that occurred in previous decades.

Following the more intense eutrophication, the biomass of the phytoplankton surpassed that of the past. Some essential structural changes have occurred and new quantitative and qualitative characteristics have been recorded.

The increase of the amplitude and frequency of algal blooms is a significant ecological consequence of the accumulation of nutrients in sea water. Since 1970, blooms have no longer been exceptional phenomena. For example, in the 1980s alone, 46 blooms due to 15 algal species were recorded in the Rumanian littoral waters.

Besides the species producing the blooms, other numerous mass species are remarkably developed. During the 1980s, 79 species recorded densities of more than 100 000 cells/dm^3, compared to 57 species in the 1970s, and only 38 species in the 1960s.

Numerical density of the main species increased from the levels of the 1960s, for 66% of the species in the 1970s, and 79% of the species in the 1980s. From the 1960s up to the 1980s, the proportion of non-diatoms in the numerical density of the phytoplankton increased from below 8% of the total up to 62% with a corresponding decrease of the diatoms. The changes of the quantitative proportions of the main algal groups are due to the changes in the nutritive basis. These changes include: (i) the decrease in the Si:N and Si:P ratios (which is detrimental to diatoms); and (ii) the increase of organic matter (which favours the phytoplankters belonging to *Dinoflagellata*, *Euglenophyta*, and *Chrysophyta* with mixotrophic affinities.

The average biomass of phytoplankton in the Rumanian littoral zone between 1983 and 1990 was more than 8 times higher than that assessed between

1959 and 1963.

The evolution of zoobenthos communities is marked by a qualitative impoverishment, expressed by the reduction of species number by 50-60% at present relative to the 1960 period, as well as by the numerical reduction of the numerous species that formerly were omnipresent in the communities.

The qualitative structure of the communities was altered by the diminution of those species that were prevailing and characteristic formerly (*Spio filicornis*, *Corbula mediterranea*, *Syndesmia fragilis*, *Spirula subtruncata*, *Mytilus galloprovincialis*) and by the proliferation and autoacclimation of some opportunistic species (*Neanthes succinea*, *Polydora limicola*, *Mellina palmata*, *Mya arenaria*, *Scapharca inaequivalvis*).

Increases in the population size of opportunistic species did not compensate for the reduction of general biomass and density, which are lower by 35-84% than those measured 25 years ago. The zoobenthic communities become more and more homogeneous as a result of mass proliferation of a few species. Their community structure is unstable owing to the permanent disturbance generated by blooms and related benthic mass mortalities.

The evolution of the zooplankton communities was marked by simplification of structure and diminution of the species diversity, especially in the shore areas. Besides the total disappearance of some species (three species of copepods belonging to the family Pontellidae), the populations of some holoplanktonic species have diminished greatly, as, for example, *Centropages kroyeri*, *Penelia avirostris*, *Evadne tergestina* and *E. spinifera*.

The population of the meroplanktonic component of the zooplankton (the planktonic larval stages of benthic biota) has also diminished as a consequence of the mortalities produced in the benthic fauna.

In contrast, the density of a small number of opportunistic species (e.g., *Acartia clausi* and *Pleopis polyphemoides*) increased, the species becoming dominant in the communities.

Another characteristic feature is the explosive development of *Noctiluca scintillans*, especially during the summer, following a significant algal bloom (in the summers of 1986 and 1987, this species represented 91-99% of the entire zooplankton biomass). Massive accumulation of the jellyfish *Aurelia aurita* has also been recorded.

Between 1980 and 1987, the total zooplankton increased in mean values of density and biomass up to 10 times the mean values in the decade 1960-1970, because of large populations of *Noctiluca* in the summer.

The zooplankton has experienced a substantial decline of the population (especially during 1990-1991) and a decrease of the catches of plankton-feeding fish species concomitantly with the appearance in the Black Sea waters of the ctenophore *Mneniopsis leidyi* (a big consumer of plankton and fish larvae). For the ecosystem components of the Black Sea as a whole, the inseparable relationship between the dynamics of the structure of biocoenoses with space and time, as well as the variable character of dynamic processes at community level, became obvious during the last thirty years.

The number of bottom fish inhabiting the shallow coastal waters sharply declined because of hypoxia. Pelagic fish have also undergone changes in the last two to three decades. Changes in the Black Sea ecosystem were reflected in the taxonomic composition of commercial catches.

Three species of dolphins inhabit the Black Sea. At present all riparian countries withhold from fishing for these marine mammals. However, in spite of this measure, their standing stock continued to decline.

Dr. Mihnea (Rumania) provided additional information on the plankton ecology of the Black Sea.

Ammonia and urea levels have increased in the Black Sea. Dissolved organic matter (DOM) is also at a high level; these increases are accompanied by increased bacterial activity. The phytoplanktonic community now has a high biomass. New species of *Chrysophyta*, *Dinoflagellata* and *Cyanophyta* have been reported. In general, the proportion of haplophytic forms has increased with increasing BOD levels. Light penetration is now much reduced, even within the first half metre; hence the euphotic layer is also greatly reduced.

The phytoplankton production is such that it cannot all be consumed by the zooplankton. Excess dissolved and particulate organic matter is responsible for increased levels of ammonia and hydrogen sulphide (anoxia). Although the zooplankton biomass has increased in response to the high phytoplankton standing crop, there has been a dramatic reduction in the number of zooplankton species. Similar changes have been observed in the benthic fauna, whereas fish abundance has more simply decreased.

Dr. Mihnea believed that it would now be better to deal with such eutrophic phenomena through an energy/matter flux approach to ecosystem analysis, for which increased regional co-operation would be necessary.

Dr. Saydam gave some additional information on the Black Sea with particular reference to the Sea of Marmara.

The Black Sea is an anoxic basin, in strong contrast to the Levantine Basin in the Mediterranean. The Black Sea is an exporter of low-salinity surface water, via the Sea of Marmara, but there is an inverse compensatory movement of more saline water at depth from the Aegean Sea. About 12 000 years BP, the Black Sea was a freshwater lake, becoming progressively brackish ever since. The present average salinity is $17\text{-}19 \times /10^{-3}$. It is also tideless.

The nitrogen and oxygen maxima in the Black Sea vary in depth but are closely related to the density field. The nitrate maximum, at $6\text{-}8 \mu g/dm^{-3}$, is at about the 15.4 isopycnal level. The first phosphate maximum also <u>starts</u> at this level, but its maximum value occurs at the 16.2 isopycnal level. This distribution is a very conservative feature, since graphs for 1987, 1988, 1990 and 1991 are very similar to each other. What is more, Russian data also agreed closely with the Turkish results. Anoxia is considered to be established at the 16.2 isopycnal level, and the beginning of the suboxic layer is also at about the 15.4 isopycnal level. There are, however, seasonal variations in the oxic, suboxic and anoxic layers, but they maintain a surprisingly constant relation to each other.

The anoxic volume is about 95% of the total volume. It is therefore possible to establish rather a precise relationship with the density field: pycnocline (15.4) - nitrate maximum (15.4) - nitrite maximum (15.8) - anoxic layer (16.2). Adequate precision requires high-quality CTD measurements, however.

The copepod density is just above the H_2S layer. However, silicate is the phytoplankton growth-limiting nutrient in the Black Sea.

Eutrophication has tended to move the dissolved-oxygen maximum nearer the surface and it has been discovered, by careful acoustic oceanographic observations that anchovy distribution is closely related to the oxygen level and the copepod distribution, within a range of about 4m: the top 2m of this range ensures an oxygenated environment; the bottom 2m, a supply of food. At any greater depth, suffocation by hydrogen sulphide will occur. It is a remarkable though not surprising adaptation to present conditions.

Dr. Konovalov gave a short talk on the comparison of eutrophication in the Black, Baltic and Mediterranean Seas and the Sea of Azov.

Dr. Konovalov noted that international co-operation in the study and comparison of large freshwater ecosystems was much more advanced than that of marine ecosystems.

He then gave detailed comparisons of these four seas in terms of their general geography, bathymetry, hydrography, effects of growing population pressure, particularly pollutant loads (metals, organochlorines and petroleum), nutrients and community structure. He explained that the predominant (i.e., very abundant) species indicating environmental stress in the Black Sea had been obsessed to alternate on an approximately decadal cycle, expressed as a sequence of *Noctiluca scintillans*, *Aurelia aurita* (jellyfish) and *Mneniopsis leidyi* (ctenophore).

Discussion

(i) Dr. Wasmund asked Dr. Mihnea about the role of bacteria.

Dr. Mihnea said that more work is certainly needed on this aspect, especially on the bacterial role in eutrophication.

(ii) Dr. Olenin asked about the role of shellfish and other filter feeders.

Dr. Mihnea explained that the growth of certain groups had been observed in the Black Sea, but one by one their abundance has declined, to the point even of forming faunal "deserts". There has, however, been some replacement by some short-lived fish species, some of which have been subject to fishery.

Dr. Halim noted that the amount of fresh water leaving the Black Sea had fallen considerably in the last thirty years, allowing the hydrogen sulphide level to rise. He believed however that the freshwater export had now become stabilized.

(iii) Dr. Savchuk asked what processes actually produce the nitrate maximum so closely associated with the pycnocline in the Black Sea?

Dr. Saydam believed this phenomenon was the result of several factors operating in a now stabilized system.

(iv) Dr. Johansson pointed out that copepods usually have a tendency to make large vertical migrations and expressed some surprise at their remarkable adaptation.

Dr. Saydam stressed the fact that the Black Sea ecosystem had progressively changed from a grazing to a detrital feeding type, to which the flora and fauna had to adapt.

(v) Dr. Moncheva asked Dr. Saydam why the phosphate levels are so low, and whether they even reach the zero level.

Dr. Saydam thought zero levels were possible; however, it is unlikely that, with high nitrate levels due to the high content of DOM/POM in the upper water layer, zero levels of phosphate would exist.

Dr. Sherman felt that the comparison of LMEs, which he considered most useful, had been firmly supported by the success of Dr. Konovalov's information on the Black Sea.

3.6 THE MEDITERRANEAN ACTION PLAN WITH SPECIAL REFERENCE TO EUTROPHICATION AND PLANKTON BLOOMS

Dr. Gabriel Gabrielides (FAO) made this presentation.

The steadily growing pollution in the Mediterranean Sea has become a considerable cause of concern, and various activities have been initiated to safeguard marine and human resources in the region. As early as 1969, FAO's General Fisheries Council for the Mediterranean (GFCM) established a Working Party on Marine Pollution in Relation to the Protection of Living Resources in the Mediterranean which, in co-operation with the International Commission for the Scientific Exploration of the Mediterranean Sea (ICSEM), produced the first comprehensive review of the state of marine pollution in the Mediterranean. As a follow-up, in 1974, FAO (GFCM) organized two meetings on the protection of living resources and fisheries from pollution in the Mediterranean. In the same year, an International Workshop on Marine Pollution in the Mediterranean was held in Monaco. This Workshop, organized by IOC and co-sponsored by FAO (GFCM), ICSEM and UNEP, reviewed major pollution problems of the area and recommended co-operative projects.

After its creation in 1972 to co-ordinate environmental activities within the UN system, UNEP promoted the establishment of regional seas programmes, starting with the Mediterranean. In late 1974 UNEP established a "task force" of selected scientists, experts and government officials who joined with representatives of FAO, WHO, IMCO (now IMO) and IOC to draw up the elements of an Action Plan for the region. This Action Plan, which was approved in early 1974 by the Mediterranean Coastal States meeting in Barcelona, was initially funded by UNEP which is still acting as the secretariat and administers the Mediterranean Trust Fund.

At a second meeting in Barcelona early in 1976, the participating States and the European Economic Community (EEC) adopted the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention) and two related protocols on: (i) the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft (Dumping Protocol); (ii) on Co-operation in Combatting Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency (Emergency Protocol).

The Barcelona Convention and the two initial protocols, which have now been ratified by 18 States and the EEC, entered into force in 1978.

Since then, the Mediterranean States have adopted, in 1980, the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources (LBS protocol), and in 1982, the Protocol on Specially Protected Areas (SPA protocol). The former entered into force in 1983 and the latter in 1986. It is expected that a new protocol will be adopted soon concerning the Protection of the Mediterranean Sea against Pollution Resulting from Exploration and Exploitation of the Continental Shelf and the Sea-bed and its Sub-soil.

For the implementation of the Emergency Protocol, the UNEP-IMO Regional Marine Pollution Emergency Response Centre (REMPEC) was created in Malta, whereas for the implementation of the SPA protocol, the Regional Activity Centre for Specially Protected Areas was created in Tunis.

The Mediterranean Action Plan has two basic components: The socio-economic component and the scientific/technical component. The socio-economic component was adopted in 1977 and is implemented by two of the regional centres. These are the Regional Activity Centres of the Blue Plan, in Sophia-Antipolis (France), and of the Priority Actions Programme, in Split, Croatia. The scientific and technical component is implemented through the Co-ordinating Unit for the Mediterranean Action Plan which is located in Athens.

The MED POL programme has traditionally been interested in studying the effects of pollutants on organisms, communities and ecosystems. Phase I, which ended in 1981, consisted of baseline studies and pilot projects. FAO (GFCM) was responsible for the technical co-ordination of four of them, namely: (i) baseline studies and monitoring of metals, particularly mercury and cadmium, in marine organisms; (ii) baseline studies and monitoring of DDT, PCBs and other chlorinated hydrocarbons in marine organisms; (iii) research on the effects of pollutants on marine organisms and their populations; and (iv) research on the effects of pollutants on marine communities and ecosystems.

MED POL Phase II is organized on a different basis from Phase I, and is divided into two main components: monitoring and research. The monitoring component is designed to provide information on the amounts and types of pollutants reaching the marine environment, and on the state of pollution of the coastal and offshore waters. The research component initially covered twelve research and study areas, four of which were: (i) research on the toxicity, persistence, bioaccumulation, carcinogenicity and mutagenicity of pollutants; (ii) research on eutrophication and concomitant plankton blooms; (iii) study of ecosystem modifications in areas influenced by pollutants, and in areas where ecosystem modifications are caused by coastal or inland engineering; and (iv) effects of thermal discharges on marine and coastal ecosystems.

More recently, the research component has been revised and restructured into just five research areas. This is partly a reflection of the fact that, as the programme developed, many relevant areas of study no longer fitted into the original topic areas and were found to require a more inter-disciplinary approach. The present five areas of research are: (i) Characterization and Measurement - the identification of chemical or microbiological hazards (characterization) and development and testing of methods for specified contaminants (measurement); (ii) Transport and Dispersion - the physical, chemical and biological mechanisms that transport potential pollutants from their sources to their ultimate sinks, priority being given to the provision of quantitative information ultimately useful for system modelling and regional assessments; (iii) Effects - of selected contaminants on marine organisms, communities and ecosystems or on human populations, priority being given to the provision of information useful for establishing environmental quality criteria; (iv) Fates/Environmental Transformation - of contaminants in the marine environment including persistence, bioaccumulation, transformation or degradation, etc., but excluding transport and dispersion (see (ii), above); (v) Prevention and Control - study of the factors determining the efficiency of waste treatment and disposal methods under specific local conditions, as well as the development of environmental quality criteria and common measures for pollution abatement.

Regarding financial assistance and training between 1982 and 1989, 150 institutions implemented 361 research projects and shared a Mediterranean Trust Fund contribution of US$ 2,151,595.

In the framework of the monitoring component of MED POL a number of fellowships and training grants are provided to Mediterranean scientists participating in the programme, especially those from the less developed countries.

The problem of eutrophication and plankton blooms, which has grown worse in recent years in many areas of the Mediterranean region, has been the subject of discussion at a number of meetings organized in the framework of the Mediterranean Action Plan. A UNESCO-FAO-UNEP Workshop on Eutrophication in the Mediterranean Sea: Receiving Capacity and Monitoring of Long-term Effects was held in Bologna in March 1987. This scientific workshop agreed a set of "Guidelines for the Monitoring, Assessment and Control of Eutrophication in the Mediterranean Sea" and made certain recommendations with the aim of providing guidance to the scientific community and national authorities concerned.

A UNEP-FAO-IOC-WHO meeting of experts on the Implications and Control of Undesirable Plankton Blooms was held in Athens in April 1989. The meeting discussed the causes and effects of plankton blooms as well as possible preventive and remedial action.

Following a recommendation of the Inter-Agency Advisory Committee for the MED POL, the Contracting Parties to the Barcelona Convention decided, in October 1991, that 50% of the MED POL research budget for 1992/93 should be allocated for projects on eutrophication and plankton blooms. To implement this decision, a consultation meeting was convened in Athens in March 1992 to prepare a detailed workplan for a regional programme. The expert group recommended, as the best approach, the organization of case studies in selected Mediterranean areas where the problems of eutrophication are evident and where scientific work had already been going on. The group recommended areas representing lagoons, closed bays and straight coastlines. Two case studies (Thermaikos Bay and the Emilia-Romagna coast) are now under preparation and will be initiated soon.

Discussion

(i) Dr. Alheit asked whether UNEP had identified training needs in the Mediterranean region in the field of eutrophication and algal blooms, and how was co-operation with Black Sea research workers being promoted.

Dr. Gabrielides explained that these needs remain to be defined, which was one reason why the UNEP MEDAP Co-ordinating Unit had co-sponsored the present workshop. The Black Sea, however, was not included in MEDAP. A Black Sea Action Plan has been developed and the experience of MEDAP would be applied there.

(ii) Dr. Halim stressed the need for training in ecosystem modelling, and for a regional programme on eutrophication, of which intercalibration would be a key component.

Dr. Saydam believed it was essential to promote interchanges between scientists.

Dr. Ignatiades expressed concern that marine pollution monitoring had been discontinued rather than continued and extended.

Dr. Korichi complained of the discontinuity in the technical assistance developed by UNEP.

Dr. Gabrielides explained that UNEP can only do what the Member States parties to the Barcelona Convention authorize it to do; moreover, it has to work exclusively through National Contact Points, so cannot ensure wide distribution of UNEP information within each country.

(iii) Dr. Aps asked how can UNEP Regional Seas Action Plans be used to help develop activities in other regions not covered by UNEP.

Again Dr. Gabrielides stressed that, after initial funding of MEDAP by UNEP, further development has been financed by the Mediterranean Trust Fund set up by the Member States, which also decide the budget. Now, the World Bank and the EEC are important sources of funding.

(iv) Dr. Ben Amour wanted to see co-operation between MEDAP and MEDRAP (Mediterranean Regional Aquaculture Programme) to reduce eutrophication due to aquaculture.

Dr. Gabrielides pointed out that, although MEDRAP had been initiated by MEDAP it had later been financed independently by UNDP and was no longer an active programme.

(v) Dr. Marasovic asked whether UNEP had ever organized intercalibration of phytoplankton measurements.

Dr. Gabrielides said it is still not clear how this could be done. He hoped that the present Workshop would make a recommendation on this question. One problem is that participating institutions agree to study selected species but in fact study others, making intercalibration virtually impossible.

3.7 ALGAL BLOOMS: A GENERAL OVERVIEW

Dr. Malte Elbrächter (Germany) made this presentation

Harmful algal blooms are a world-wide phenomenon and are increasing in frequency, extent and effect. They are harmful to Man because: their toxins contaminate human food and may kill fish; they may also kill fish by clogging their gills or by creating a very high oxygen demand to oxidize dead algal cells, leading to anoxic water; they may be present in aerosols which affect human health adversely (e.g., *Gymnodinium breve* in the Gulf of Mexico). Some algae produce sea foam (e.g., *Phaeocystis* in the North Sea), which is adverse to tourism, and some are moreover harmful without producing blooms.

While some blooms give the sea a brownish, whitish or a greenish colour, the best known are red and known as red tides. Normally, high cell numbers (at least 10^6 per cubic decimetre) are necessary for the red tides to be manifested as such, and likewise for the consequent effects.

Shellfish are common integrators of algal toxins and may cause quite serious illness when ingested. The common categories of toxins are: Paralytic Shellfish Poisoning (PSP) the toxins of which are called saxitoxin, gonyantoxin (and others); Neurotoxic Shellfish Poisoning (NSP) the main toxin of which is brevitoxin; D(Diarrhoetic)SP the toxins of which are ocadaic acid and related compounds; A(Amnesic)SP the toxin of which is domoic acid. The organisms commonly associated with harmfulness are diatoms and dinoflagellates and, to a lesser extent, Prymnesiophycae, some Cyanophycae and some Ciliata.

A relatively common disease, ciguatera, particularly in the Caribbean and the tropical Pacific, is due to ciguatoxin and related compounds which are accumulated by fish feeding on corals and algae on which the epiphytic dinoflagellate *Gambierdiscus toxicus* is growing.

Several Cyanobacteria genera (*Aphanigomenon*, *Microcystis*, *Nodularia* and *Oscillatoria*, for example) produce hepatotoxins. Several *Prymnesiophyta* genera (*Chrysocromulina* and *Prymnesium*, for example) produce ichthyotoxins, as do the dinoflagellates *Amphidinium carterae* and *Gymnodinium aureotum*.

How they are toxic is less clear. The toxicity may arise from endocytic bacteria in the algal cells, or from cell plasmids. Also, the level of toxicity is very variable in time in each species and depends appreciably on the ecological conditions. Some species (e.g., the dinoflagellate *Dinophysis*) have a high toxin content per cell so that counts of less than 10^3 per dm^3 may be sufficient to intoxicate shellfish.

The majority of the species reproduce by simple binary division, but the rate is very variable, depending mainly on ambient temperature, nutrient availability and light, the division rate increasing with increasing light and temperature. Salinity also has an effect, and the cells can migrate (vertically mainly) to attain the optimum "optical" depth in the middle of the day. The various possible combinations of environmental and ecophysiological factors, as well as the instantaneous standing crop, may explain the difficulty in determining the cause of algal bloom, harmful or otherwise.

Under certain adverse conditions cysts may be formed and survive in sea-bed sediments for long periods, but they can reproduce (sexually or otherwise) when forced back into convenient conditions in the water column. Nitrogen-deficient waters often promote cyst formation. Some cyst toxins are much more powerful than those of free-living vegetative cells.

Some algae are distributed widely by ships (especially those taking on or discharging sea water to maintain optimum vessel stability).

Regarding research and training, the need for these is often felt with respect to: (i) selection of aquaculture sites; (ii) toxin analysis;

(iii) taxonomy; (iv) monitoring; (v) phytoplankton culture; (vi) culture collection; (vii) ecophysiological studies; (viii) determining the links to physical oceanography.

Discussion

(i) The question of the link between eutrophication and algal blooms was raised.

Dr. Elbrächter said that the link is not simple and not yet clarified, although both require a relatively high abundance of nutrients. What actually triggers a bloom is not, however, known.

(ii) The question of whether the toxicity of the endocytic bacteria is hard to determine was also raised.

Dr. Elbrächter said yes, because the effects of the bacterial toxins are very variable. However, in general, algae are more, or even only, toxic when they contain endocytic bacteria.

3.8 PROBLEMS CAUSED BY HARMFUL ALGAL BLOOMS IN CHINA

Dr. Yuzao Qi (China) made the presentation; he reminded the Workshop that he was presenting this paper also on behalf of his co-authors Hong Ying, Qian Honling and Lu Shonhui.

The number, magnitude and economic impact of harmful algal blooms (commonly called "red tides") have increased dramatically in Chinese coastal waters in the last decade. These outbreaks have paralleled the expansion of mariculture, coastal development and international maritime traffic, suggesting that the red-tide problems are being worsened by coastal eutrophication, alteration of the hydrography and land-use patterns of coastal areas, and possibly the accidental introduction of harmful species. China now experiences a broad range of harmful events in coastal waters due to the noxious algal blooms.

Over 70 red-tide phytoplankton species have been identified in Chinese coastal waters; of these, the harmful, toxic or potentially toxic species include: *Alexandrium tamarense*, *A. catenella*, *Gymnodinium nagasakiense*, *G. catenatum*, *Cochlodinium catenatum*, *Pyrodinium bahamense*, *Noctiluca scintillans*, *Chattonella marina*, *Heterosigma akashiwo* and *Nitzschia pungens*.

Noctiluca scintillans blooms are now common along the entire coast of China. Some argue that the magnitude of these spectacular outbreaks has increased considerably, especially in eutrophic areas. In the estuary of the Yangtze River, a systematic increase in the number of *N. scintillans* blooms has been documented; they covered some 10 square kilometres in 1982, but increased to over 6100 square kilometres in 1988.

Although *Noctiluca* blooms are usually harmless, the outbreaks in China have been so severe that they have resulted in massive fish and shrimp mortalities.

Red-tides due to *Heterosigma akashiwo* first appeared in Dalian Bay in the north of China in 1985, and blooms have recurred there in each succeeding year until 1987. A related species, *Chattonella marina*, which is also implicated in massive fish kills, was first identified in Dapeng Bay in the South China Sea in 1991.

For an algal bloom to begin, a seed population of the species must be present to act as an inoculum. Several investigations have discovered dormant cysts along the coast of China. Some of the vegetative cells arising from these cysts were identified in Dapeng Bay, Daya Bay and Shenzhen Bay, in the South China Sea. The initial vegetative cells may excyst from the benthic cysts. When the cells are introduced into a physically more suitable area for growth, the population undergoes a rapid expansion to form a bloom.

Although red-tide phenomena have been recorded in China since the beginning of the last century, it is only in the last two decades that they have become a major problem that has justified a significant expansion in research.

In Daya Bay and Dapeng Bay, a *Rhizosolenia alata f. gracillina* bloom in April 1983 resulted in the death of many fish, shrimp and shellfish and devastation of 75 tons of fish catch and 1 ton of cage-cultivated fish.

In August 1987 a *Noctiluca scintillans* red tide occurred on the Zhejiang coast; many scallops and abalone were killed, yet, in April 1989, another *Noctiluca* red tide killed 11 000 tons of razor clam (valued at 30 million yuan) and one million yuans' worth of shrimp.

The most spectacular fatality and economic hardship caused by a red tide occurred in Bo-hai Bay, in 1989, between August and October; on the basis of incomplete statistics, the economic loss due to shrimp and fish mortality was 200 million yuan (ca. US$ 40 million).

Species that cause toxicity in human consumers of shellfish have also begun to make their presence known. In 1978, toxic snails were responsible for numerous poisonings in Zhejiang where levels as high as 37µg/g were recorded. The causative organism remains unknown. In December 1986, 136 people became sick and one died after eating the bivalve *Ruditapes philipinensis* in Xiamen, Fujian province. The causative species was tentatively identified as *Gymnodinium sp.* The toxicity test revealed that oral doses of 0.1-0.6 ml of the clam liquid caused 100% lethality of the tested mice within 8 hours. In 1991 there were 3 fatalities in the Dapeng Bay area of the South China Sea after shellfish were consumed, presumably from PSP, based on mouse-bioassay results. Preliminary examination of sediments from this area has revealed the presence of *Alexandrium* resting cysts.

This growing problem affects the coastlines of all of China's seas, but it is especially severe in embayments and areas where rivers enter the sea. However, it is supposed that all coastal regions are potentially at risk. There has also been speculation that the rapid expansion of mariculture in China, specifically the alteration of coastal wetlands for shrimp and fish-pond farming, has increased the eutrophication problem and led to more red-tide events. This effect could relate to the replacement of natural wetlands (which can cover and sequester nutrients) with man-made grow-out ponds that are highly enriched with fertilizers and that serve as sources of dissolved and particulate nutrients. The release of soluble inorganic nutrients from intensive fish and shrimp farming has the potential to cause eutrophication of water bodies. Investigation of the fish-cage culture area of Dapeng Bay in 1990 and 1991 showed that phosphate concentrations were up to 78.4 µg/dm^3 and nitrate up to 27.5 µg/dm^3; these values are much higher than those of non-fish-farming regions.

In parallel with the red-tide problem, Chinese research emphasis on red tides has also grown dramatically in recent years. Nationally co-ordinated projects were initiated in 1987 and in 1988 to investigate the East and South China Seas. A significant development occurred in 1990 when red tides were given the highest possible research ranking, which is accorded only to a few projects throughout all the scientific disciplines. The national red-tide programme involves eight institutions and universities, and over 100 scientists. The institutions include: the Institute of Hydrobiology, Jinan University; the South China Sea and East China Sea Branches of the State Oceanic Administration (SOA) of China; the Third Institute of Oceanography, SOA; the Institute of Oceanology and the South China Sea Institute of Oceanology, both of the Academia Sinica; the Institute of Environmental Science, Zhongsan University; and the South China Sea Institute of Fisheries, the Chinese Academy of Fisheries.

The four research priorities are: (i) biological basis of red tides (taxonomy, cultivation, life cycles, toxicology); (ii) experimental ecological studies (physiological requirements, growth characteristics, enclosed marine ecosystem experiment); (iii) monitoring (three-year monitoring programme at two sites in the South and East China Seas, plus major coastal cruises); and (iv) mathematical modelling.

<u>Discussion</u>

(i) Drs. Corrales and Ordoñez asked whether China was culturing *Pyrodinium bahamense* and was its occurrence limited to Daipeng Bay? They also wondered when it had first been observed, since there was a possibility that the organism may have been carried by currents from the Philippines region following blooms there.

Dr. Qi said that *P. bahamense* was proving very difficult to culture. He did not exclude the possibility of transport by currents from the Philippines.

(ii) Dr. Santhanam reported that *Noctiluca scintillans* blooms were often observed in India but are often greenish owing to symbiotic (or parasitic?) green algae in the cells.

Dr. Qi indicated that this was sometimes the case in China, but it is not known where it comes from.

(iii) Dr. Gonzalez asked whether standards for toxicity levels in shellfish had been established in China, and to what depth had toxins been found in the sediments.

Dr. Qi explained that standards are decided by the National Institute of Oceanography, and he did not know what these standards are.

(iv) Dr. Park asked whether *Heterosigma* blooms were causing fish kills and what was the mechanism. He also wished to know which species of *Gymnodinium* had been implicated in the illness caused in 1985-86.

Dr. Qi said he did not know the effects of specific *Heterosigma* blooms and it was only recently that they had been able to attempt an identification.

(v) Dr. Park also wished to know which species were being cultured in China, and whether Chinese research had revealed specific successions of red-tide organisms; in particular, is there a relation to the tidal regime?

Dr. Qi said it depends on the region. Work so far has concentrated on the South China Sea where diatom-flagellate-diatom sequences are observed. In the East China Sea, blue-green algae (*Trichodesmium*) blooms are more often observed.

Dr. Park explained that two species of *Gymnodinium* are commonly responsible for PSP, but in Korea only *G. catenatum* has been found to be toxic.

3.9 HARMFUL ALGAL BLOOMS AND FISHERIES

Dr. Karl Tangen (Norway) made this presentation.

Finfish and other marine life are constantly exposed to planktonic algae that occur in the free water masses in varying concentrations. In their food sources marine animals are exposed to chemical compounds derived from the algae. Negative and sometimes dramatic effects are observed in cases when toxin-producing algae exceed critical concentrations. Although the public and scientific attention has been attracted mainly to toxic algal blooms (red/green/brown tides) associated with mortality in fish farms or human poisoning due to consumption of toxic bivalves, there are indications that the negative effects on natural fish resources have been underestimated.

Primary negative effects on fisheries and commercial fish stocks include: (i) acute mortality of adult and larval stages of finfish after exposure to toxic algae or algal toxins dissolved in the seawater; (ii) mortality due to poisoning from algal toxins that contaminate the food-source of the fish; (iii) harvesting of natural stocks of bivalve molluscs banned due to accumulated algal toxins; and (iv) accumulation of algal toxins in finfish. One or more of these effects has been observed at irregular frequencies in much of the world, as documented abundantly during recent international conferences on harmful algae. Secondly, effects on the fisheries related to negative responses from the markets have been reported during a number of blooms. Usually, the blooms of, for example, the brown tide of the microalga *Aureococcus anophagefferens* on the northeast coast of USA, of the dinoflagellate *Gymnodinium breve* in the Gulf of Mexico and of the flagellate *Chrysochromulina polylepis* in Scandinavian waters, have been associated with a variety of noxious effects. Other blooms, as of PSP-producing dinoflagellates, may have a more limited range of effect on marine organisms, but have serious impacts on the harvest of natural stocks of bivalves which may become toxic due to accumulation of PSP toxins or other toxins.

In a recent bloom in Norwegian waters (summer 1992) of the PSP-producing dinoflagellate *Alexandrium excavatum*, mortality was observed in natural herring and flatfish stocks as a result of PSP accumulation in their natural food sources; i.e., zooplankton eaten by herring or sand-dwelling bivalves eaten by plaice. Another effect of planktonic algae on other marine life, particularly on benthic animals, as demersal fish, is through oxygen depletion. Hypoxia and associated fish kills seem to be an increasing problem world-wide, especially in nearshore eutrophicated waters. Attempts to assess the magnitude of economic losses after noxious algal blooms indicate that the negative consequences to the fisheries may be very significant.

The historical development of problems related to harmful algae in Norway may be representative for most nations that have a growing activity in their coastal zones, including the development of aquaculture and the public use of coastal resources for recreation purposes.

Important events include:

1860	First human intoxication (DSP)
1901	First PSP epidemic (two deaths)
1966	First bloom (in Europe) of *Gyrodinium aureolum*
1976	Mortality in fish farms due to *Gyrodinium aureolum*
1980	First documented DSP epidemic
1981	Massive wild fish mortality due to *Gyrodinium aureolum*
1986	Detection of new types of toxicity in mussels
1988	Massive mortality in fish farms and ecosystems due to *Chrysochromulina polylepis*
1989	*Prymnesium parvum* causes fish kills
1989	*Skeletonema costatum* associated with fish kills
1991	*Phaeocystis pouchettii* associated with fish kills
1991	Massive mortality in fish farms due to *Chrysochromulina leadbeateri*
1992	*Alexandrium excavatum* causes fish kills and human intoxication

This series of events clearly indicates that the frequency of harmful blooms is increasing, involving an increasing number of algal species from several algal classes.

In order to detect algal blooms as early as possible to reduce economic losses in fish farms and bivalve farms and for public health reasons, a monitoring and forecasting system is run by OCEANOR on contract with, for example, insurance companies and the state health authorities. The system is based on state-of-the-art technology, including continuous transmission of environmental data from anchored buoys along the coast, computerized information, and numerical models for forecasting. The low-tech elements in the system include daily data and weekly algal samples from local observers (fishfarmers) along the coast and traditional microscopic examination and interpretation of algae samples.

With this system, which has been operative since 1988, a large number of harmful blooms have been detected.

Discussion

(i) Dr. Ignatiades and Dr. Qi both asked whether the Norwegian researchers were successful in forecasting blooms.

Dr. Tangen admitted that it had not been easy but, with experience, their predictive capability had improved and allowed them to pick up early signs of blooms. Often, fronts were kept under observation. They also conducted hindcasting and evaluate blooms as they occur.

(ii) Dr. Indrani Karunasagar asked about combatting the problem?

Dr. Tangen explained that they try to prepare fish (in cages) to deal with stress; sometimes, cages are lowered into clearer water. In some cases the fish farmers are advised to start removing and processing the fish before the bloom reaches the fish farms.

(iii) Dr. Iddya Karunasagar asked which algal species had been used in tests on mice.

Dr. Tangen admitted that they still had a long way to go to determine which species were able to intoxicate, especially after the detection of toxicity in mice that could not be related to any known group of toxins.

(iv) Dr. Halim asked whether it was known what actually triggers a bloom.

Dr. Tangen suggested that light and water stability may play as big a role as nutrient concentration.

3.10 ENVIRONMENTAL ISSUES RELATED TO AQUACULTURE DEVELOPMENT

Dr. Harald Rosenthal (Germany) made this presentation.

World aquaculture production has increased substantially in recent years and in many regions aquaculture has been identified as the only growth sector within fisheries.

Aquaculture - as any other industry - has the potential to cause environmental problems: (i) those caused by aquaculture from land-based andwater-based systems; and (ii) those imposed on aquaculture by natural events and other human activities (e.g., competitive use of common resources).

In water-based systems (e.g., cage culture) the most important aspects to be considered relate to benthic enrichment, impact on water quality and primary production, and build-up of antibiotic resistance in sediments and benthic organisms.

Farm effluents from land-based systems should be considered in relation to total dry-weather flow of the recipient water and to appropriate management schemes.

Environment problems imposed on aquaculture are largely related to red-tide phenomena.

Techniques presently available and/or under development to mitigate negative environmental impacts caused by aquaculture include waste removal, improved feed technology, trends towards offshore culture and integrated semi-intensive farming systems.

Principles for developing a management scheme include site selection criteria, licensing practice, monitoring issues, health control and the assessment of holding and carrying capacity of designated areas in coastal waters. Fish-farm effluent standards have been proposed by EIFAC (European Inland Fisheries Advisory Commission of FAO) and ICES (International Council for the Exploration of the Sea). A decision model should be developed, based on the recommendations of the GESAMP Working Group on Reducing Environmental Impacts of Coastal Aquaculture.

Discussion

(i) Dr. Ibe reported a sharp drop in aquacultural production in Africa and asked why this had occurred.

Dr. Rosenthal thought that the problem had been that the approach used had been from the European standpoint and had not taken local socio-economic considerations into account.

(ii) Dr. Choo believed that aquaculture was often conducted at the expense of wild fish or shellfish resources. Valuable natural resources such as mangrove swamps were often taken over for aquaculture thus compromising those wild resources, often exploitable at lower cost, that depended on the mangrove ecosystem.

Dr. Rosenthal felt that this was a good reason for conducting very careful preparatory studies before initiating aquaculture.

(iii) Dr. Houvenaghel asked whether fouling continued to be a serious problem.

Dr. Rosenthal said it is; moreover, highly toxic tributyltin is still being used to combat fouling. However, some new anti-fouling paints are less toxic, and some new types of netting and cleaning techniques are proving helpful. To deal with the problem some aquaculturists are often induced to return to good husbandry.

(iv) Dr. Piyakarnchana asked whether the level of methane production by aquaculture was known.

Dr. Rosenthal did not have specific data to hand but offered to provide references.

3.11 MONITORING THE HEALTH OF LARGE MARINE ECOSYSTEMS

Dr. Ken Sherman (USA) made this presentation.

Human intervention and climate changes are sources of increasing variability in the natural productivity in the world oceans. The sources of large-scale changes in the yields of living marine resource species and pollution problems at the continental margins of marine ecosystems that impact on natural productivity cycles need to be addressed, including eutrophication from high nitrogen and phosphate effluent from estuaries, the presence of toxins in poorly treated waste-water discharge, and loss of wetland nursery areas to coastal development.

From the ecological perspective, the concept that critical processes controlling the structure and function of biological communities can best be addressed on a regional basis has been applied to ocean space in the utilization of marine ecosystems as distinct units for marine research, monitoring and management.

The concept of monitoring and managing environmental quality and renewable resources from a regional ecosystem perspective has been the topic of a series of symposia and workshops initiated in 1984 and continuing till now, wherein the geographic extent of each region is defined on the basis of ecological criteria. As the regional units under consideration are large, the term "Large Marine Ecosystem" (LME) is used to characterize them. Large marine ecosystems are extensive areas of ocean space of approximately 200 000 km^2 or greater characterized by distinct bathymetry, hydrography, productivity and trophically dependent populations. By monitoring selected components of the ecosystems, the changing states of ecosystems can be detected, and the source of the change, whether natural or due to human activities, identified; warnings of events with possible economic repercussions can be issued, and mitigation action directed to the sources of stress.

Although marine ecosystem sampling schemes and efforts vary among programmes (depending on habitats, species present, and specific regional concerns), they generally involve systematic collection and analyses of key ecosystem components and some level of regional-scale risk assessment. Among the parameters indexed in monitoring LMEs for variability in biomass are productivity (especially primary), resilience, stability, diversity and yield. Available information on factors influencing the natural productivity and the changing states and health of LMEs is synthesized in an effort to identify principal, secondary and, if considered important, tertiary driving forces causing major changes in ecosystem states and biomass yields.

Ecosystem "health" is a concept of wide interest for which a single precise scientific definition is problematical. The term is used to describe the following indices of the ecosystem in relation to the changing states and health of marine ecosystems: (i) diversity (the so-called biological diversity, a measure of the relative abundances of the biotic components of the ecosystem; these indices are not, at present, able to take species substitution effectively into account); (ii) stability (the tendency to return to equilibrium following a disturbance); (iii) resilience (the rate of return to equilibrium); (iv) productivity (the rate of creation of new biomass and its distribution through the ecosystem); (v) yield (the biomass that can be removed from the system without overcoming its inherent resilience).

The data from which to derive these experimental indices are obtained from time-series monitoring of key ecosystem parameters. A prototype effort to validate the utility of the indices is under development by the US National Oceanic and Atmospheric Administration (NOAA) and the US Environmental Protection Agency (EPA).

The ecosystem monitoring strategy is focused on parameters relating to the resources at risk of overexploitation, on species protected by legislative authority (marine mammals), and other key biological and physical components at the lower end of the food chain (plankton, nutrients, hydrography).

Discussion

(i) Dr. Rabbani asked whether decision-makers always wait for an estimate of a sustainable reduction in exploitation of an LME.

Dr. Sherman thought yes, but stressed that there is a need to cut "effort of exploitation" by 50% to reach a sustainable yield (of about one million tons) in the northwest Atlantic coast LME; this would imply significant socio-economic displacements in the coastal community (e.g., buying out a proportion of the present fishing community and converting the fishermen to other economic activities).

(ii) Dr. Gabrielides noted that many of the points made referred to pelagic organisms but asked whether they applied equally well to benthic organisms.

Dr. Sherman said no: bottom-fish catches are declining rather than increasing.

(iii) Dr. Johansson stressed the importance of not ignoring the microbial loop in the ecosystem; this loop may, however, be of varying importance from one system to another, but one cannot simply evaluate phytoplankton, zooplankton, nekton etc. in a semi-independent way.

Dr. Sherman agreed that this approach would be preferable though more difficult to achieve.

(iv) Dr. Piyakarnchana pointed out that the coastal zone is vulnerable to eutrophication owing to lack of sewage treatment. Developing countries often do not have the means to treat sewage, and certainly not at the tertiary level (i.e., to remove some nitrogen and phosphorus).

Dr. Sherman noted that tertiary treatment was even difficult for many developed countries; some recycling back to the land is a possible solution in some circumstances.

3.12 GLOBAL CHANGE: PHYSICAL AND BIOLOGICAL ASPECTS

Dr. Andy Bakun (FAO) made this presentation.

Monitoring and data analysis may be of doubtful value without some understanding of the mechanisms involved in the process or phenomenon being monitored. The classical scientific method for gaining insight into mechanisms is the experimental method, but it is very difficult to establish experimental controls on the ocean-atmosphere system. In fact, motion of the ocean makes it impossible to maintain the integrity of the volume of water in which an experiment is taking place without confining it in some way, thereby altering the basic processes themselves.

Sometimes, another classical method of science, the comparative method, may be used to substitute the naturally different conditions of differing regional situations for controlled variation of experimental conditions in providing the multiple views of a process required to draw scientific inferences.

Many marine ecosystems of the world share one striking attribute in their biological community structures. They typically contain a very large number of species at the lower (e.g., planktonic) trophic levels, and substantial number of species (e.g., predatory fishes, large coelenterates, sea birds, marine mammals, etc.) which, as adults at least, feed at the apex or near-apex levels. However, in many of the marine ecosystems of the world, there is often a crucial intermediate trophic level, occupied by small, plankton-feeding pelagic fishes, that is typically dominated by only one, or at most several, species.

For example, the fish biomass of temperate coastal upwelling systems tends to be dominated by one species of sardine and one species of anchovy, and most often only one of the two is dominant at any particular time. Similarly, temperate ecosystems influenced by western ocean boundary currents may be dominated by a single sardine species (e.g., *Sardinops sagax* in the Kuroshio region near Japan), an anchovy species (e.g., *Engraulis anchoita* in the Falkland/Malvinas Current of eastern South America), or a menhaden species (e.g., *Brevortia tyranus* in the Gulf Stream region off the eastern USA).

Tropical analogs of these temperate ocean ecosystems tend to be dominated by analogous tropical species: sardinellas, anchoviellas, thread herrings, etc. Other examples are the herring or sand-eels of boreal shelf ecosystems such as the North Sea, the Bering Sea, etc., and the capelin of the subarctic Atlantic. The krill of the Southern Ocean may represent an invertebrate analog. The German Bight is an important reproductive habitat for North Sea sprat; the recent decline of the anchovy population and massive increase of a newly introduced Ctenophore species in the Black Sea may be another example. Because of this typical community configuration, featuring many species at the bottom, many at the top, but constricted to a very few dominant species at the mid-level, these ecosystems have been referred to as **wasp-waist** ecosystems. Modelling studies have shown that variability in the trophic dynamics of these ecosystems tends to be largely dominated by variations in these mid-trophic level **wasp-waist** populations. These small pelagic planktivores tend to undergo radical population variations, and these variations may have major effects on the trophic levels above, which depend on the **wasp-waist** populations as their major food source, and on the trophic levels below, which are at times heavily grazed by the variable but massive **wasp-waist** populations. The small clupeoid fishes that most often constitute the **wasp-waist** population have notable "weak links" in their life cycles through which the variability in the physical ocean-atmosphere system is potentially able to exert direct control on their population dynamics, and thereby on the trophic dynamics of entire ecosystems. (This is one reason the Sardine-Anchovy Recruitment Project, or "SARP", was made the initial focus of the IOC-FAO Programme of Ocean Science in Relation to Living Resources.)

A general pattern is emerging from current studies wherein a combination of three general factors is associated with favourable reproductive habitat for coastal pelagic fishes. These factors are: (i) enrichment of the food web by physical processes (upwelling, mixing, etc.); (ii) opportunity for a concentrated patch structure of food particles to accumulate (stability, lack of active turbulent mixing, and/or strong convergence in frontal structures); (iii) availability of mechanisms promoting retention of larvae within (or transport of larvae to) appropriate habitat.

These three factors are not generally mutually compatible. For example, upwelling is a response to divergent horizontal flow. Upwelling and convergence therefore cannot directly coincide. Likewise, mixing may lead to enrichment but destroy vital small-scale concentrated structure in food particle distributions. Coastal upwelling, being induced by offshore surface transport, is directly linked to loss of larvae from the coastal habitat. The wind that drives the upwelling also mixes the upper ocean layer, destroying its structural stability.

Thus, the three factors can combine favourably only in special environmental configurations. Each factor must be present to a sufficient degree, but not to so overwhelming a degree as to preclude the others. Alternatively, the favourable configurations may involve temporal and spatial lags that allow effects of opposing processes to be mutually supportive.

Dr. Bakun presented examples from the northeastern Pacific and southwestern Atlantic to illustrate the importance of wind conditions and freshwater inflow in the maintenance of favourable reproductive habitat configurations. A key point is that the very restricted zones where material such as pollutants, toxic blooms, etc., are concentrated by physical processes, appear generally to be the very zones that biological adaptations have selected for the most vital life-cycle processes.

Runoff and wind appear to be subject to major alterations. In the second half of the 20th Century, global water use has been rising by 4-8% annually. It is continuing to grow in the developing world. And although it is stabilizing in industrial countries, withdrawals are nearly equal to locally generated runoff, and water quality has deteriorated markedly.

Human population growth, industrial development, deforestation, etc., which directly alter the properties and processes of the marine ecosystem are also apparently acting to change the basic climatic context in which these processes and properties operate. The concentrations of carbon dioxide and other "greenhouse" gases in the earth's atmosphere have increased significantly in recent decades, leading to predictions of global climate changes. Although there is presently some controversy as to the precise nature of the changes that may occur, the general scientific consensus is that substantial climate changes are likely to occur and to do so over a relatively short time (decades).

One "greenhouse effect" that seems rather certain to occur is an increased contrast in temperature between the land masses and the oceans during the warmer seasons. Such an increase of heating during spring and summer intensifies the thermal low-pressure cell over the coastal land mass which leads to an enhanced onshore-offshore pressure gradient between the continental thermal "low" and the oceanic "high" offshore. The stronger pressure gradient induces strengthened alongshore geostrophic wind, causing enhanced offshore Ekman transport and amplified coastal upwelling on either side of a continent and in either the northern or the southern hemisphere. The increased upwelling and mixing implied by such a wind increase, by cooling the coastal ocean surface layers and further accentuating the ocean-continent temperature contrast, might constitute a positive feedback loop leading to further amplification of the effect.

However, examination of coastal wind time-series in various eastern ocean coastal boundary regions suggests a consistent increasing trend. Likewise, continental lows appear to have been intensifying over the past several decades, and there are indications from sea-level measurements that the alongshore sea-level slopes are also increasing in a manner suggesting increased equatorward wind stress along the coast.

Relatively little study has been made of the potential effects of climate change on fresh-water runoff. It appears that many land areas would experience increases in precipitation while others may experience decreases. Certainly, reductions in winter snow storage due to increased winter temperatures will have important effects on seasonal runoff patterns. Marine ecosystems associated with mountainous drainage basins where precipitation is highly concentrated in the winter season, and are therefore dependent on snow melt for summer runoff, can be expected to be particularly affected.

An example of a possible scenario linking global climate change to harmful algal blooms is provided by the ocean adjacent to the west coast of the Iberian Peninsula. It is a "classic" eastern ocean coastal upwelling system. The upwelling process is most intense in spring and summer but declines in the fall (autumn) and winter. Nutrient-rich upwelled waters lead to high rates of organic production, a rich trophic pyramid and important local fisheries. Mariculture is a major industry in the Rías Bajas, a series of oceanic bays on the coast of Galicia, where intermittent enrichment during upwelling events supports intensive raft culture of mussels.

In this area, the toxic dinoflagellate *Gymnodinium catenatum* (Graham) was first observed in October 1976, coinciding with the first recorded outbreak of paralytic shellfish poisoning (PSP) in Spain. Over the past decade, PSP outbreaks have become a serious threat to the local mariculture industry. *G. catenum* blooms in the Galician Rias have been associated with the autumn relaxation of the summer upwelling.

If climate change does lead to increased upwelling intensity, the input of nutrients in the rías will increase, as will the primary production during the upwelling season (April-September). This will increase the production of particulate organic matter, notably increased fecal matter from increasingly well nourished mussels, which will enter the transport-sinking-decomposition-remineralization "loop". Thus, a greater accumulation of decaying organic matter on the bottom would result. Subsequent remineralization would lead to greater concentrations of nutrients in the layer beneath the deep nutricline following the upwelling season. Vertically migrating chain-forming motile phytoplankters such as *G. catenatum* might have the best access to this increased deep nutrient pool.

In addition, with increased intensity of upwelling, the sea surface slope along the coast of the Iberian Peninsula, as a reflexion of the density field, would also be expected to increase in an offshore sense. Thus, the initial reflux of the offshore surface water toward the coast upon cessation of the wind stress that produces the upwelling would tend to be intensified. Again, if the vertical migration capacities of forms such as *G. catenatum* provide them with a special competitive advantage in this situation, their bloom frequency might increase.

The following general conclusions may be drawn:

(i) The hydrodynamical advantages of increasing cell length may be an important factor in interpreting adaptive biological behaviour (and species successions, particularly of very small organisms).

(ii) Analysis of the use of the mechanical energy of the ocean-atmosphere system to augment trophic energy balance appears to offer a useful simplified framework for interpreting the effects of environmental variations and trends on biological processes and population dynamics.

(iii) Marine ecosystems in many ways do not operate as relatively homogeneous entities but are strongly patterned by physical mechanisms; calculations based on large-scale averages may turn out to be substantially in error.

(iv) The comparative method is advocated as a means of gaining insight into effects of global trends on marine processes.

Discussion

(i) Dr. Ignatiades asked whether observational data were available to support the proposed model for *Gymnodinium* dynamics.

Dr. Bakun said that experimental studies were under way but the results are not yet conclusive.

(ii) Dr. Wyatt noted that some mechanisms were established in the Pleistocene where marine conditions were quite different, so has there been time to evaluate the kinds of ecological adaptations being proposed?

Dr. Bakun explained that palaeo-ecological studies have shown that stronger upwelling occurred during periods of high solar activity; this evidence tends to corroborate the model he had proposed.

Dr. Tangen pointed out that many phytoplankton species do not take up nutrients in the dark, whereas the proposed model suggested that such uptake was light-independent.

(iii) Dr. Hempel thought that the "wasp-waist" model might not be the same everywhere and hence not be useful for comparisons between similar though distant ecosystems. The dominant species in one case may be, for example, sardine/anchovy, which replace each other, and, in another case, herring/jelly fish (as in the German Bight). Also, upwelling is usually considered to be good for fishing; however, it could add nutrients to a coastal system subject to upwelling and could therefore contribute to the development of coastal eutrophication, which may be bad for fish stocks, hence fishing. Is this so?

Dr. Bakun thought that such a contradiction was not an improbable *prima facie* conclusion, which may be right or not right, depending on local circumstances.

Dr. Alheit informed the Workshop that SARP (IOC-FAO Sardine/Anchovy Recruitment Project) studies have shown that the biological observations conform well to models suggested by Dr. Bakun and co-workers.

Dr. Twesukdi Piyakarnchana (Thailand) briefly described the eutrophication problems of the Gulf of Thailand.

This is a shallow semi-enclosed part of the South China Sea bordered by Thailand itself, Cambodia, Vietnam and Malaysia. The maximum depth of the Gulf is about 80 metres, and it can be divided geographically into an Inner Gulf and an Outer Gulf. The Inner Gulf is primarily influenced by the large output from five large rivers, while the Outer Gulf is influenced by the intrusion of water from the South China Sea. There is shallow upwelling along the middle part of the west coast and downwelling on the east coast of the Outer Gulf.

Natural eutrophication is frequently found in the upwelling areas. The dominant species here is a blue green algae, *Trichodesmium erythrium*. These areas are also the breeding ground of a species of chubmackerel *Rastrelliger brachysoma*.

In the Inner part of the Gulf, especially the areas near the river mouths, frequent blooms of phytoplankton have been observed since 1979; alarming increases in the extent of the blooms have also been noticed. Nowadays, these blooms are adversely affecting the tourist and fishery industries. The dominant species of these blooms are *Trichodesmium erythrium* (1983) and *Noctiluca scintillans*. No blooms of certain toxic PSP dinoflagellates have been reported, however.

The eutrophication mechanisms, and especially the effect of the river inputs to the Inner Gulf, were studied in 1988-1989. The results indicated that the concentrations of nitrogen and phosphorus in the wet season (August) were higher than at the beginning of the dry season (December). Nitrogen:phosphorus ratios were generally below 16. Therefore, that the estuarine ecosystems were probably nitrogen-limited.

The marine plankton species considered to be dominant in these eutrophication studies was the diatom, *Chaetoceros pseudoeurisetum*, which is also frequently the dominant species in red tides. *Noctiluca scintillans* was commonly found in the dry season at the high-water level of the Inner Gulf.

Dr. José Ordóñez (Philippines) presented an outline of the structures set up or being set up in the Philippines to deal with eutrophication problems within the fishery sector programme.

The principal objective of this programme is Institutional Strengthening. Its components are: (i) Resource and Ecological Assessment (REA); (ii) Coastal Resources Management (CRM); (iii) Red Tides (RT); and (iv) Aquaculture Site Assessment (ASA).

The Action Plan has twelve priority areas (bays, gulfs, etc.)

I REA:
- (i) Oceanography - physical, chemical, biological (plankton, benthos);
- (ii) Resource evaluation - pelagic fish, demersal fish, coral reefs etc.

II CRM: The goal is to move forwards community-based management:
- (i) Community organization (e.g., co-operatives);
- (ii) Devolution of the management function from central government to local government.

III RT: Study of areas of potential occurrence of red tides

IV ASA:
- (i) Assessment of existing aquaculture sites;
- (ii) Assessment of areas likely to be suitable for aquaculture (e.g., for sea needs) as an alternative livelihood.

4. TRAINING REQUIREMENTS

The Workshop decided to constitute two Sessional Working Groups to deal with the two main aspects of its work: a Sessional Working Group on Training Requirements in the Field of Eutrophication; and an Sessional Working Group on Training Requirements in the Field of Algal Blooms.

These two Sessional Working Groups were asked to report back to the Workshop.

4.1 TRAINING REQUIREMENTS IN THE FIELD OF EUTROPHICATION

The Sessional Working Group considered possible training needs in this field and made the following proposals.

Inter-regional Workshops

I. A Workshop on Integrated Coastal Zone Management with Respect to Eutrophication. This Workshop should be designed for decision-makers, managers and administrators, with the goal of increasing their awareness of the environmental consequences of uncontrolled economic development and the advantages of integrated coastal-zone development.

Rationale: Many important decisions, with potentially considerable adverse consequences, are often taken by high-level decision-makers, resource managers and public administrators on the basis of inadequate information on, or understanding of, the phenomena or processes principally determining the parameters of the system they are called upon to regulate, manage, monitor or control. While socio-economic, political or other non-technical circumstances may compel such poorly based decisions to be made, it is often more simply a question of their not having been given the basic knowledge required, or having been given a too highly technical explanation on which to base their decisions. It is therefore useful to provide such high-level officials with a basic understanding of what is at stake.

In the coastal zone, in the present context, this means an understanding of the main causes and effects of eutrophication, and of toxic algal blooms, which are often to be found as a result of uncontrolled discharges or unconsidered and disintegrated coastal-zone development.

II. A Workshop on the Evaluation of Relevant Existing Data on Eutrophication. This Workshop should be designed for scientists and technicians, increasing their capability to evaluate existing data with a view to assessing not only the state of eutrophication of the marine environment but also to understanding the processes involved.

Rationale: The detailed study of coastal-zone eutrophication is costly and there is, therefore, little room for error in the choice of areas, parameters, environmental components and organisms to be studied preferentially. A considerable amount of data taken in past studies of the coastal zone, but usually in a different context, is available and can be evaluated to reveal past variations and trends in certain parameters relevant to the study of eutrophication and harmful algal blooms. Such evaluation must be made in the context of the objectives of further planned studies and, to this end, scientists and technicians will benefit greatly from sharing experience in the evaluation and correct interpretation of existing data.

III. A Workshop on the Effects of Eutrophication on Fish Resources.

This Workshop is intended for scientists involved in fishery work.

Rationale: Besides training needs, there appears to be an important need to summarize the experience gained on the effects of eutrophication on fishery resources. Various accounts of possible beneficial effects of mildly increased nutrient input (on eastern Mediterranean pelagics, Dutch flatfish fisheries, for example) are sometimes cited, but there are also cases of disastrous dislocation and collapse of such resources.

In the "real" world of polarized political activities, it is important to provide a credible evaluation of the trade-offs and transitions from possible initial beneficial effects to serious, and perhaps irreversible, resource and ecosystem damage related to increasing eutrophication.

Inter-regional Training Courses

I Monitoring of Eutrophication in Coastal Waters as a Tool of Coastal-Zone Management.

This course should comprise: (a) the design of a conceptual model; (b) data handling and interpretation relevant to eutrophication; (c) verification of models and simulations.

Rationale: The problem can be discussed in terms of regenerative capacity of renewable resources. The equilibrium between input of nutrients and the carrying capacity of the environment should be considered in the implementation of an integrated system for the management of marine and coastal areas. Preserving the regenerative capacity of the environment means certain demands on the biological, physical and chemical state of the environment. The variables involved may be interpreted as "concentrations" of environmentally active agents at the places where organisms are to be found. The limit values sought for the "concentrations" are the sustainable standards.

Apart from the growing concern about the present and expected effects of eutrophication in coastal zones all over the world, there are also shortcomings in our understanding of the mechanisms involved. Such shortcomings are quickly felt when the eutrophication problem is addressed: from data acquisition to scientifically based decision-making. There is therefore an urgent need to provide those involved in coastal-zone studies and management with the basic knowledge of eutrophication and to demonstrate how a system approach and the use of a conceptual model of eutrophication can be applied to:

(i) The optimization of existing monitoring programmes;

(ii) The design of new goal-oriented ones; handling and evaluation of historical and newly collected data;

(iii) Development and exploitation of simulation models to study and to forecast reactions of ecosystems under different scenarios of natural variation and human impacts;

(iv) Elaboration of the information needed by decision-makers to help them to arrive at cost-effective solutions.

The conceptual model of eutrophication should take into account:

(i) Biogeochemical cycles (including mass balances, measurement of hydrochemical parameters) within the marine ecosystems;

(ii) External driving forces (natural and man-made);

(iii) Hydrodynamics; and,

(iv) Expected effects of eutrophication on the marine environment and their socio-economic consequences.

The development and optimization of monitoring programmes will require not only a conceptual model, but also the preliminary assessment of the current state of the marine environment as well as the state of knowledge required for such optimization; moreover, the elaboration of an observing system will require an evaluation of existing facilities and available resources, and the organization and exploitation of appropriate databases.

The interpretation and evaluation of the monitoring data will require:

(i) Statistical analysis to pick up trends in concentrations, biomasses;
(ii) The calculation and application of biological indices or indicators; and,
(iii) Mass balance evaluations.

Simulation modelling will require:

(i) Model development;

(ii) Calibration and verification of models;
(iii) Development of scenarios;
(iv) Conduct of simulations; and
(v) Improvement or adjustment of models.

II Biological Indices/Indicators, Using Statistical Ecology Models.

Rationale: Eutrophication can be recognized by changes in species composition and abundance, changes in the trophic structure of a biocenose and by the appearance (or disappearance) of particular species.

To identify biological features of eutrophication, evaluate the trophic status of a water body, the problem may be approached by the determination of shifts in the following parameters: (a) species composition and occurrence of particular species (indicators); (b) indices related to biomass (primary production; assimilation ratio; chlorophyll content of the water and organisms; cell numbers; diatom/flagellate ratio etc.); (c) indices related to biodiversity (species dominance, species diversity, evenness, richness, redundancy, etc.).

III Microbiological Processes Involved in Eutrophication.

Rationale: In recent years, evidence has grown that the role of microbiological processes is fundamental to many aspects of the problems posed by eutrophication. The understanding of the microbiological processes is essential to the search for the solution to such problems; also the modelling of the ecosystem is unsatisfactory unless these processes are adequately taken into account. In many countries there is an urgent need for specialized training for microbiologists to deal with the problems.

The training course should cover: (a) sampling problems; (b) isolation of strains from different environmental compartments; (c) the role of micro-organisms (e.g., bacteria, fungi) in the sulphur and nitrogen cycles; and (d) public health aspects.

IV Application of Remote-sensing Techniques to the Monitoring of Eutrophication

Rationale: The use of remote sensing techniques, especially from satellites and with especial emphasis on colour sensors (e.g., the NASA Coastal Zone Colour Scanner and the proposed NOAA sea-viewing, wide-field-of-view scanner), is important to the assessment of ecological changes due to eutrophication in an extensive coastal zone. These techniques provide a quasi-synoptic and repetitive series of observations of key parameters such as pigment fluorescence spectra, sea-surface reflectivity changes (as a result of changes in organic content, for example), sea-surface temperature changes (as an indicator of upwelling, convection and advection - i.e., coastal currents.

It is, however, necessary to familiarize scientists with the constraints on the use of such technology (low signal strength, atmospheric interference with signal transmission, significance and choice of specific spectral bands reflecting such processes as chlorophyll fluorescence, and the need for relevant ground-truth data, at worst, and considerable understanding of underlying ecological processes, at best), not only to improve the algorithms used to process the satellite data, but also to optimize the design, implementation and efficiency of monitoring systems and management programmes.

The use of other forms of remote sensing based on non-satellite systems such as fixed and drifting buoys, bottom pressure sensors, sea-level/tide gauges, etc. that transmit their data directly to receiving centres may also be envisaged.

4.2 TRAINING REQUIREMENTS IN THE FIELD OF ALGAL BLOOMS

This Sessional Working Group was constituted to develop proposals to meet specific training needs in this particular field.

The Sessional Working Group identified a range of topics in which it felt training was required and assigned priorities to them. Those that emerged as being of greatest importance were:

I Phytoplankton taxonomy;
II Toxins and toxicity;
III Data analysis and modelling;
IV Algal culture techniques;
V Water quality control and harmful algal blooms in aquaculture management.

The Sessional Working Group agreed that all the training courses and/or workshops proposed should be preceded by a "general module" of two days, in which participants would be given a broad perspective of the harmful algal blooms problem.

I Phytoplankton Taxonomy

The Sessional Working Group believed that advanced training courses should be designed for participants having a basic knowledge of phytoplanktology. The contents of such courses should be:

(i) Principles of the taxonomy of planktonic algae;
(ii) Methods of identification, particularly of the potentially harmful species;
(iii) Training in identification of species in mixed samples containing diatoms, dinoflagellates and flagellates;
(iv) Training in the use of the specialized literature and computer-based identification tools.

The proposed courses should last two weeks and comprise about fifteen participants.

The Sessional Working Group agreed that such courses were needed in: China; southeast Asia and the Pacific region; the Black and Mediterranean Seas; the Baltic and North Seas; and the Indian Ocean.

The Sessional Working Group recognized the value of the taxonomic identification computer programme known as "Linnaeus Protist" developed at the Institute of Marine Research in Bergen, Norway, with UNESCO support.

The Sessional Working Group recommended the further development of the system, particularly with a view to preparing regional versions as a high priority, and urged UNESCO to continue its support for the development of the "Linnaeus Protist" software.

II Toxins and Toxicity

The basic introductory course should cover toxins, their chemical properties, toxicological properties, and common examples thereof.

Besides this introduction to the topic, the Sessional Working Group recommended that each trainee's knowledge be updated according to each trainee's requirements. The identification of any lack should be made through a check list completed and returned by each candidate trainee before starting the programme.

The general view was that the main need is for training in toxicity testing for monitoring purposes (as opposed to research), and that the first essential of this training is to tackle sampling and preparation of potentially toxic materials.

The Sessional Working Group agreed that training should cover the use of mouse bioassay and of high-performance liquid chromatography (HPLC). It noted, however, that there remain some problems that are not always fully appreciated in the application of HPLC, which is nevertheless often considered to be an ideal tool for analysing toxins. This technique is delicate and sensitive. The cleaning up and extraction of the sample is a basic step where losses of target compounds may occur. The analysis, which requires precision equipment (expensive and difficult to run by an untrained operator) is difficult to perform so as to ensure satisfactory recovery; the better the recovery is, the better the overall accuracy of the procedure will be.

The application of this technique also requires standards for calibration purposes. These standards are not yet widely available and, in any case, certified toxins are expensive.

On the chemical side, besides the known target molecules, others may occur but not be detected. This is largely due to the changes occurring in toxin spectra in cells according to their developmental and physiological states. Moreover, transformation of toxin molecules within the digestive system of molluscs is not yet known but may lead to the production of undetectable compounds.

Participants in these training courses need to have a good knowledge of chemistry, organic chemistry and HPLC.

The Sessional Working Group recommended that the training be divided into three phases, 1 and 2 covering different levels of needs, and corresponding to different levels of technology required:

(i) mainly for routine monitoring or surveys or for fast and "easy" controls;

(ii) for high-tech laboratories in official agencies (veterinarian and public health services), fishery institutes and universities.

A third phase is described below.

Preparatory Phase

- Identification of known potentially harmful algae in the region and the associated or potentially associated toxins;
- Checking trainees' level of acquaintance with the problem, the prerequisites and the methods (completion of a checklist).

Phase 1

- Theoretical introduction to toxins and toxicologies;
- Sampling methods for toxin measurements in plankton and in filter feeders (molluscs, fishes etc.);
- Bioassay methods, according to needs and availability at the time of the training, including the use of mice, rats or chicken;
- Immunological methods available at the time of the training: ELISA procedures (theory) and ELISA kits for toxins;
- Practical work on bioassays immunotechniques to be performed on contaminated samples available or to be prepared during training;

- Demonstration of the HPLC method on those samples;
- Comparisons, correlation of results and conclusions.
- Final recommendations to set up surveys and controls taking into account the priorities (accuracy, speed, budget, number of analyses etc.)

Phase 2

- HPLC theory: refresher course;
- Choice of a HPLC and factors determining the choice of parts and accessories;
- Techniques in sample preparation and cleaning;
- Practical HPLC analysis;
- Calibrations, standards etc.

Phase 3

Post-training intercalibration exercise in HPLC, aimed at:

- Controlling the accuracy, the suitability or possible improvements of the existing HPLC infrastructure;
- Monitoring the skill of each team in preparing samples and in tuning up the procedure.

The Sessional Working Group also suggested that, owing to the fact that the training is aimed at improving analytical capabilities, participants in the training should only be people who are or will be directly involved in toxin surveys, monitoring or research.

Having recommended the foregoing elements of a training course on toxins and toxicity testing, the Sessional Working Group recommended that the following points be kept in mind.

When setting up a training session, part of the introductory information may be handed over to trainees before the session; this would save time and allow every participant to prepare himself at his own speed according to his previous experience in chemistry.

The mouse bioassay method requires equally stringent protocols if it is to be used efficiently, as comparisons between Spanish and Portuguese laboratories, for example, have shown. As in the case of HPLC, sample preparation is as important as the actual analysis. Also, although the public health applications of HPLC and bioassay methods are paramount, it is often the research input that maintains a public-health analytical laboratory up to the very best standards.

A course in toxin analysis should be held in a fully operational laboratory using these techniques, and not be held in the country requiring training. The number of participants in such a course might be 10-20 for a period of three weeks.

The Sessional Working Group agreed that a training course of the kind described above is required by all regions represented at the Workshop. However, the Philippines and Taiwan would need training only in the HPLC method, and a training course on seafood toxicity testing is required in the Mediterranean and Black Seas since most of the coastal countries there do not have the necessary expertise.

In the Baltic Sea, for example, heavy blooms of *Cyanobacteria* and *Dinoflagellata* occur regularly. Toxic effects are seldom noticed, however, perhaps because no shellfish are cultured there. The question is: are these algae, which are known to be toxic in other regions, really not toxic in the Baltic? Also, in recent years, fish and duck kills have been noticed in coastal waters, which have been related to toxic blooms of *Microcystis* and *Prymnesium*. Allergic reactions in man (when swimming) may also be related to algal toxins, but the precise mechanism remains unknown.

To answer these questions, a toxicity testing programme has to be undertaken. Baltic marine biologists have no experience in this field and training is required. Taxonomic training is also necessary. Groups of especial interest are: *Cyanobacteria* (filamentous as well as coccal picoplanktonic species), *Flagellata* (including cysts), and *Haptophyceae*.

III Data Analysis and Modelling

The Sessional Working Group believed that such courses should cover computer programmes and software, statistical teaching, the setting up of data bases, and some standardization of criteria (for assessing water quality, for example). The training should also give attention to the problem of ways by which the results of data analysis are translated into management strategies, in addition to their role in advancing ecological understanding.

Outbreaks of *Pyrodinium* red tides are a common problem among some Indo-West Pacific countries such as Palau, Papua New Guinea, the Philippines, Malaysia, Brunei, in Latin America (Guatemala, Venezuela) and in China. These outbreaks have caused negative health impacts and large economic losses in the southeast Asian region. Many of these countries have established their own monitoring systems following the recommendations made during the IOC-supported Workshop on Biology, Epidemiology and Management of *Pyrodinium* blooms, held in Brunei in 1989.

Large amounts of data have been gathered on the physico-chemical characteristics of the coastal regions before, during and after the blooms, as well as plankton distributions and shellfish toxicity patterns.

There is now an urgent need to analyse these data sets at national and regional levels for modelling that could be used to develop improved monitoring and management strategies.

Hence, the Sessional Working Group proposed that regional training courses on data analysis and modelling, with particular reference to the management of *Pyrodinium* red tides be held as soon as possible. It proposed four such courses, which are briefly described below.

Scientists/fishery biologists and managers involved in monitoring and in dealing with *Pyrodinium* problems should be invited to the proposed training/workshop. Data sets from each country should be made available for the training/workshop. At least four participants from each country should be involved.

The areas proposed to be covered are:

China

Here there is an abundance of trained statisticians, but a need to find ways of crossing disciplinary boundaries by involving physical and chemical oceanographers, meteorologists and biologists in interdisciplinary efforts. Thus training in the philosophy of ecosystem modelling would be an essential component of such a course.

Western Pacific

This proposed Training Course should use the data bases that already exist on the toxic dinoflagellate *Pyrodinium bahamense*, from Malaysia, Indonesia, Philippines and other concerned countries of the region. Such a training course or workshop would constitute an excellent follow-up to that held in Brunei-Darussalem in 1989 on the basic ecology of *Pyrodinium*.

Eastern Mediterranean and Black Sea

Here the need was identified for training in statistical methods, data interpretation, and ecological theory. Excellent data series exist in Rumania, Bulgaria, Turkey, Greece and Croatia, and could provide the materials for a course of this nature. The training needs identified by participants from this region coincide with those discussed by the ICES Sessional Working Group on Harmful Algal Blooms (Vigo 1992), where it was concluded that the processes controlling the population dynamics of harmful blooms present problems requiring urgent solutions.

India, Bangladesh, Pakistan

Although there is considerable data-handling capability in this region, there is a need for basic training on all aspects of data analysis and modelling as applied to toxic algal blooms, which are common in the region's coastal areas.

IV Algal Culture Techniques

Several participants (from Rumania, Bulgaria, India, the Philippines and Thailand) expressed the need to learn culture techniques for microalgae in order to establish culture collections, to provide materials for ecophysiological studies and, in the case of toxic species, to provide sufficient quantities of toxins for identification and analysis, with the aim of defining their specific toxicity.

Culturing algae is a highly specialized activity and different species have different requirements. It is also necessary to initiate cultures from cysts since cysts can initiate blooms. The conditions that lead to germination (and encystment) are important components of bloom dynamics.

V Water Quality Control and Harmful Algal Blooms in Aquaculture Management

The Sessional Working Group recalled that test-kits for water quality control are often used by aquaculturists, fish veterinarians and by field stations of government and university laboratories. These kits are cheap and handy, but their reliability depends on a number of conditions. Most users are unaware of how sampling and handling of the test-kit procedures influence the results. Unfortunately, the manuals provided by companies producing test-kits are often incomplete, not sufficiently detailed to allow proper interpretation of the importance of interfering factors and sometimes even misleading.

There is also a lack of awareness as to which test-kit is most suitable for which type of water. In past studies it has been shown that results using the same test-kit on ostensibly similar samples may deviate by 200% and more, depending on how users employ the procedure.

The Sessional Working Group concluded that training is required on sampling, handling (storage) and processing of water samples and on how to use the commonly available water-quality test-kits in order to improve the quality of data derived from their use. Trainees should include scientists, fishery officers and fishermen, and others who assist in basic data gathering. The quality parameters should include temperature, salinity, Secchi disc reading, ammonia and nitrate concentrations, pH-values, and others, as appropriate.

The five preceding sections summarize those training needs which were clearly perceived by the Sessional Working Group to be of importance in all regions. The Sessional Working Group also recognized that many countries that were not represented at this meeting might have identified additional training requirements had they been present.

The Sessional Working Group also identified additional training required.

Monitoring

Three aspects were discussed, with particular reference to: (i) water quality, specifically in relation to existing aquaculture facilities and the rational siting of future installations; (ii) phytoplankton species changes and the identification of potentially harmful species; (iii) toxicity testing in order to provide warnings to public health authorities that farmed and wild seafoods may be unsafe for marketing and consumption.

The requirements of (i) and (ii) overlap, as phytoplankton sampling and measurement of environmental parameters (S, T, O_2, nutrients) are normally features of both procedures; (ii) and (iii) are also related, since the former provides a useful guide to the frequency of toxicity monitoring required.

The Sessional Working Group identified several problems that need to be solved before existing monitoring programmes can be improved, or before new ones can be implemented. These are: (i) a lack of general strategic principles for location of monitoring stations, and sometimes a lack of adequate background hydrographic information on which such principles need to lean; (ii) insufficient diffusion of information on bioassay procedures, high-performance liquid chromatography (HPLC), analytical kits and other analytical techniques, on their use and reliability in different environments, and on the protocols that allow them to be used effectively; (iii) lack of regionally up-to-date identification guides and other media (e.g., videos) with which to improve the quality of taxonomic information generated by monitoring.

The Sessional Working Group decided that, at this stage, it would not recommend a specific training course on monitoring, since the subject could be included in the two-day preparatory sessions ("general module") recommended hereabove for all workshops and training courses proposed herein.

Risk Assessment, Contingency Planning and Management of Harmful Algal Blooms

Early detection of harmful algal blooms is the basis of adequate operations aimed at reducing economic losses in aquaculture and the risk of human intoxication. Monitoring networks and procedures should be integrated into risk assessment and contingency planning on national and local levels. A training course on this subject could help decision makers (e.g., representatives of local governments and legislators, aquaculture managers and food quality controllers and scientists) in the development and implementation of monitoring programmes and contingency plans.

Management

Algal blooms are a major constraint to the sustainable development of coastal aquaculture in many parts of the world. There is a need to include environmental issues, such as the assessment of risks of harmful algal blooms, into the overall management scheme for aquaculture development as part of coastal zone management plans. In the past, licensing authorities and the industry have not considered algal blooms as an important factor in defining site selection criteria in many developing countries.

There is therefore a training need at all levels on how existing management schemes (decision models) employed elsewhere can be effectively used.

Scientific Project and Communication Centre

The Sessional Working Group supported the IOC's efforts to set up a Scientific Project and Communication Centre to act as a depository of information on such algae, for use by the international community, particularly the marine scientific component thereof. The material, which could be sought actively or received passively, could comprise reports, theses, case studies, veterinary information, relevant governmental or administrative statutes or administrative decisions on shellfish marketing and trade, for example. The Centre could also envisage the preparation of specific (i.e., regional or technical) information syntheses. It could be equipped and staffed to dispatch information to developing countries, on request, by mail, telefacsimile or electronic mail, as appropriate.

Manuals

There is a clear need for up-to-date manuals addressing regional taxonomic problems, as well as manuals on methods. Dr. Henrik Enevoldsen of the IOC informed the Sessional Working Group that IOC has decided to publish a manual on methods used in harmful alga research; he invited the participants to give him their views on the contents of such a manual.

The Sessional Working Group received this news enthusiastically and strongly supported the IOC initiatives.

Leaflets

The Sessional Working Group felt that leaflets should be made available, together with other materials (Secchi discs, nets, microscopes, etc.) suitable for the use of aquaculturists, to help them to become aware of potentially harmful developments by routine monitoring of the quality of the water surrounding their installations. The Sessional Working Group recommended that these leaflets contain illustrations of the species likely to cause problems, and, if feasible, be made available in local languages. It recognized, however, that this was not an easy requirement; there are five major languages in the Philippines, and seven relevant ones in India. However, the Sessional Working Group suggested the predominant use of illustrations and/or photographs in the leaflets with a minimum of text. Leaflets should also include a brief description of symptoms of intoxication and of the main ecological manifestations of a bloom.

Video-materials

The Sessional Working Group agreed that educational videos would be valuable for helping aquaculturists and others to become aware of the problems created by harmful algal blooms. One produced by Professor F.J.R. Taylor (University of British Columbia, Canada) could provide a model for other regions; it contains an introduction to the kinds of problems algae can cause, images of the species involved and of the different ways in which they can be sampled, an outline of microscopic techniques, and a description of the monitoring system in British Columbia, Canada.

Increasing public awareness

The magnitude of the effects due to harmful alga events are often closely related to the level of knowledge among fishery and aquaculture managers and the general public. A high level of information is crucial to minimize or avoid negative economic and health effects. Harmful alga events often receive extensive press coverage which can over-emphasize the real danger of a specific event. This can prolong the period during which the economic impact on fisheries and aquaculture (reduced fish and fish-product sales) is maintained.

To prevent the popular press from exaggerating the dangers, it is often sufficient for an authoritative ministerial press release to be made available weekly to the media by representatives of various government institutions responsible for the protection of public health and the environment. This approach is used in Manila to reduce significantly the chaos created by inaccurate media reporting; after the issuance of the first paid update, following a major event in 1988, no additional cases were reported. The cost of such publication is, however, high.

The First Session of the IOC-FAO **ad hoc** Intergovernmental Panel on HAB endorsed a programme on Harmful Algal Blooms. This programme consists of three main elements: (i) Educational Elements; (ii) Scientific Elements;

and (iii) Operational Elements.

The Sessional Working Group agreed that there is a basic need for information for the general public and that these needs should be identified in the relevant regions. This should be carried on in co-operation with organizations with expertise in basic education and public awareness. UNESCO, through its Education Sector, is an appropriate organization and the Sessional Working Group urged IOC to investigate the possibilities of such co-operation.

5. CONCLUSIONS

The Workshop considered carefully the proposals and recommendations of the two Sessional Working Groups and fully endorsed their findings.

It recognized the valuable contribution these findings would make to the development of the specialized fields of study represented by eutrophication in semi-enclosed seas and algal blooms, especially harmful ones.

The Workshop hoped that its efforts to identify training requirements in these fields would add to, and not duplicate, any other international efforts in this direction. It thus hoped that the proposals would, if implemented, contribute to increased understanding and greater public awareness of the problems posed.

In particular, the Workshop expressed the hope that its outcome would be beneficial to the IOC-FAO Programme of Ocean Science in Relation to Living Resources (OSLR), on the technical side, and to the IOC Programme of Training, Education and Mutual Assistance in the Marine Sciences (TEMA), on the capacity-development side.

The Workshop particularly appreciated the effort of the Government of the State of Bremen, and of the Bremen Maritime Training Centre, in providing the facilities and positive atmosphere for the discussions that had taken place, and expressed the hope that the State of Bremen would be able to make a major contribution to the implementation of the Workshop's recommendations, in the context of its international development activities.

6. CLOSURE

As Chairman and as the original conceiver of the Workshop, Dr. Jürgen Alheit expressed his satisfaction with the way the Workshop had proceeded, in a friendly and constructive spirit, and with the results obtained. The twelve keynote speakers and six supporting speakers had provided a considerable amount of background information on which to base the conclusions and recommendations emanating from the Workshop.

He felt that the key difficulties, which require the organization and conduct of several workshops and training courses on specific themes, had been fully identified by the two Sessional Working Groups - on Eutrophication and on Algal Blooms - set up to address these two related but distinct subjects, and, to the extent possible, priorities had been established, although these might vary from one region to another.

He expressed his appreciation to the State of Bremen, as the sponsor and to the Bremen Maritime Training Centre and POLARMAR GmbH as the organizers of the Workshop, and to the co-sponsors for their kind support.

He particularly thanked the staff of BMTC and of POLARMAR for the hard work they had all put in to make the Workshop a success. Finally, he thanked Dr. Rolf Schneider, of the Baltic Sea Research Institute, for assisting him as Co-Chairman, and the two Rapporteurs, Messrs. Griffiths and Wyatt, for ensuring the proper preparation of the Report of the Workshop which would be sent to participants very soon.

On behalf of the State of Bremen, Dr. Gunther Hilliges expressed his thanks to all those who, in one capacity or another, had helped to make a success of the Workshop. He recalled that Mrs. Brundtland, the Norwegian Prime Minister and Chairman of the World Environment Commission, had once said that knowledge often exceeds the structures available to apply it. But both are essential if sustainable development is to be achieved. The present Workshop had been, he believed, a small but important brick in the construction of the sustainable development edifice. This was due in no small measure to Dr. Alheit's persistence in pursuing the support of the State Government for this Workshop.

Finally he expressed the satisfaction of BMTC and the State Government with the outcome of the Workshop, and thanked the co-sponsors and POLARMAR for their considerable help. He was also pleased with the help given by the IOC and FAO and with the active participation of their representatives in the Workshop.

Mrs. Ursula Nix, on behalf of BMTC, and Dr. Wolfgang Welsch, on behalf of POLARMAR, thanked the participants for their enthusiastic participation and their very useful recommendations.

Finally Dr. Pia-Elena Mihnea, of Rumania, expressed the satisfaction of all the invited participants for the very kind hospitality they had received from the host government institutions and staff, and with the excellent chairmanship of Dr. Alheit and Dr. Schneider. She hoped to receive the Report soon and the training and technical assistance that BMTC might be able to promote as a result of the recommendations of the Workshop.

ANNEX I

WORKSHOP PROGRAMME

TUESDAY, 29 SEPTEMBER

09.00	Registration
10.00	Opening Address Senator Uwe Beckmeyer (State Minister) Senator for Ports, Shipping and Foreign Trade
10.10	Welcome Address Mr. G. Hilliges, State Office for Development Cooperation, Chairman of BMTC
10.20	Welcome Address Dr. C. Ibe, IOC Intergovernmental Oceanographic Commission of UNESCO, Paris
10.30	Introduction to Workshop Dr. J. Alheit, Baltic Sea Research Institute, Warnemünde
10.45	Coffee Break
11.15	Training of Scientists from Developing Countries in the Field of Marine Pollution Dr. C. Ibe, IOC Intergovernmental Oceanographic Commission of UNESCO, Paris
12.45	Lunch Break
14.00	Eutrophication of the Baltic Sea - a Common Problem Dr. S. Johansson, Swedish Environmental Protection Agency Solna, Sweden
14.45	Harmful Algal Blooms: General Overview Dr. M. Elbrächter, Biologische Anstalt Helgoland, Sylt
15.30	Coffee Break
16.00	Monitoring the Health of Large Marine Ecosystems Dr. K. Sherman, NOAA National Oceanographic and Atmospheric Administration, USA
16.45	Coastal Eutrophication: Causes and Consequences Dr. E. Nöthig, Alfred Wegener Institute, Bremerhaven
18.30	Reception by the Lord Mayor of Bremerhaven, Mr. Karl Willms, Parkhotel, Wintergarten

WEDNESDAY, 30 SEPTEMBER

09.00	The Mediterranean Action Plan with Special Reference to Eutrophication and Plankton Blooms Dr. G. Gabrielides, FAO-MAP, Greece
09.45	Problems Caused by Harmful Algal Blooms in China Prof. Dr. Yu-Zao Qi, Institute of Hydrobiology, Guangzhou, People's Republic of China

10.30 Coffee Break

11.00 Eutrophication Problems in Black Sea
Prof. Dr. Y. Zaitsev, Institute of Biology of Southern Seas, Odessa, Ukraine

11.45 Eutrophication Problems in Eastern Mediterranean
Prof. Dr. N. Friligos, National Centre for Marine Research, Athens, Greece

12.30 Lunch Break

13.30 Harmful Algal Blooms and Fisheries
Dr. K. Tangen, OCEANOR, Trondheim, Norway

14.00 Environmental Issues Related to Aquaculture Development
Prof. Dr. H. Rosenthal, Fisheries Biology Department, Kiel

14.45 The global Change: Physical and Biological Aspects
Dr. A. Bakun, FAO, Rome

15.30-16.00 Coffee Break

16.00-18.00 Working Group Sessions on:
- "Eutrophication in Semi-enclosed Seas"
- "Harmful Algal Blooms"

THURSDAY, 1 OCTOBER AND FRIDAY, 2 OCTOBER

09.00-18.00 Working Group Sessions (continued)

10.15-10.45 Coffee Break

12.00-13.30 Lunch Break

15.30-16.00 Coffee Break

THURSDAY, 1 OCTOBER

19.30 Presentation of the Linnaeus Software on Identification of Algae
Dr. R. Sluys, Expert-Center for Taxonomic Identification, Amsterdam, The Netherlands

SATURDAY, 3 OCTOBER

09.00-12.00 Presentation and Discussion of Results of Working Group Sessions

10.15-10.45 Coffee Break

12.00-13.30 Lunch Break

13.30-15.00 Discussion and Formulation of Recommendations with Respect to Training Requirements and International Co-operation in the Fields of "Eutrophication in Semi-enclosed Seas" and "Harmful Algal Blooms" in Relation to Coastal Living Resources

15.00-15.30 Presentation and Discussion of Workshop Report - Executive Summary

16.30 Closure of Workshop
Mr. G. Hilliges, State Office for Development Cooperation, Chairman of BMTC

ADDITIONAL PRESENTATIONS ACCORDING TO THE DEMANDS OF THE PARTICIPANTS

Water Quality and Fish Behaviour in Highly Intensive Tank Systems. Video presentation (approx. 20 min.).
Prof. Dr. H. Rosenthal, Fisheries Biology Department, Kiel

Consequences of Eutrophication on Aquaculture: a Case Study on Mass Mortalities of Cultured Rainbow Trout in Kiel Fjord Video Presentation (approx. 15 min.)
Dr. W. Welsch, POLARMAR

ANNEX II

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ANNEX III

SUMMARY OF TRAINING NEEDS IDENTIFIED BY INDIVIDUAL PARTICIPANTS

ANDRUSHAITIS (Latvia)

1. Methodology for elaboration/development of monitoring programme;
2. Data handling, treatment, analyses;
3. Eutrophication mechanisms.

The principal communities requiring the training are:

a) science organizations responsible for monitoring;
b) scientists; and
c) state officials making management decisions.

Financial support is needed to continue present observations in adjacent marine areas, especially in terms of consumables: chemicals, filters, etc.

APS (Estonia)

Estonian needs in terms of equipment and chemicals will be specified shortly. 2-5 hydrobiologists should be trained to work on harmful algae.

BADRAN (Jordan)

The main community of the Gulf of Aqaba, as well as of the Red Sea is the coral reef. The flourishment of this community depends to a large extent on the nutrient levels in the water and the related phenomena. Therefore, regional monitoring programmes to evaluate baseline concentrations of nutrients in the Red Sea are of a very significant importance. To be able to participate in such programmes effectively, Jordan would need serious training of personnel at the technical and scientific levels.

BELIN (France)

The monitoring of phytoplankton populations is performed along the whole French coastline by IFREMER laboratories, under national co-ordination. The monitoring is completely financed by IFREMER.

Needs of France are not funds but of exchange of experience with other countries, especially concerning taxonomic identification (intercalibration!), sampling methods, toxicity tests, time series, processing methods.

The monitoring system in France (called "REPHY") is at the present time in an improving phase, to optimize the organization (maybe by reducing costs) and to have better results. The main objectives in the short term are: to work on a project of a new database, better adapted than the actual one, taking into account all parameters concerning monitoring and including a GIS (Geographical Information System); to homogenize and simplify species identification in the different coastal labs (this is under way, with regular training of people concerned).

BEN AMOR (Tunisia)

We have in Tunisia a need for training in the monitoring of eutrophication and harmful algal blooms and in methods of analysis and detection of biotoxins in sea water and bivalves.

A small project that we could carry out with external funding would require equipment for a laboratory for biotoxin analysis.

BOLOGA (Rumania)

Coastal erosion (diminishing biological sediment production, as a consequence of mass shellfish mortalities, and disappearance due to eutrophication).

Databases and GIS for environmental factors (including major pollutants).

Toxicity tests for mass algal species responsible for producing massive and frequent blooms.

Acclimation of seaweeds.
Eco-physiology of phytoplankton.
Ecological reconstruction (to increase natural biofilter capacity in shallow waters).
Aquaculture (invertebrates, fish, crayfish).
Equipment, computer techniques, spare parts, literature.

CHOO (Malaysia)

1. Training needs pertaining to a comprehensive monitoring programme which includes studies on the surface mixed layer, surface chlorophyll concentrations, nutrients such as phosphates and nitrates, as well as plankton and benthos composition and identification.
2. Identification of cysts of toxic dinoflagellates.
3. Prediction models for red tides.
4. HPLC methods for toxin identification and the use of other simple identification kits.
5. Training needs to implement the red-tide watch programme which is currently being implemented in Norway and Thailand.

CORRALES (Philippines)

1. Taxonomy of dinoflagellates and diatoms.
2. Culture and biology of harmful algae.
3. Monitoring of HAB's.
4. Physico-chemical factors affecting HAB's.
5. Development of toxicity tests.

DO VAN KHUONG (Vietnam)

To train scientists to meet the needs of studies on ecology, taxonomy and genetics, and toxicology and toxin chemistry of harmful algal blooms, so we can carry out a small project: population dynamics of harmful algal blooms and methods of preventing algal blooms in brackish water ponds.

It is necessary to obtain fund for these studies and to cooperate firmly with other countries in the training and in the study of harmful algal blooms.

FRILIGOS AND IGNATIADES (Greece)

Identification and quantification of toxins.

GONZALES (Philippines)

1. Eco-physiology of Pyrodinium and other toxic phytoplankters.
2. Taxonomy of toxic phytoplankton.
3. Culture of phytoplankton.
4. Modelling and prediction of blooms.
5. Management strategies.

A project on the detoxification of contaminated shellfish is necessary to mitigate the impact of toxic red-tide organisms on the livelihood of people dependent on shellfish farming and its trade.

GÖBEL (Germany)

Current information on algal development, assessment of the toxicity of algae and the effects of algal blooms. Only possible with optimal species identification (sometimes new species are detected).

Training needs:

1. taxonomic workshop;
2. current identification literature;
3. current information on toxicity of species.

HALIM (Egypt)

Eco-physiology of meso-algae.
Toxicity tests.

HOUVENAGHEL (Belgium)

With the help of EC funding and with a colleague specialized in toxin chemistry, J.C. Boekman, we improve the HPLC methods applied to the DSP and PSP toxins. This requires algal culture to provide material and reference; the culture includes a strain collection and a mass culture. Having toxic cells at disposal as well as adequate analytical tools, we are presently engaged in a mollusc toxification exercise.

A next step will include detoxification kinetics.

KARUNASAGAR, INDRANI (India)

Training needs:

1. Taxonomy of phytoplankton and culture specifically of dinoflagellates.
2. Chemical analysis of marine toxins (esp. Brevetoxins and domoic acid).
3. Training in standardized method of water quality analysis and levels of nutrients.

Projects that BMTC could possibly support:

1. Assist in continuation of monitoring programmes that have presently been stalled for want of funds;
2. Help in dissemination of vital information to fish farmers and technicians involved in field work (this is possible by use of aids like video, microscopes that have a video display: "Seeing is believing" and the above-mentioned method would certainly help;
3. Provide accessories for existing HPLC system microscope, etc.;
4. Development of test kids based on immunological reaction (field test kits).

KARUNASAGER, IDDYA (India)

1. Taxonomy of bloom-forming species.
2. Identification of cysts.
3. Culturing algae for studies of toxicity.
4. Chemical characterization of toxins (HPLC).
5. Development and use of newer test kits based on immunological detection.
6. Training on water monitoring for prediction of toxicity.

Developing countries need some newsletter that would compile publications on algal blooms and toxicity at periodic intervals (6 months or 1 year). This would be important because it is difficult to obtain many journals that publish articles on these areas.

1. BMTC could help to organize a regional training course in the areas mentioned earlier for the countries in the Indian Ocean region. My university would be willing to host such a course and we have some basic facilities for toxicity testing and identification of algae. We need to be strengthened to run the course.

2. BMTC could also help my university to organize a training course for fish farmers and fishermen on algal blooms and recognition of early warning signs of blooms. Fishermen and fish farmers could be provided microscopes and identification sheets so that they could give a feedback to scientists.

3. BMTC could help scientists from third world countries by providing abstracts of papers in the field of algal blooms and toxicity.

KORAY (Turkey)

Training on the ecological modelling of algal blooms.
Training on mouse bioassay and HPLC.
Financial assistance for monitoring studies.
Financial assistance for an image-analysis system and remote sensing data.

KORICHI (Algeria)

We want to study the relation between our currents (hydrology), the evolution of phytoplankton, zooplankton and the fish stocks. We now have a problem of the availability of the fish (perhaps due to the displacement of the upwelling).
We want to develop the marine aquaculture and to prevent eutrophication.
So, we need equipment and the transfer of technology to enable us to study algal toxicity.

MARASOVIC (Croatia)

We need training in toxicology. In my region there are many fish and shellfish farms and people need a certificate to export fish and shellfish. We have to organize a laboratory for testing toxicity (mouse bioassay or testing with kits). At the same time we want to investigate toxicity by HPLC (scientific interest). Projects: Mechanisms of initiation and termination of red-tide bloom in Kaitela Bay (cysts, physical, chemical and biological conditions).

MIHNEA (Romania)

1. Phytoplanktonic species eco-physiology.
1.1 Interrelation between blooming species and environmental particularities.
1.2 Interrelation between blooming species and consumers.
1.3 The fate of the large amount of biomass produced by bloom processes.

2. Taxonomy of new species belonging to the Chrysophyta, Cryptophyta, Dinophyta and blue-green Cyanobacteria.

3. Toxic species identification.

Needs for

1. Training and funding for devices, apparatus and reagents;
2. Training and funding to purchase identification tools.

MONCHEVA (Bulgaria)

Training needs:

1. Taxonomy of Chrysophyta, Chlorophyta, cysts (including identification reference book);
2. toxicity;
3. analysis and modelling (ecology);

Project: Key factors responsible for harmful algal blooms along the Bulgarian Black Sea coast (abiotic and biotic).

OLENIN (Lithuania)

Development of national monitoring system.
Development of coastal management plans.
Training in taxonomy and ecology of potentially toxic algal blooms.
Monitoring data statistical treatment and implementation.
Development of marine environmental monitoring system.

ORDOÑEZ (Philippines)

1. Training workshop on standardization of methods for coastal oceanographic monitoring.
2. Training on modelling and prediction of eutrophication. Funding assistance needed in establishment of culture facilities and short term consultancy services of an expert on red tide organisms.

PARK (Korea)

Training needs are as follows:

Taxonomy of toxic plankton such as flagellates including cysts involved in fish kills, PSP and DSP;
Culture;
Mechanisms of blooms and mortalities of marine organisms;
Toxicological study of red-tide organisms and assays of shellfish for PSP and DSP;
Extermination of causative organisms of red tide.

Prediction is important and techniques for reducing damage to cultured organisms should be developed.

PIYAKARNCHANA (Thailand)

Immediate needs:

1. Taxonomic identification of the red-tide species, with stress on toxic dinoflagellates;
2. Systematic monitoring methodology development;
3. Remote-sensing techniques for studying eutrophication;
4. Purification of contaminated economically important species.

Future needs:

1. Role of certain bacteria and other micro-organisms; e.g., sulphobacteria and flavobacteria in eutrophication;
2. Modelling and predicting of eutrophication;
3. Quantifying the spread of toxic phytoplankters by ships.

If funding from outside were available I should:

1. Strengthen the culture facilities in the phytoplankton laboratory at my university;

2. Monitor certain toxic species of dinoflagellates in Thai waters.

QI (P.R. China)

Training needs :

1. Taxonomy of dinoflagellates;
2. Monitoring techniques especially those for automatic recording of parameters and biomass estimation;
3. Skill: manual and literature needed.

Projects with funding outside:

1. We have developed a joint-research project with Woods Hole Oceanographic Institution;
2. I am now trying to establish projects with the Crouch Foundation (England-Hong Kong) and hope to have more with Finland, Germany (because my research team is a national team).

Also, I hope:

1. To establish an exchange between Chinese and German experts and researchers to develop a training course on a research programme.
2. An international symposium on red tides could be held in China; we will apply to IOC to support this symposium and hope Bremen-BMTC can be a co-sponsor with us.

SANTHANAM (India)

1. Taxonomy and ecology of harmful algae in coastal ecosystems and aquaculture systems of the east coast of India.
2. Impacts of harmful algal blooms in water quality and fish yield in natural and pond ecosystems of the east coast of India.

SAVCHUK (Russia)

At the moment I cannot specify local training needs, but I can offer assistance in training on subjects related to simulation modelling of eutrophication (biogeochemical cycles); starting from the formulation of models and analysis of simulations and ending in collaboration in the elaboration of models for specific areas (regions).

SAYDAM (Turkey)

The worst affects of eutrophication and algal blooms have been observed in the Black Sea and the Aegean Sea, but whether or not they are harmful is not known. Thus, any training on how to identify and detect harmful algal blooms is of considerable importance to us. I would therefore like to suggest that training is needed on the identification of toxic effects of algal blooms.

SU (Taiwan)

We suggest the establishment of a collecting centre for toxic algae, so that people could get live material or a video tape, to compare the morphology of toxic algae to assist identification.

TANGEN (Norway)

1. On the national level (Norway):
   a) training in sampling and processing of samples (algae, bivalves) for monitoring purposes;
   b) training in contingency planning and desktop exercises in contingency operations (scenarios; similar to oilspill desktop operation);

2. Taxonomy training (North Sea and the Baltic):
   a) intercalibration of phytoplankton methods (counting, identification).

WASMUND (Germany)

There is a need for training in:

Taxonomic identification of harmful algal species (incl. cysts); determination of whether a potentially toxic species is really toxic or not: simple methods to be developed, perhaps to replace the mouse test (also for ethical reasons) by a bioassay method, where the algae (to be tested) are simply introduced into a water containing the indicator organisms (e.g. Daphnia);

More sophisticated methods (e.g. HPLC) for identification of the single toxins (perhaps also some other methods are available: fluorescence staining, immunological procedures).

Monitoring should be connected with ecological research (incl. culture algae) to identify the conditions for the development of toxic algal blooms.

ZHU (P.R. China)

Taxonomy: dinoflagellates and pico-phytoplankton; comparison of the method and results.
Monitoring: comprehensive assessment of water quality, sediment quality, community health.
Instrumentation: calibration.
Modelling: data processing.
Toxicology: chemical analysis with HPLC (which we already have); bioassay.
Public health: seafood safety monitoring.
We can carry out the culturing of HAB species, toxic analysis with HPLC; and monitoring in shrimp ponds (with outside funding).

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