

**COOPERATIVE RESEARCH REPORT
NO. 167**

**REPORT OF THE ICES ADVISORY COMMITTEE ON
MARINE POLLUTION, 1989**

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International Council for the Exploration of the Sea
Palægade 2-4, DK-1261 Copenhagen K
DENMARK

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The Advisory Committee on Marine Pollution (ACMP) was established by the International Council for the Exploration of the Sea with the task of formulating, on behalf of the Council, scientific advice on marine pollution and its effects on living resources to the Member Governments and to Regulatory Commissions. In its work, the ACMP considers, among other things, the results of work carried out in relevant ICES Working Groups (which also report to their respective Standing Committees during the annual Statutory Meetings). It is a firm procedure within the Council that reports of other subsidiary bodies concerned with pollution pass the ACMP.

The ACMP consists of a number of scientists acting - when they work as Committee members - in their personal capacity of scientists, responsible only to the Council. The membership of the Committee is such that it covers a wide range of expertise related to studies of marine pollution. The members do not act as national representatives. The 1989 membership of the Committee is found on page 1.

ERRATUM:

COOPERATIVE RESEARCH REPORT No.167

(Report of the Advisory Committee on Marine Pollution)

p.108 line 2 of the Table heading should read:

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REPORT OF THE ADVISORY COMMITTEE ON MARINE POLLUTION, 1989

LIST OF MEMBERS

Dr J.E. Portmann - Chairman
Dr P. Tulkki - Chairman of the Marine Environmental Quality Committee
Dr M.M. Sinclair - Chairman of the Biological Oceanography Committee
Dr H.J. Brosin - Chairman of the Hydrography Committee
Dr H. Rosenthal - Chairman of the Mariculture Committee
Prof. C. Hopkins - Chairman of the Shellfish Committee

COOPTED MEMBERS

Dr E. Andrulewicz
Dr J.M. Bowers
Mr R.G.V. Boelens
Prof. I. Dundas
Dr (Ms) M. Estrada
M M. Joanny
Dr P.J.H. Reijnders
Dr (Ms) K. Richardson
Dr G. Topping
Prof. R. Wollast

Mr J.G. Pope, Chairman of the Consultative Committee, also attended

Dr (Ms) J.F. Pawlak, ICES Environment Officer
Secretary to the Advisory Committee on Marine Pollution

OVERVIEW OF THE 1989 ACMP REPORT

The 1989 report of ACMP, as in earlier years, is addressed mainly to the questions posed to ICES by the regulatory Commissions of the Helsinki, Oslo and Paris Conventions. The Executive Summary that follows this overview provides an outline of the content of the report in respect to work requested by the regulatory Commissions, under three sub-headings for the Oslo and Paris Commissions, broadly corresponding with the groupings under which they record their requests, and a single sub-heading relating to the requests specifically raised by the Helsinki Commission. The Executive Summary is followed by a more detailed report on the progress made in relation to the specific or individual questions raised by the three Commissions. This is intended to direct the reader to the sections of the report likely to be of most interest in relation to a particular question.

The more careful reader of the report will note that in a number of cases the advice or information provided goes beyond that specifically requested by the Commissions. This additional material is provided, in part, simply for the sake of completing the picture so far as it is practicable at this point in time. As such, it will be of benefit to the wider audience within ICES that ACMP is also expected to advise. It is, however, hoped that the regulatory Commissions will find this material of interest, since it is directly related to the questions they raised. Examples of such topics are algal blooms, seal stocks, and the environmental impact of mariculture.

In addition to providing advice in direct response to the Commissions' requests, the ACMP has, as in previous years, included in this report information on a number of other issues of environmental concern. Since these are not mentioned in the Executive Summary, particular attention is drawn to them here.

Acid rain has been implicated in the decline of certain salmon stocks, but its impact appears to vary with area, even though rainfall and its acidity are similar. An explanation for this and an indication of the short-term remedial measures that may be effective are provided in Section 20 of this report.

The scale of extraction of marine sediments for use by the construction and other industries is increasing in several ICES countries. There is now no doubt that such activities can, if allowed to proceed unrestricted, cause environmental damage which can be of considerable scale and duration. Information on the moves towards assessing the possible scale of impact, and the methods by which it can be charted and minimised, are included in Section 15 of the report.

The third issue of interest is regulatory approaches to environmental management, which has been of concern to ACMP since 1979, and its first comments on this topic were recorded in the 1981 ACMP report. Having presented a further detailed statement in its 1986 report, the ACMP has since continued its deliberations on the question. The outcome is presented in Section 21 of this report. One of the main purposes in including this section of the report is to indicate the concepts and concerns which underlie

the ACMP advice on other issues. The ACMP does, however, believe, in the light of the interest expressed both within the regulatory Commissions and elsewhere, that this section of the report will stimulate the interest of a wider audience. This section gives a detailed explanation of the key elements of the conceptual framework for overall environmental protection. The reader will note that this scheme differs markedly in certain important aspects from the present array of regulatory mechanisms.

DEFINITIONS OF TERMS USED IN THIS REPORT

The following terms, used repeatedly throughout this report, are often interpreted in other documents in different ways. For the sake of clarification, in this report the terms should be interpreted as follows:

Pollution - means the introduction by Man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities.

Contamination - is used to describe the situation which exists where either the concentration of a natural substance (e.g., a metal) whilst clearly above normal, or the concentration of a purely man-made substance (e.g., DDT), is such that pollution (i.e., adverse effects) does not occur.

Monitoring - is the repeated measurement of an activity or of a contaminant or of its effects, whether direct or indirect, in the marine environment. It may be undertaken either for compliance purposes or with the objective of establishing patterns and trends or for research purposes.

A full list of acronyms, other than those for the working groups, which are given on the first page of the Executive Summary, is given on the final page of this report.

EXECUTIVE SUMMARY

This Executive Summary provides a brief outline of progress in respect to work requested by the regulatory Commissions, separate from the body of the report.

The work requested from ICES by the Commissions comprises some items that can be completed in a single year, some that require a number of years to prepare an in-depth and authoritative response, and others that require continuing review in the light of improvement in scientific understanding. An annual work programme, therefore, contains a mix of items, some carried over from previous years and others that are new. The ACMP Report contains both completed responses to individual questions and progress reports on issues receiving longer-term study. Where appropriate, these latter issues are amplified in detailed technical annexes to the Report.

At its 1989 meeting, the ACMP considered, inter alia, the most recent reports of the following ICES groups:

Marine Chemistry Working Group (MCWG)

Working Group on the Baltic Marine Environment (WGBME)

Working Group on Marine Sediments in Relation to Pollution (WGMS)

Working Group on the Statistical Aspects of Trend Monitoring (WGSATM)

Working Group on Biological Effects of Contaminants (WGBEC)

Working Group on Pathology and Diseases of Marine Organisms (WGPDMO)

Working Group on Environmental Assessments and Monitoring Strategies (WGEAMS)

Benthos Ecology Working Group (BEWG)

Shelf Seas Oceanography Working Group

Working Group on the Effects of Extraction of Marine Sediments

Working Group on Environmental Impacts of Mariculture (WGEIM)

Working Group on Harmful Effects of Algal Blooms on Mariculture and Marine Fisheries

Study Group on Toxicological Mechanisms Involved in the Impact of Acid Rain and its Effects on Salmon

Study Group on Patchiness Investigations in the Baltic

Report of the Joint Meeting of the Working Group on Baltic Seals and the Study Group on the Effects of Contaminants on Marine Mammals

Report of the Workshop on the Chrysochromulina polylepis bloom in the Skagerrak and Kattegat in May-June 1988.

WORK REQUESTS FROM THE OSLO AND PARIS COMMISSIONS

Brief summaries of the progress made in response to questions raised by the Commissions are presented, under the topic headings assigned by the Commissions, in Section 2 of this Report. For the benefit of readers not wishing to study the detailed report, a brief summary of the main topics of interest to these two Commissions is presented below under three headings: "General Monitoring Issues", "Continuing Responsibilities" and "Specific Issues".

General Monitoring Issues

Work has continued within the remit of WGSATM on a range of issues related to the assessment of trends over time of the concentrations of contaminants in a variety of marine media. The report outlines the progress made in the analysis of available data sets on contaminants in fish muscle and fish liver and on the implications of pooling either samples or data on the detectability of trends. Attention is drawn to the fact that variance in analytical results can lead to the spurious indication of trends. An outline of the implications of this and other sources of variance, e.g., in the collection of samples and their storage, on the feasibility of detecting trends in either time or space is given in the context of the design of monitoring programmes. Preliminary consideration has also been given to the revision of the existing guidelines on sampling and analysis of fish, with a view to extending the usefulness of a single set of samples. In view of the Commissions' continued desire to use sea water samples for the assessment of temporal trends in metal concentrations, this question has been re-examined, but in the light of the scale of change anticipated and the sample and analytical variance, this practice is still not recommended.

Progress continues on the development of biological effects techniques for use in the context of marine pollution monitoring studies. Details are provided of the conceptual framework of biological effects studies in this context and of their planned testing in the course of a sea-going and shore-based workshop to be held in Bremerhaven in March 1990. Attention is also drawn to the fact that a series of leaflets will be produced on techniques that have been shown to be reliably reproducible and give interpretable results.

Further attention has been paid to the need to ensure analytical quality control and, in the light of experience, some minor modifications to earlier ACMP advice are included in this report. Specifically, the suggestion is that the less experienced laboratories should use certified reference materials rather than attempt to produce internal reference materials. The need for the Commissions to endorse the necessity of using uncompromised reference materials and encourage their production is again highlighted in this report.

Continuing Responsibilities

In the context of analytical quality control, work continues in the conduct of intercomparison exercises. Three such exercises are currently in progress, all with the first phase due for completion by late summer 1989. These are an intercalibration exercise for the determination of nutrients in sea water and intercomparison exercises for chlorinated biphenyls (CBs) and PAHs in marine samples. In the case of the last two exercises, a step-wise approach is being followed with the first phase involving analysis of solutions of mixed standards. Plans have been drawn up and details are provided for the assessment of the results and the conduct of the second and subsequent stages involving various marine matrices, including sediments. In addition to these three exercises, details are provided of the preliminary phase of an intercomparison exercise for the determination of the trace metal content of marine suspended particulate matter. This exercise is also in progress.

Seven new publications in the Techniques in Marine Environmental Sciences series are announced in the report; at least four of these will be published in autumn 1989.

Work continues on the assessment of the prevalence of fish diseases and their possible association with contamination. An outline is given of the results of surveys reported by seven countries and attention is drawn to the fact that the advice provided by ACMP in its 1988 report on the need to standardise reporting on a collaborative basis has yet to be fully implemented. Mention is also made of a new immunocompetence measurement technique that may prove useful in a wide survey context and of experimental exposure testing that is currently underway in two countries.

After a gap in the 1988 report, work has been undertaken again on the production of overviews on chemicals of interest in a marine pollution context. A revised and updated report on mercury is included in this report, along with an update on dioxins and furans, which provides information on concentrations and sources not included in the earlier overview that was provided in the 1984 ACMP report.

ICES continues to provide automatic data processing (ADP) services on behalf of the Commissions and this report notes that the extent to which these are being, and are likely to be, used in the context of the Commissions' programmes is increasing. It is pointed out that more attention should be paid to the provision of additional information on methods and intercomparison status than currently appears to be the case.

The report also draws attention to the impact of mariculture on the marine environment and the fact that the very nature of this type of operation implies a certain exclusivity of use, at least at a local level. It is noted that this will require management of marine environmental use and change in much the same way as that adopted in agriculture. Attention is also drawn to the wide variety of chemicals currently in use in the aquaculture industry

and the fact that their use cannot be totally avoided. However, examples are given of the successful reduction in use achieved by some countries relative to increases in scales of production.

The report also provides details of the scientific views on the causes of the bloom of Chrysochromulina polylepis that affected large areas of the Kattegat and Skagerrak in spring 1988. Mention is also made of the scale of the effects encountered and the degree to which similar events are likely to occur. Preliminary information is also provided on the impact on seal stocks of the disease that affected seals in large areas of the Northeast Atlantic and southwestern Baltic Sea in 1988.

Specific Issues

Items on specific topics covered in the report that will be of particular interest to the Commissions are: the subject of normalization in the context of sediment monitoring, the use of benthos in monitoring studies, and advice on the marine matrices that are most appropriate for the provision of the greatest information in relation to different monitoring purposes.

The advice on normalization comes after a delay of one year, but is now commended to the Commissions as a definitive answer to their questions on this topic. The advice on benthos studies in relation to pollution comes in the form of examples of the application of the guidelines provided in the 1988 ACMP report. These guidelines were generic in nature and the examples are intended to complement the guidelines by illustrating their practical application to real situations.

The matrix tables are intended to provide practical advice on how the scale of monitoring effort might be optimized by the use of one rather than several types of sample for particular purposes. The ACMP is, however, concerned that the tables should be used with care and not taken out of context of the textual advice that accompanies them. In particular, attention is drawn to the fact that existing programmes, particularly those aimed at studying temporal trends, should not be abandoned simply because there is no appropriate entry in a matrix table.

WORK REQUESTS FROM THE HELSINKI COMMISSION

Brief summaries of the progress in answering the questions raised by the Helsinki Commission are presented in Section 3 of this report. Progress has, in fact, been made on all but one of these requests and a very brief outline of the nature of that progress is given below.

The item on which progress has not been as complete as had been expected is that related to the specific assessment of contaminants in Baltic marine sediments. Nevertheless, the ACMP feels that enough information is now available to permit it to offer preliminary advice on the probable implications for the design of sediment monitoring programmes in the Baltic Sea and this advice is provided in the report.

Other issues on which advice or information is provided are as follows. An assessment of the implications for seal stocks in the Baltic Sea as a direct consequence of the disease outbreak in 1988 leads to the conclusion that the species at greatest risk, the ringed seal, has not been affected. However, the ACMP again stresses the need for this species to be protected from hunting until such time as its numbers sufficiently recover.

The assessment of the results of the Multi-Ship International Investigation of Patchiness in the Baltic Sea (PEX) is now complete and the ACMP considers that they have quite major implications for monitoring in the Baltic Sea. The study confirmed the extensive patchiness in the Baltic Sea and the ACMP advises that this means that more extensive sampling around fixed stations will be necessary in the future if data for these stations are to be considered truly representative of spatial or temporal trends.

Information is provided on both the state of progress of the nutrient intercalibration exercise and the relative scale of inputs of nutrients from mariculture relative to other sources; it is suggested that the mariculture source is not significant. The likelihood of further troublesome algal blooms is also discussed in the report, especially in relation to nutrient inputs. It is concluded that algal blooms are natural events and that, although reductions in nutrient inputs from man-made sources may reduce their occurrence, it will not prevent them.

In response to the request for advice on new contaminants, this report includes an updated review of the state of knowledge on mercury and additional information on the sources and concentrations of dioxins and furans in the marine environment. A progress report is also provided on the analytical intercomparison exercises for PAHs and for trace metals on suspended particulate matter. Both studies are presently in progress and the results of phase 1 of each should be available in time for the next meeting of ACMP. Plans are also in hand for the development of an intercomparison exercise on the determination of concentrations of suspended particulate matter in sea water.

1 INTRODUCTION

In dealing with requests put to it by Member Governments of ICES and by the Regulatory Commissions, the ACMP draws on the expertise of its own members and also on the work of various expert ICES Working Groups. The ACMP considers the reports of these Working Groups and calls upon them to carry out specific activities.

The ACMP Report is structured in terms of the ACMP's overall deliberations on subjects related to contamination and pollution of the marine environment, but specific features relevant to the various Commissions' requests are brought together in an Executive Summary, which is at the beginning of the Report, and are further detailed in Sections 2 and 3, where the individual work items from each Commission are listed and related to relevant sections of the main text.

2 REQUESTS FROM THE OSLO AND PARIS COMMISSIONS

A summary of the progress in the 1989 programme of work requested by the Oslo and Paris Commissions is given below, along with reference to the relevant sections and annexes of the report. Where only limited or no progress has been possible, a brief statement is given as to when a response can be expected.

- (A) Work which is expected to be undertaken by ICES and reported on in the ACMP Report for 1989;

- A1 To advise on the need for an intercomparison exercise for nutrients in sea water and, if appropriate, to draw up proposals for the conduct of such an exercise that could cater for the needs of both ICES and JMP laboratories;

Advice was included in the 1988 report of ACMP to the effect that an intercomparison exercise for nutrients is necessary, and the Commissions accepted this advice. The detailed plans for this exercise, which is open to JMP laboratories, are provided in Section 13.4 of this report. The exercise involves three samples of water, with low, intermediate, and high levels of nutrients, and is due to be completed by late August 1989. It is hoped that at least a preliminary report on the outcome will be available in time for inclusion in the 1990 report of ACMP.

- A2 To advise on the approaches to be used in conducting assessments of the environmental status of regions of the marine environment and the strategies to be adopted in monitoring to meet various purposes, including the frequency necessary for periodic reassessments of the geographical extent/variations in contamination of the Commissions' areas of interest;

Detailed advice on this issue was included in the 1988 report of ACMP. Section 4 of the present report notes that this advice has been adopted by the North Sea Task Force and Section 5 notes that this advice is also being utilised in the preparation of a number of other regional assessments.

Section 5 also notes that, in accordance with the guidelines provided in 1988, further work is underway in one area previously studied, the Irish Sea, with a view to deciding on future action on issues identified in the earlier regional assessment of that area.

- A3 To report on aspects of trend monitoring related to contaminants in seawater;

The ACMP has previously advised that the monitoring of metals in sea water for trend purposes is not recommended. Having re-examined the question, the ACMP confirms this advice on the grounds that more efficient methods are available, given the likely scale of change to be expected (see Section 6.1). In relation to the monitoring of temporal trends of other contaminants, preliminary advice is also given in Section 6.1 of this report. It is expected that advice relative to further substances will be provided in fu-

ture reports. The early indications are, however, that sea water is unlikely to be suitable for monitoring changes over time of the concentrations of many substances.

- A4 To provide advice on how most effectively to monitor each contaminant of interest for each of the purposes defined by the Commissions;

Information on this topic is provided in the matrix tables for monitoring purposes (Section 6.1). Consideration is being given to streamlining the existing guidelines that at present involve the separate sampling and analysis of material according to different purposes; this is mentioned in Section 6.2.

- (B) Work which is essentially of a continuing nature and on which it is expected that ICES will submit a progress report in 1989;

- B1 To report routinely on all on-going and planned ICES intercalibration exercises, preferably by means of a full report to JMG on the intercalibration exercises carried out;

Mention has previously been made of the nutrient intercalibration exercise (Question A1 and Section 13.4). Section 13.3 of this report provides further information on the conduct of the intercomparison exercise for chlorobiphenyls (CBs). Analysis of the samples for the first phase of this exercise is due to be completed by the end of June 1989 and a preliminary report on the outcome should be available for inclusion in next year's report of ACMP. Plans have been prepared for the conduct of the second phase of the study in relation to the analysis of biological tissues; an outline is included in Section 13.3 of this report. Plans are in hand for a parallel second phase which would be relevant to sediments, if the Commissions confirm their interest in such an exercise.

Section 13.2 of the report provides an outline of the outcome of the first phase of the intercomparison exercise on polycyclic aromatic hydrocarbons (PAHs). Some difficulties were encountered by analysts using high pressure liquid chromatography (HPLC) techniques; these were attributed to the solvent matrix used to issue the samples. There was also some evidence that there had been small weight losses in the ampoules used to issue the samples. For these reasons, it is intended to repeat the first phase of the exercise. A more complete report on both sets of results can be expected in the 1990 report of ACMP.

In both cases, the full reports will be published in due course in the Cooperative Research Report series.

Section 13.5 of the report provides information on the plans for the preliminary phase of an intercomparison exercise for the analysis of trace metals in suspended particulate matter. This is due to be completed in autumn 1989 and a report can be expected in 1990.

- B2 To provide copies of relevant descriptions of methods of sampling and analysis as published in the Techniques in Marine Environmental Sciences series;

The titles of the volumes so far published in this series are given below. Copies of each have been provided to the OSPARCOM Secretariat.

- No. 1 - Cadmium and lead: Determination in organic matrices with electrothermal furnace atomic absorption spectrophotometry
- No. 2 - Trace metals in sea water: Sampling and storage methods
- No. 3 - Cadmium in marine sediments: Determination by graphite furnace atomic absorption spectroscopy
- No. 4 - Lipophilic organic material: An apparatus for extracting solids used for their concentration from sea water
- No. 5 - Primary production: Guidelines for measurement by ^{14}C incorporation
- No. 6 - Quality control procedures: Good laboratory practice and quality control

The following leaflets are under preparation with publication expected prior to the 1990 meeting of ACMP. The titles given are working titles only.

- Collection of suspended particulate matter for gravimetric and trace metal analysis
- Total and partial methods of digestion for estuarine and coastal sediments and suspended particulate matter
- Collection and treatment of soft bottom macrofauna samples
- Determination of organic halogens: Group parameters in investigations of marine pollution
- Determination of some organochlorine compounds in biological material
- Determination of organic and total tin in sea water by extraction and graphite furnace atomic absorption spectroscopy
- An introduction to the study of temporal and spatial trends in contaminant levels in the marine environment, in particular, marine biota.

- B3 To keep under review the experience with the ADP handling of the JMP data and technical problems of access to the JMP data by other computers;

Section 23 of the report provides details of the position regarding ADP handling of the JMP data. It remains to be seen whether the JMP laboratories meet the Commissions' agreed deadline of 1 August 1989 for submission of 1988 data. The ACMP is concerned that inadequate attention is being paid to the ancillary details on methods and intercomparison status that are stored with the data. Section 23 also draws attention to the problems likely to be encountered by "on-line-access" to the data and the ACMP questions the need for this, provided that ICES continues to be in a position to provide reasonably prompt output to other users.

- B4 To keep under review the question of new contaminants that may be of interest to JMG; this should be regarded as a current awareness exercise and implies an expectation that advice will be provided on those contaminants which ICES considers may give cause for concern in the future;

The ACMP has included in this report two overviews on contaminants in the marine environment. The first of these is an updated and revised overview on mercury and the second is intended as a supplement to the earlier overview on dioxins and furans contained in the 1984 ACMP report (Coop.Res.Rep. No. 132). It provides new information, particularly on concentrations in relation to sources, and confirms the ubiquity of low levels of contamination, some of which is attributable to the incineration of natural materials. These overviews are contained in Sections 19.1 and 19.2, respectively, of this report.

- B5 To keep under review and report as appropriate on the results of studies on the relationship between fish diseases and pollution;

Section 9 of the report gives a brief resumé of the current status of fish disease studies in relation to pollution. These are split into two categories: field studies of the prevalence of disease in wild fish and experimental studies using polluted sediments and flat fish.

- B6 To keep under review the question of the bioavailability of contaminants in sediments and dredged material and to provide advice on methods for determining the potential bioavailability of contaminants in sediments and dredged material;

Information on this topic was provided in Section 17 of the 1986 ACMP report (Coop.Res.Rep. No. 142); it is expected that an update on the available information will be provided in the 1991 report and, with this in mind, several ICES Working Groups are addressing the question.

- (C) Special topics, on which it is expected that ICES will carry out an in-depth study;

No such tasks have been assigned at present.

- (D) Work already under way, on which it is expected that ICES will report in the ACMP Report for 1988;

- D1 To report on the experience gained from trend monitoring studies, including the results of studies using organs other than fish muscle and liver, and including cases where fish tissues or shellfish have been pooled prior to analysis;

Substantial progress has been made in this area, with several data sets analysed and conclusions drawn. The results of statistical analyses of temporal trend data on contaminants in fish muscle tissue, up to 1985, have been published in Cooperative Research Report No. 162. An outline of the main findings to date both in relation to fish muscle and liver tissues, as well as the pooling of mussels, is included in Section 6.4 of the report.

- D2 To report on all aspects of trend monitoring related to sediments; to supply advice on the value and the use of normalization methods for interpreting contaminant levels in sediments, including dredged materials;

Full details of such a normalization procedure are provided in Section 14.1 of the report. It should be noted that this relates primarily to metals, though similar procedures could be used for organic contaminants.

- D3 To provide advice on methods for monitoring dumping grounds and coastal areas affected by land-based discharges by means of studies of the composition of benthic communities;

Full guidelines in response to this request were provided in the 1988 ACMP report. However, the ACMP considered that the value of these guidelines would be enhanced by the provision of a number of illustrative examples of their application. Three such examples are provided in Annex 1 of this report.

- D4 To provide an overview paper on trends in nutrient concentrations in seawater;

A preliminary report on this topic was provided in the 1988 report of ACMP (Section 11.1). Steps are in hand to analyse other data sets, but continue to be inhibited by the lack of availability of these data sets to the ICES Hydrographer. A further report is unlikely to be provided in any detail before 1991.

- D5 To provide information on appropriate procedures for the storage of sediment samples prior to analysis for inorganic and organic contaminants, with a view to enabling laboratories who presently hold archived sediment samples to determine whether analysis may be worthwhile;

Advice on this question was provided in the 1988 ACMP report (Section 14.2).

- D6 To provide information on methods for the estimation of net riverine inputs to the marine environment, with particular emphasis on net inputs from the estuary to the sea; taking into account the view of the PARCOM ad hoc Working Group on Input Data;

Advice on this question was provided in Section 16 of the 1988 ACMP report.

- D7 To provide advice on future strategies for monitoring of the marine environment including preliminary advice on which substrates or compartments would be most suitable for monitoring each contaminant of interest for each of the Commissions' monitoring purposes.

Advice on this question was included in preliminary form in Section 4 of the 1988 report of ACMP dealing with monitoring strategies. Further, more complete, advice is included in Section 6.1 of this report in the form of matrix tables and a detailed explanation of their use. In providing its advice in this form, the ACMP wishes to emphasize that the matrix tables should not be used except in the context of the explanatory text. It also wishes to stress the importance of continuing the existing temporal trend studies, even though from consultation of the matrix tables alone, they may appear to be no longer necessary.

3 REQUESTS FROM THE HELSINKI COMMISSION

The ACMP took note of the current requests by the Baltic Marine Environment Protection Commission (Helsinki Commission) and reviewed the present status of the work, as follows:

1. To conduct a specific assessment of contaminants in sediments;

Progress in the conduct of the specific assessment has been slower than anticipated, as reported in more detail in Section 14.2. It is intended that the specific assessment will be completed in mid-1991. Although this document has not yet been completed, on the basis of the recommendation of the Working Group on the Baltic Marine Environment, the ACMP proposes to the Helsinki Commission that extended baseline studies of contaminants and geochemical parameters in Baltic Sea sediments should be included in the Baltic Monitoring Programme. The ACMP proposed that these baseline studies should be conducted at a frequency of once every five years or more, and that the first such study should not be conducted before 1993.

2. To continue the work on evaluating the size of seal populations in the Baltic and to assess their condition in relation to contamination;

Section 18 contains a review of the present state of seal populations in the Baltic Sea area and information on the impact of the disease outbreak in 1988 that affected seals in the Kattegat, Belt Seas and southwestern Baltic Sea. Although a number of studies of the influence of contaminant burdens on seals in relation to this epidemic are underway, very few results are yet available. The ACMP advises that the measures taken to protect the seals in the Baltic Sea should continue to be applied in the foreseeable future.

3. To review the results of the Patchiness Experiment (PEX) in terms of any possible implication on sampling schemes used in the BMP;

On the basis of the results of PEX, the ACMP has prepared recommendations relevant to the BMP concerning (1) measures to take to obtain an idea of the degree of patchiness around a station near the time of sampling, i.e., to assess the natural variability in the parameters being measured, and (2) measures to take to improve the analytical quality of the data obtained and stored in international data banks. Details are contained in Section 17.2.

4. To provide advice on reliable, intercomparable methods to determine concentrations of suspended particulate matter in sea water;

A detailed description of a reliable, intercomparable method to determine concentrations of suspended particulate matter in sea water is presently being published in the ICES Techniques in Marine Environmental Sciences series. Copies will be provided to the Helsinki Commission in due course.

5. To study the problem of the intercomparability of nutrient analyses and coordinate an intercalibration exercise on analyses of nutrients and oxygen;

ICES is coordinating an intercalibration exercise on analyses of nutrients in sea water, in which laboratories around the Baltic Sea have been invited to participate. Three samples have been distributed and results are due to be submitted in late summer 1989. It is hoped that a preliminary report on the outcome will be available for inclusion in the 1990 ACMP report. Information on procedures for oxygen determinations are contained in Section 13.6 of this report. If the Commission feels that an intercalibration exercise on the determination of dissolved oxygen in Baltic water is required, ICES can readily provide the design for such an exercise.

6. To provide information on "new contaminants", particularly those of special concern to the Baltic marine environment;

An updated overview on mercury in the marine environment is provided in Section 19.1 and an overview on dioxins and furans in Section 19.2 provides information supplementary to that contained in the overview on these substances published in the 1984 ACMP report (Coop.Res.Rep. No. 132). In addition, work has been initiated to provide a scheme for identification of chemical substances that might be of concern to the marine environment based on toxicity, chemical properties, etc. This work is still in the early stages of development.

7. To provide information on progress in the intercomparison work on determination of specific hydrocarbons in marine samples;

The first stage of the intercomparison programme on the determination of specific hydrocarbons is underway. A progress report is contained in Section 13.2

8. To provide information on the environmental impact of aquaculture, including nutrients and organic load impacts;

A summary of the available information on the types and extent of mariculture operations in the Baltic Sea area is provided in Section 10, along with information on some of the potential environmental impacts.

9. To report on the outbreak of recent epidemic diseases in seals in northern Europe in 1988 and its impact on seals in the Baltic Sea Area;

This question has been considered in conjunction with question 2; information on the outbreak of epidemic disease in seals in northern Europe and its consequences is contained in Section 18.

10. To provide information on as quantitative a basis as possible on conditions (physical, chemical and biological) relevant to the potential development of unusual algal blooms in the Baltic Sea Area.

This topic will be discussed at the first meeting of the Phytoplankton Ecology Working Group in Helsinki in early July 1989.

4 NORTH SEA TASK FORCE ACTIVITIES

The ACMP took note of the progress being made by the North Sea Task Force. It concluded that, in the development of the mechanisms for the preparation of the North Sea Assessment and the Monitoring Master Plan, ICES advice had clearly been noted. However, in the proposals for the conduct of the regional assessment, the ACMP considered that there appeared to be some confusion between the conduct of the sub-regional assessments and the purpose of the resulting overall final document. In this context, the ACMP considered that the North Sea Task Force should pay particular attention to answering the six questions to be addressed in relation to the available evidence for environmental effects, and not simply to bear them in mind. In this way, there should be every prospect both that the sub-regional assessments will be conducted comparably and that the overall result will serve the purpose of both administrators in defining what action should be taken and scientists in defining what further research and monitoring is necessary.

In the context of the North Sea Monitoring Master Plan, the ACMP noted with appreciation that the principles of its monitoring strategies advice had been followed. In particular, the ACMP was pleased that the Task Force had agreed that relevant recent data could be used rather than pointlessly using scarce resources in repeat surveys. Some concern was, however, expressed at the potential scale of effort that may be deployed on the measurement of complex organics, such as dioxins, if the 1990 survey were to cover all sites. Concern was also expressed that the term negligible should be used in relation to some form of environmental standard and not simply to a level of analytical detection that might be unduly high. The ACMP also wished to emphasize that, once the 1990 results were available, the monitoring strategy principles should be adhered to. In particular, the results should be carefully reviewed in relation to the need for further data before decisions are taken on any extensions to the survey or repeat survey activity.

In the context of North Sea monitoring activities, it was noted that the Continuous Plankton Recorder programme provides the only consistent, long time-series (more than 40 years) of data on plankton in the North Sea. The ACMP felt that this activity should be supported, if possible, at the international level.

5 REGIONAL ASSESSMENTS

The ACMP noted that a number of regional assessments are now in progress generally following the ICES guidelines provided in the 1988 ACMP report.

A joint Canadian - US effort had started in order to undertake an environmental assessment of the Gulf of Maine, the Bay of Fundy, and Georges Bank. Funds for assessment and monitoring had been allocated and the ICES guidelines had been provided. The work was to be conducted at the State/Province level, with the State of Maine as responsible coordinator. This arrangement would call for a major input to be prepared by consultants. Also relevant was a book on Georges Bank produced by the US Woods Hole Oceanographic Institution. Furthermore, Dalhousie University (Halifax) was co-ordinating the compilation of a computerized data bank covering the Bay of Fundy, the Gulf of Maine, and Georges Bank.

In the UK, the Marine Pollution Monitoring Management Group is working on an assessment of the northeast coast of England (including the Flamborough Front). This assessment is being carried out according to the ICES guidelines. The next assessments planned by this group will be for the Clyde estuary and a joint UK-French project concerning the English Channel.

The conditions in the Skagerrak in the border area between Sweden and Norway have been extensively discussed by the environmental protection agencies of the two countries. It has been agreed that some intensified complementary studies should be conducted over a two-year period, to be followed by an assessment based on the status report that had been prepared by the former ICES Working Group on Pollution-Related Studies in the Skagerrak and Kattegat (published as Coop.Res.Rep. No. 149 (1987)) and all new material brought forward thereafter.

Following the basic status report on the Baltic Sea, published in 1981, the Baltic Sea environment is re-assessed every five years. The basis for the assessment is data from the Baltic Monitoring Programme, that are also reviewed every five years. Thus, the system is designed for a mutual feed-back between the two elements of monitoring and assessment. It was pointed out that, mainly due to the morphological and hydrographic conditions in the Baltic Sea, the assessment is based on multinational drafting groups dealing with subjects (e.g., hydrography, oxygen conditions, nutrients, etc.) on a sub-regional basis. From this, a comprehensive assessment is built up including all parameters for the whole area. It was noted that ICES is assisting in the preparation of the Second Periodic Assessment of the Baltic Sea Environment, particularly with the preparation of a chapter on trends in fish stocks in the Baltic Sea (see also Section 17.3).

The Netherlands had started an evaluation of the morphological, geological, and chemical characteristics of the Wadden Sea. The study is to be expanded to include benthic community material. The study will continue on an annual basis and will, eventually, lead to the preparation of an assessment.

The ACMP also noted that, following publication of the report on the Status of Current Knowledge on Anthropogenic Influences in the Irish Sea (Coop.Res.Rep. No. 155 (1988)), which was based on the previous ICES assessment guidelines, work on the Irish Sea is continuing within a joint UK/Ireland Irish Sea Study Group. It is expected that the results of this study, consisting of four specialist group reports (natural resources, waste inputs, nature conservation, and management) will be published in 1990 prior to a conference on the future management of the Irish Sea to be held on the Isle of Man in the autumn of 1990.

In addition to these regional assessments, the ACMP noted the assessment document being developed by the North Sea Task Force, on which more detailed comments are provided in Section 4, above.

Finally, a document entitled "Monitor 88", issued by the Swedish National Environment Protection Board, was brought to the attention of ACMP. This document represents an easily understood summary of conditions in and threats to the Baltic marine environment. It offers a useful model for the presentation to non-specialists of the complex issues associated with assessments of the state of regional environments. The ACMP commends this document as an example of a manner in which scientific assessments can be conveyed to the public.

6 MONITORING ISSUES

6.1 Matrix Tables for Monitoring Purposes

The Oslo and Paris Commissions have requested that ICES provide advice by means of matrix tables on how most effectively to monitor each contaminant of interest for the Joint Monitoring Programme (JMP). Based on the report of the Working Group on Environmental Assessments and Monitoring Strategies (WGEAMS), the ACMP endorsed the matrix tables presented below with the caveat that such tables must not be considered out of context with the following text.

6.1.1 Introduction

The matrices are selected as those most appropriate for the provision of the greatest information in relation to each monitoring purpose. They have been selected on scientific grounds, and do not take any account of relative costs or the convenience of the alternative choices.

In some cases, no matrix has been recommended, either because the monitoring of a particular contaminant is not appropriate to the monitoring purpose, or because advice could not be given for technical reasons. More complete explanations of individual cases are given below.

In many cases, primary and secondary choices of matrix are given, and, in some cases, tertiary choices. These choices should be viewed as alternatives, or complementary choices, but if circumstances permit, a primary matrix should preferably be selected for analysis, as this would provide the greatest return for effort in terms of information relevant to the particular monitoring purpose. Suitable primary matrices may not be available in all monitoring locations and, in such cases, secondary or tertiary matrices should be considered. In some cases, particularly in relation to the assessment of the existing level of marine pollution, a more comprehensive expression might be obtained by the analysis of the contaminant in all matrices. However, the priority selections of matrices were made with the aim of providing the most useful scientific information for assessing distributions of contaminants, and focussing attention on those matrices that might enable the most consistent picture of distributions over wide areas to be obtained through the collective efforts of a number of laboratories and countries.

In some cases, matrices will be chosen on the basis of pre-existing local information and on-going monitoring programmes. The ACMP wishes to stress that the advice in the following sections should not be taken as opposing the continuation of existing monitoring programmes, designed in the context of local conditions, that are yielding useful information even if they do not wholly match the selections advocated here.

In all circumstances, the reliability of the information from a monitoring programme, and its consequent value, is dependent upon the attention paid to quality assurance at all stages of the measurement programme (sample collection, storage, preparation,

pre-concentration, analysis, standardization and interpretation). Participating laboratories should be required to adopt appropriate procedures in this area.

6.1.2 The assessment of possible hazards to human health (JMP purpose (a) - Table 1)

In the general area covered by the JMP, none of the contaminants considered presents a widespread serious hazard to human health through the consumption of marine foodstuffs. Moreover, in some cases (e.g., copper, zinc, arsenic, chromium, and nickel), the contaminants are not normally of concern with respect to fisheries products. Equally, the monitoring of contaminants in sea water or sediment would not have any direct applicability to human health risk, and these considerations are reflected in the matrix Table 1. This table, therefore, provides advice on the contaminants and matrices that might be included in a regional or wider scale survey to assess the possible hazards to human health presented by the presence of selected contaminants in marine foodstuffs. In several cases, primary and secondary choices of matrix are given.

There may be areas where sources of contamination could give rise to localized increases in the concentration of one or more contaminants in marine foodstuffs. Such situations are unlikely to be detected or adequately described by large-scale surveys, and are better approached through specially designed and targeted monitoring exercises by national or local authorities. In such circumstances, the relevant authorities should assess the most important exposure pathway by which the contaminant may reach the public through marine foodstuffs. The monitoring programme should be directed at that pathway, and not be constrained by the advice given in Table 1 in relation to broader scale surveys. For example, in some areas there may be concern over the concentrations of CBs in the muscle of fatty fish species such as herring or mackerel, and in such circumstances it would be appropriate to analyse herring or mackerel muscle.

Matrix Table 1

In relation to the assessment of possible hazards to human health
[JMP Purpose (a)].

(This matrix table must not be considered independently of the preceding text)

Matrix	Contaminant									
	PCB/CBs	γ -HCH	Hg ⁵	Cd	Cu ³	Zn ³	As ⁴	Cr ³	Ni ³	Pb
Shellfish	P	P	P	P						P
Fish muscle			P							
Fish liver	S ²	S ²		S ¹						

P: primary matrix

S: secondary matrix

Notes and Qualifications:

1. If fish liver is not a consumed fisheries product, no analysis is needed.
2. If fish liver is not a consumed fisheries product and there remain human health concerns, transfer attention to fish muscle.
3. These contaminants are not normally of concern in respect to the consumption of fisheries products.
4. Arsenic is present in seafood in measurable concentrations, but its chemical form makes it of little concern with respect to human health.
5. Hg should be understood to include methylmercury compounds. In countries where public health regulations refer to methylmercury rather than total mercury, samples may be analysed for methylmercury.

CBs: Chlorobiphenyls on an individual basis, congener Nos. 28, 52, 101, 118, 153, 138, and 180.

6.1.3 The assessment of the existing level of marine pollution (JMP purpose (c) - Table 2)

Water

A distinction is to be made between nearshore and offshore waters. In the former, marked salinity gradients occur, and contaminant distribution is more likely to be influenced by riverine or land-based inputs. In the latter, which is more remote from the above-mentioned inputs of contaminants, gradients are normally substantially less marked.

The use of water analysis to reflect current levels of marine contamination is attractive in that it concerns the important aqueous phase, the environment in which both biota and sediment exist. However, considerable efforts are still required to improve the comparability of analytical performance among laboratories engaged in sea water analysis in member countries. The requirements for precision and accuracy of analysis at low concentrations limit the number of determinands that can be considered in offshore waters to mercury, cadmium, copper, zinc, lead, and lindane, all at secondary matrix level. Even in these cases it would be essential for each laboratory to establish in-house quality control procedures, and for rigorous attempts to be made to establish comparability between laboratories, with particular attention being paid to lead.

In nearshore waters subject to anthropogenic influences, concentrations may be somewhat more variable, and chromium and nickel analyses might also be added to the above list. The same quality assurance precautions would be needed. In nearshore waters it is necessary to take account of any correlation between contaminant concentrations and salinity, and of the influence of the concentration and composition of suspended matter on the dissolved contaminants.

Sea water is not a matrix of choice for CBs, as the octanol:water partition coefficients indicate that the compounds would be predominantly associated with sediment or biota.

The concentrations of arsenic naturally present in sea water make the discrimination of anthropogenic influences from natural processes difficult and, therefore, sea water is not indicated as an appropriate matrix.

There are some sheltered bays or lagoons in which the inputs of contaminants are sufficiently large to cause marked elevations of contaminant concentrations in sea water, or in which changes in concentrations can be expected. As agreed by the Commissions, in such areas it might be appropriate for national authorities to give more prominence to water analysis in monitoring programmes, but this should not be regarded as a general recommendation.

Matrix Table 2

In relation to the assessment of the existing level of marine pollution
(i.e., contamination) [JMP Purpose (c)]

(This matrix table must not be considered independently of the preceding text)

Matrix	Contaminant										
	PCB/CBs	γ-HCH	Hg	Cd	Cu	Zn	As	Cr	Ni	Pb	TBT
Nearshore water		P	P ¹	P ¹	P ¹	P ¹		P ¹	P ¹	P ¹	S ¹
Offshore water		S	S ¹	S ¹	S ¹	S ¹				S ¹	
Surficial sediments ²	P		P	P	P	P	P ⁵	P	P	P	P
Shellfish	S ³	S ³	S ¹	S ¹		S ¹				S ¹	P
Fish muscle			T ^{1,4}				S ^{1,4}				
Fish liver	S ⁴		T ^{1,4}							T ^{1,4}	

P: primary matrix
S: secondary matrix
T: tertiary matrix

Notes and Qualifications:

1. Potential addition/alternative to sediment measurements in areas where sediment conditions are not wholly favourable.
2. Should be accompanied by organic carbon measurements and appropriate normalization procedures, following the most recent ICES guidelines for monitoring contaminants in sediments.
3. Could be carried out on an opportunistic basis, as may provide additional information on distribution.
4. Sedentary species only (e.g., flatfish).
5. The signal-to-noise ratio for discriminating between anthropogenic and natural influences is extremely low.

CBs: Chlorobiphenyls on an individual basis, congener Nos. 28, 52, 101, 118, 153, 138, and 180.

Sediments

There is very considerable emphasis laid on the use of surficial sediments as a primary matrix for most of the contaminants. Participating laboratories should take full account of the most recent advice on the selection of sampling locations and methods (see, e.g., Section 15, 1986 ACMP Report (Coop.Res.Rep. No. 142); Annex 2, 1983 ACMP Report (Coop.Res.Rep. No. 124); Annex 2, 1984 ACMP Report (Coop.Res.Rep. No. 132)). Areas of high sedimentation and low bioturbation rates are particularly favourable. It is also necessary to subject the samples or data to appropriate normalization procedures to compensate for the natural distribution of contaminants in relation to the texture, provenance and grain-size of the sediment (see Section 14.1 of this report).

Biota

Both sediment and shellfish are indicated as primary monitoring matrices for tributyl-tin (TBT). Whilst the main area of concern over TBT is its effects on shellfish, particularly molluscs, for example oyster and dogwhelk, these organisms are by nature of limited geographical distribution. TBT, and its derivatives DBT (dibutyl-tin) and MBT (monobutyl-tin), can be found in sediments, especially near shipyards and busy shipping lanes, in harbours and marinas and, at least until recently, in the vicinity of some mariculture operations. The monitoring of sediment for these compounds would allow the use of a single matrix in a wider range of environments (e.g., into low salinity areas of estuaries) than would be possible using a single molluscan species.

6.1.4 Assessment of the effectiveness of measures taken for the reduction of marine pollution within the framework of the Conventions (JMP purpose (d) - Table 3)

Measures taken within the framework of the Conventions to reduce the level of marine pollution are primarily directed at the control and reduction of inputs of contaminants. The main inputs are from riverine sources, land-based discharges, the atmosphere, and direct dumping. The most efficient way to assess the effectiveness of the measures taken to reduce inputs is, therefore, to monitor the inputs. The Joint Monitoring Group (JMG) may wish to take note of the comments in the 1988 ACMP report on the estimation of gross and net riverine inputs, and on atmospheric inputs. The monitoring of inputs can give detailed information on the effects of control measures on individual or localised groups of contaminant sources, and can, therefore, be particularly useful in regulatory procedures.

It is also necessary to assess the effectiveness of the control measures in improving the quality of the marine environment. It is this aspect of trend monitoring that is covered by Table 3. The table represents a statement of the current "state of the art" and, as the subject is developed, additional combinations may become appropriate. Thus, most of the recommendations are indicated as primary matrices, to reflect that they are very much alternatives.

Matrix Table 3

In relation to the assessment of the effectiveness of measures taken for the reduction of marine pollution (i.e., contamination) in the framework of the Conventions [JMP Purpose (d)].

(This matrix table must not be considered independently of the preceding text)

Matrix	Contaminant										
	PCB/CBs	γ -HCH	Hg	Cd	Cu	Zn	As ⁵	Cr ⁵	Ni	Pb	TBT
Water		p ²									
Sediment profiles ⁴	P		P	P	P	P			P	P	P
Shellfish			P	P	P	P				P	P
Fish muscle			p ^{1,3}								
Fish liver	s ^{1,3}										

P: primary matrix
S: secondary matrix

Notes and Qualifications:

1. Considerable care has to be taken with species selection and availability, sampling protocol, and statistical aspects of data analysis.
2. Considerably greater effort is required, in respect to sampling and analytical frequency, if measurements are made in water, but the potential signal-to-noise ratio for trends is greater than that in sediments.
3. Sedentary species should be selected.
4. Care should be taken in selecting favourable areas of high sedimentation rate and limited bioturbation, following the most recent ICES guidelines for monitoring contaminants in sediments, including organic carbon measurements and appropriate normalization procedures.
5. No recommendation can yet be made, except that the sediment does not seem to be appropriate for purpose (d).

CBs: Chlorobiphenyls on an individual basis, congener Nos. 28, 52, 101, 118, 153, 138 and 180.

When considering monitoring for temporal trends, it is necessary to consider the likely length of time that may elapse before any change in input may be reflected in the monitoring matrix. This length of time will be a complex function of environmental factors and processes, the magnitude and rate of changes in inputs, analytical factors, and data analysis procedures, with particular emphasis on the variance of each of the contributory media and processes. This may have particular importance in relation to the frequency with which the JMG may wish to assess the effectiveness of measures taken by the Commissions, or the frequency of regional assessment exercises (e.g., in the North Sea area).

Biota

Given the situation described above, it is important to note that it is difficult to interpret biota trend monitoring data in relation to changes in environmental levels in response to "measures taken to reduce marine pollution" in areas other than those where marked changes were involved (e.g., near strong point sources). In other words, the levels of change referred to are levels of change within the organisms, which cannot necessarily be assumed to reflect levels of environmental change.

Sediment

Table 3 particularly emphasises the potential of down-core analysis of sediments in temporal trend monitoring for a wide range of contaminants. As noted with respect to Purpose (c), and in footnote 4 to Table 3, it is particularly important to pay attention to the site selection and data normalization procedures discussed in other ICES documents, including Section 14.1 of this report. Arsenic and chromium analyses are not recommended as it is as yet unclear how the distribution of these elements may be affected by variations in redox potential in coastal sediments.

The JMG should take note of comments in the 1988 ACMP report (Annex 2) on the influence of sedimentation rate and bioturbation intensity on the ability of sediment core samples to reflect changes in input to the sediment. It is also likely that sediment core analyses will reflect general basin conditions, rather than changes resulting from discharges from single sources or particular types of input.

Water

Water analysis is not recommended for trend monitoring (except for lindane). However, in circumstances of marked contamination and where changes are expected, contaminant monitoring in sea water may be appropriate, provided that statistical considerations indicate that such analyses could reliably reflect the effects of control measures.

It should be noted that the CBs referred to on the matrix tables are the chlorobiphenyls that ICES has recommended for determination in general monitoring situations, namely, primarily, IUPAC Nos. 28, 52, 101, 118, 153, 138, and 180, and, secondarily, IUPAC Nos. 18, 31, 44, 66/95, 110, 149, 187, and 170.

6.2 Guidelines for Monitoring Contaminants in Marine Media

The ACMP took note of the JMG request that ICES review the current ICES or JMP guidelines for sampling and analysis of biota for use in temporal trend and spatial distribution purposes, taking account of their wish to have a sampling strategy for both purposes that would allow use of only one set of samples. The response to this request is still being developed. In the interim, the ACMP recognized that these two purposes are distinctly and importantly different. The only compromise that might be made is to state that a sample taken for the temporal trend purpose can be used to estimate a single value for use in spatial distribution monitoring, provided that it meets the detailed requirements of the spatial distribution monitoring guidelines with respect to, e.g., the time of sampling and the length range of organisms to be sampled.

However, the ACMP noted that sampling and analysis guidelines for temporal trend and spatial distribution monitoring may need to be modified in the light of the investigations carried out within ICES on monitoring data by the Working Group on the Statistical Aspects of Trend Monitoring (WGSATM), and that such changes will be presented in 1990. It is envisaged that any recommended change to the guidelines will be of a nature that would aid data analysis, with both past and future data in mind.

The ACMP noted that the WGSATM is developing revised guidelines for the monitoring of temporal trends of contaminants in mussels. The main alteration in the procedure relates to the proposed use of a single size/age class of mussels from each site, instead of a range of sizes as presently recommended. The ACMP identified the need for clarification of some aspects of the guidelines and has requested the Working Group to make the necessary amendments, with a view to adoption of the revised procedures at next meeting of ACMP. In the meantime, laboratories engaged in trend monitoring studies using mussels can be assured that the existing procedures were adequate.

6.3 Use of Seaweeds in Monitoring Contaminants in the Marine Environment

The ACMP noted that the WGSATM had discussed a paper examining the potential of using seaweeds for monitoring purposes. In this paper, the authors concluded that, while the application of seaweeds to the monitoring of dissolved copper and zinc in water was limited by the physiological controls exerted by seaweeds on these metals, the ability of seaweeds to reflect distributions of lead in water showed some promise for monitoring purposes. The ACMP considered that it would be premature, given this limited scale of applicability, to recommend the adoption of this additional substrate for routine use in monitoring programmes. However, with a view to the potential application in monitoring, the topic is being referred to the Working Group on Environmental Assessments and Monitoring Strategies (WGEAMS) for further study.

6.4 Temporal Trend Monitoring Issues

The ACMP considered the report of the WGSATM and accepted the following information and advice it contains.

6.4.1 Statistical analysis of data on contaminants in biota

The ACMP took note of the status of the on-going activities of WGSATM concerning the statistical analyses of the Cooperative ICES Monitoring Studies Programme (CMP) data on contaminants in fish and shellfish for the determination of temporal trends. With the publication of the results of the statistical analyses of data on contaminants in fish muscle tissue, covering the period up to 1985, in ICES Cooperative Research Report No. 162, the WGSATM is currently concerned with the evaluation of the data on contaminants in fish liver tissue and shellfish soft body tissue.

The ACMP reviewed the arrangements which had been made in order to coordinate the activities of the WGSATM and the ad hoc Working Group on Monitoring (under the Joint Monitoring Group (JMG) of the Oslo and Paris Commissions) with regard to their respective evaluations of the, largely overlapping, CMP and Joint Monitoring Programme (JMP) data sets. The following procedure has been agreed: the WGSATM will undertake the statistical analyses of the data and transmit the results to the ad hoc Working Group on Monitoring, meeting in December 1989, for incorporation into their evaluation of the JMP temporal trend monitoring data which will also address the interpretative stages in the evaluation of these data.

Referring to progress in the WGSATM analysis of the data sets on contaminants in blue mussels, the ACMP noted that two levels of treatment had been applied to the data. The first treatment consisted of a basic presentation of "apparent trends" as reflected by plots of the yearly arithmetic means of the reported contaminant concentration values, including both pooled and individually analysed samples. This approach represented a basic means of looking at the data from all available data sets, regardless of data characteristics and ignoring possible biological effects and the effect of pooling. As a second approach, a more involved analysis was undertaken by investigating the use of shell weight as a possible covariate to adjust contaminant burden estimates for biological variation between years, using that sub-set of the data where the necessary parameters had been reported.

After considering the results obtained by the two methods, the WGSATM had concluded that some further work was required in order to assess (i) whether the shell weight relationship constituted a useful approach, and (ii) whether geometric means should be computed as an alternative to arithmetic means in the basic data presentations. The ACMP noted that this work would be concluded as soon as possible so as to complete a statistical analysis of the data, by whichever method proved to be most appropriate, for consideration by the JMP ad hoc Working Group on Monitoring in December 1989.

With respect to the analysis of the data on contaminants in fish liver tissue, the ACMP reviewed progress in studies aimed at

elucidating two of the main problems with these data, which had delayed their analysis in previous years. The first of these studies focussed on the influence of specific biological covariables on concentrations of PCB, cadmium, copper, lead, mercury, and zinc in liver tissue of cod, whiting, flounder, and plaice in areas of the North Sea. The following problems were encountered:

- a) only those data sets from the ICES CMP where data on individual fish length, liver weight, and fat percent were present (variables which had been identified in previous work as influencing concentrations of PCB and cadmium in cod liver) could reasonably be selected for analysis;
- b) not all contaminant/species combinations were present for consideration;
- c) some data sets were very small (< 20 observations); and
- d) the results obtained indicated that the importance of variables differed among contaminants and species (although, in some cases, this could have been due to the restricted range of the variables).

Despite the above-mentioned limitations, the work provided a rationale for deciding which covariables should be introduced into the analysis for any given data set.

A second study had been conducted in order to examine the problems associated with the fact that the statistical distribution of contaminant concentrations when analyzed in bulked tissue may be different from the distribution of concentrations when analyzed in the tissues on an individual organism basis, a subject of continuing work within WGSATM over the past years.

For cases where the concentrations in the tissues of individuals are log-normally distributed, and on the basis of some simple approximations, the study had shown that increasing the degree of bulking would not affect accuracy, but would lead to an apparent increase in geometric mean contaminant levels. These results were extended using computer simulation to monitoring levels of PCB in cod livers. Bulking had the expected effect of not affecting the measured difference between contaminant levels between years, although the probability of finding a significant difference was reduced.

The ACMP noted that, on the basis of the information obtained from these two studies, it was intended that the preliminary assessment of the data on contaminants in fish liver tissue would continue. The results will be finalized with a view to publication in the ICES Cooperative Research Report series.

With respect to the statistical analyses of the liver tissue data sets for the JMP ad hoc Working Group on Monitoring, the ACMP noted that the studies themselves had incorporated a number of the relevant analyses. Work aimed at completing the outstanding analyses of the pooled data sets was due to be finished in good time, but these analyses would be conducted according to the priorities of the ad hoc Working Group on Monitoring so as to ensure that, as far as possible, commitments would be met.

An overview of the intended intersessional work due to be conducted by the time of the meeting of the ad hoc Working Group on Monitoring would be communicated to the Oslo and Paris Commissions Secretariat.

In reviewing the work of the WGSATM, the ACMP recognized the need to consider how continuing evaluations of the trend monitoring data sets should be achieved in the future, both within ICES and the OSPARCOM. Statistical analyses of these data sets has been shown to constitute a major commitment in terms of time and manpower resources and the ACMP confirmed the role of the WGSATM as primarily concerned with the development of the statistical methods for temporal trend elucidation rather than their routine application.

6.4.2 Multivariate and univariate approaches to analysis of temporal trend data

The ACMP took note of the continuing activities within WGSATM aimed at consideration of multivariate techniques in the analysis of temporal trend data. The WGSATM had reviewed two papers in which univariate and multivariate techniques were compared and contrasted: the first paper used a limited data set to keep the statistical models and analysis as simple as possible for the non-mathematical reader; the second paper presented time trend studies on the Canadian Atlantic cod data.

The ACMP took note of the following conclusions of this work.

- a) The Multiple Analysis of Covariance (MANCOVA) techniques may indicate trends in a mixture of contaminants and provide a test of whether such a mixture varies with time, i.e., taking account of contaminant-physiological interactions. Where contaminant concentrations are mutually correlated, as is often the case, temporal variations which are identified by the multivariate procedure become increasingly more difficult to identify by univariate analysis as the extent of the overlaps in annual ranges of individual concentrations of contaminants increases.

However, certain questions remain:

- are differences between the MANCOVA and Analysis of Covariance (ANCOVA) results due to competition or synergism between the contaminants?, and
- how do they reflect inputs and changes in inputs?

In cases where contaminant concentrations are mutually correlated, the multivariate approach is preferable to the simplistic interpretation of trends in levels of a single contaminant as necessarily a direct reflection of inputs and input changes. However, at this stage there are insufficient data to answer these questions.

b) Separate Analyses of Variance (ANOVAs) or ANCOVAs are still desirable for the following reasons:

- when the manager is primarily or exclusively interested in tracking temporal variations of individual or specific contaminants, due to the problems of interpretation of the results for a composite of several contaminants; and
- when there are several missing observations in a data set, because the multivariate techniques are considered particularly susceptible to poor data quality.

When contaminants are uncorrelated, temporal variations examined by several univariate analyses would yield results which are similar to those from a single multivariate analysis.

c) A good working strategy when employing a series of univariate analyses would be to supplement them with a multivariate analysis for drawing inferences concerning temporal variations and time trends for contaminants.

The ACMP recognized the conclusion that results from neither MANCOVA nor ANCOVA were necessarily correct. Simultaneous and individual statistical analysis of metals data does, however, provide different perspectives on what the trend data indicate. The ACMP further recognized the progress which had been achieved in relation to the application of the multivariate techniques to real data sets.

6.4.3 The efficiency of pooling in mussel watch studies

In relation to pooling studies, the ACMP took note of work reported by WGSATM addressing the effects of sample pooling on the statistics of trend determination, including the recognition that one of the main reasons why sample pooling is carried out is as a means of economizing on the costly sampling and analytical resources required in a monitoring programme.

The ACMP particularly recognized the work under WGSATM in which generalized models were developed incorporating arbitrary cost estimates for some of the main components in a programme (e.g., sampling and analytical costs); statistical tests were then used to optimize the models with respect to pooling strategies, i.e., the number and sizes of pools. In the past, relatively little attention has been paid to the final choice of the number of pools and of the number of organisms comprising a pool. Generally, pooling has been expressed in terms of extremes, e.g., one very large pool (i.e., a single sample homogenate) or no pooling at all (i.e., sampling and analysis of individual specimens). It could be shown that, in almost all cases, due to the rather flat appearance in the central part of an optimization function as compared to the steep slopes characterizing the two extreme situations noted above, a good rule-of-thumb from an economic point of view is to avoid these extremes.

The ACMP were informed that, in order to promote the wider recognition of the value of this type of study, the WGSATM had agreed that this work should be revised, incorporating an example

including real data (e.g., real costs, etc.) with a clear, non-mathematical description of how to apply the concepts.

6.4.4 Precision of measurements in relation to temporal trend monitoring

The ACMP noted that the Marine Chemistry Working Group (MCWG) had responded to a request from the WGSATM for advice on the precision of measurements in relation to trend monitoring. Specifically, the WGSATM wanted information on the long-term variance of analytical measurements (i.e., not just the within-batch variance, which is normally quoted by analysts, but the between-batch variance, which would be obtained from a series of analyses over a period of time). This was needed to assess the analytical component of the overall variance of the measurement procedure. The ACMP was informed that several members of the MCWG had agreed to provide the WGSATM with relevant results from in-house quality control studies so that the WGSATM could assess the long-term within-laboratory variance of analytical measurements.

The ACMP then discussed the need for, and the approach that should be taken by, investigators conducting trend monitoring studies to obtain the overall variance of the measurement, i.e., the variance associated with sampling, storage and analysis. In designing programmes to assess trend monitoring, it is necessary to recognize that some of the apparent changes in contaminant concentrations over time in the relevant matrices could be caused by inherent variability in the sample population. This variability has to be assessed in order to determine that changes in contaminant levels are not just artifacts of chance variation. It is best if this variability can be estimated at the beginning of the trend series in order to calculate the change in contaminant levels likely to be detectable for a given sampling effort. In practice, this means that replicate sampling has to be done at each location under investigation. In the case of organisms, this requires the investigator to collect sufficient numbers of individuals in the population and to analyse them, either individually or as a number of standardized bulk samples, in order to assess the variance associated with sub-samples of the population. A similar approach must be applied to the sampling of sea water and sediments.

Ideally, the assessment of inherent variability should be conducted on each sampling occasion. However, the ACMP recognized that this approach is very demanding on resources, particularly for some measurements for which the analytical procedures are significantly time consuming, e.g., studies requiring the analysis of organic chemicals. In view of this, the ACMP recommends that the minimum work required in relation to assessing and controlling overall variance of measurement procedures should be as follows:

- 1) At the outset of temporal trend studies, the investigator should make an assessment of inherent variability of contaminant levels in the population of marine organisms or in the water or sediments at each sampling location.

- 2) Throughout the trend study, an assessment of variance of the analytical procedure should be made on a regular basis (on each batch analysis) using either a certified reference material (CRM) or an internal reference material (IRM) to provide a measure of the long-term variance of the analytical measurement.
- 3) By combining the data on variance from (1) and (2), above, and assuming that subsequent changes in inherent variability (e.g., variance associated with sampling) are minimal, the WGSATM will obtain relevant data on the overall variance of the measurement procedure against which any changes in contaminant levels over time can be tested. It will also enable them to estimate the feasibility of a given trend being detected for a given sampling effort. The ACMP also considers that replicate sampling, throughout the contaminant trend measurement series, will substantially increase the ability of statistical tests to detect significant changes in trends.

All of this implies a substantial sampling effort by the investigator if temporal trend monitoring is to lead to unambiguous conclusions.

Finally, the ACMP noted the following conclusions from one of the papers discussed by the WGSATM:

- 1) Random variations of analytical results will increase the total variance of trend observations and, hence, make it more difficult to detect a significant trend.
- 2) A constant bias which does not change with time will not affect the ability of significance tests to detect trend differences.
- 3) Where bias changes with time, it may either cause a trend to appear greater, if the bias change serves to increase the trend result, or nullify the trend if it is in the opposite direction.
- 4) When bias is variable but undetected, it will tend to suggest statistically significant trends where there were none and make it less likely that real trends will be detected.

6.5 Baseline Study on Trace Metals in Sea Water

The ACMP noted that the MCWG had examined the 1987 data submitted as part of the 1985-1987 Baseline Study of Trace Metals in Coastal and Shelf Sea Waters. These data are to be combined with those submitted for the period 1985-1986 that have already been collated and preliminarily reviewed by the MCWG. The ACMP noted the progress being made on the completion of the report of the baseline study. Recognizing the considerable interest being shown in the results and report, by both the Oslo and Paris Commissions and the North Sea Task Force, the ACMP has proposed measures which it is hoped will allow the ACMP to include a summary of the results in its 1990 report, and lead to full publication of the final report late in 1990.

7 BIOLOGICAL EFFECTS OF CONTAMINANTS

The ACMP examined the 1988 report of the Working Group on Biological Effects of Contaminants (WGBEC) with respect to the following issues: (1) progress on development of methods for general use; (2) plans for the Workshop based at Bremerhaven; and (3) progress in evaluating the bioavailability of contaminants in sediments.

7.1 Progress on Development of Methods for General Use

The Working Group had developed a justification of the role of biological effects monitoring techniques in the study of environmental contamination. The ACMP discussed critically several aspects of this justification and decided to accept it after some modification. It is presented below.

7.1.1 Role of biological effects monitoring techniques

The interpretation of the effects of environmental contaminants is not possible without an interdisciplinary approach involving the use of both biological and chemical techniques in an interdependent manner. Therefore, monitoring programmes should be based on a close collaboration between biologists and chemists.

Chemical data are most valuable when they can be related to biological processes, although they may also be used to indicate transport pathways, bioaccumulation and biomagnification and, thus, the communities, species or tissues likely to be subjected to the highest levels of exposure. However, many criteria for marine environmental quality are biological, so it is logical to use biological systems by which to measure it. In addition, there are a number of other practical reasons for using biological techniques:

a) Detection of potential pollutants

To rely only on chemical methods of analysis presupposes that the potentially important contaminants are known and are being, or can be, monitored. Examples such as tributyl-tin (TBT) demonstrate that this is not always the case and that biological effects measurements can provide a means of detecting the presence of new or unsuspected contaminants.

b) Bioavailability

Often, chemical data do not reflect the bioavailability of contaminants due, for example, to speciation of organic compounds or the binding state of metals. By definition, biological systems can only respond to what is bioavailable, so organisms provide the most appropriate indication of bioavailable concentrations of contaminants exceeding thresholds of effect.

c) Integration of toxic effects

Typically, toxic contaminants do not occur alone and it is their combined effect that determines environmental quality. Biological systems provide an integrated response to the totality of contaminants present.

d) Integration with time

Concentrations of contaminants, particularly in nearshore and estuarine environments, may vary widely within relatively short periods of time. When it is the effect of contaminants over time that is of concern, biological systems (sessile organisms) may provide a time-integrated response.

e) Cost

The number of new environmental contaminants is growing annually and with it the number of compounds to be monitored. As the lists of contaminants routinely monitored grows, so does the cost of sustaining chemical monitoring programmes. Chemical analytical effort would be optimized by utilizing it primarily when there are reasons to suspect biological problems.

Figure 1 (modified after Bayne *et al.*, 1985) illustrates, very schematically, how each step in the biological response copes with contaminant exposure. Initially, the biochemical mechanisms of the cell change to adapt to a certain level of contaminant. If the contaminant stress continues or increases, the next higher level of organization (in this case, the cellular level) is affected. The process repeats until the whole organism is affected and mortality may occur. This can be extended to the community or even ecosystem level. It is important for managers to evaluate at what level they wish to detect pollutant impact, and then to structure the monitoring programme accordingly. It should be noted that the changes described at the lower end of the figure are easier to interpret in terms of cause and effect, because biochemical responses tend to be more contaminant specific; however, the responses are less readily interpretable in terms of significance for the well-being of the organism or species. On the other hand, death could be the result of a combination of factors.

Figure 2 illustrates the biological effects techniques employed at the IOC/GEEP Workshop on the Biological Effects of Pollutants (Oslo Workshop, 1986) (upper half) and those proposed for the ICES/IOC Biological Effects Techniques Workshop in the North Sea (Bremerhaven Workshop) (lower half). To the right are those techniques that show demonstrable effects on organisms, including bioassays and studies of pathological changes which may result in mortality. The techniques to the far left attempt to demonstrate an adaptive response to pollutants through biochemical or cellular changes. This left side of the figure represents the sub-lethal effects that have traditionally been recognized as a research subject. Methods based on reproductive capacity, scope-for-growth and immunological responses probably fall in the middle zone and are rapidly gaining acceptance. The Bremerhaven

FIGURE 1

Possible effects of toxicants

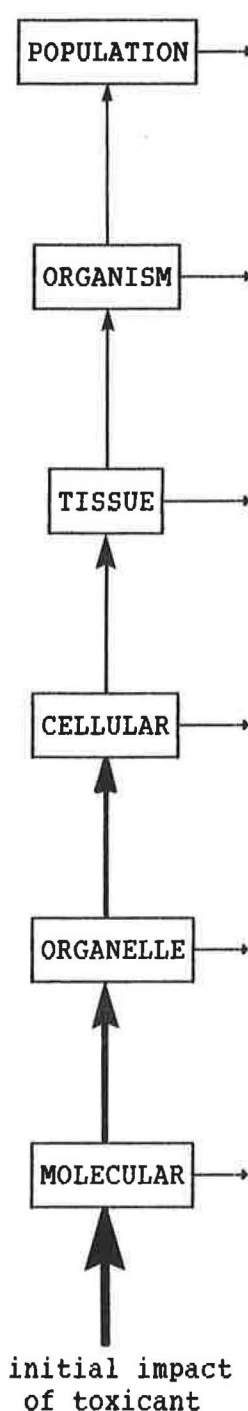
- increased mortality
- decrease in gamete or larval viability

- disruption of physiological processes
- reduced feeding rate
- growth inhibition
- reduced energy reserves
- reduced fecundity

- alteration in cell morphology
- inhibition of mitosis
- neoplastic growth

- lysosomal destabilization and autolysis
- chromosome damage

- gene mutation
- change in conformation and activity of enzymes

Possible adaptive responses

- increased recruitment

- avoidance behaviour
- excretion of toxicant
- change in energy allocation

- sequestration
- differential tissue growth

- hypertrophy
- hyperplasia

- lysosomal autophagy
- proliferation of endoplasmic reticulum
- sequestration in vesicles
- chromosome repair

- DNA repair
- detoxification by MFOs and metallothioneins
- enzymatic and metabolic responses

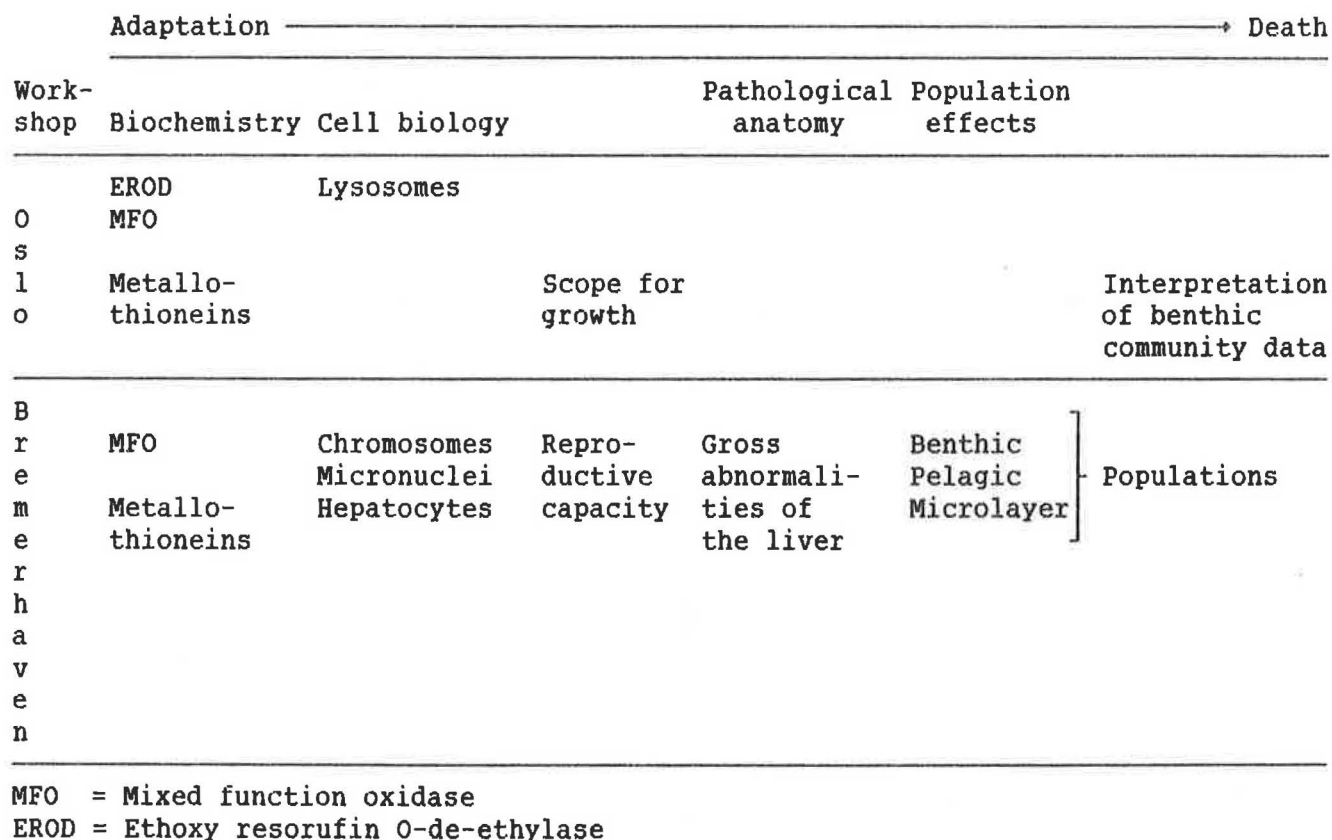
A hypothetical scheme suggesting how the impact of a toxicant upon an organism might vary as it passes through increasing levels of biological organization. Modified from Bayne *et al.*, 1985

MFO = Mixed function oxidase.

EROD = Ethoxyresorufin O-de-ethylase.

Workshop will concentrate its efforts on the ship-based techniques not covered at the Oslo Workshop. These methods are of special interest to ICES and the Commissions. The Bremerhaven Workshop will also retest some of the Oslo Workshop techniques, especially the biochemical ones. These will have strong support from the Intergovernmental Oceanographic Commission (IOC), a co-sponsor of the Bremerhaven Workshop. The result will be a series of determinations that will have been carefully tested (some also at the IOC Bermuda Workshop) and, from this series, the Working Group will be able to recommend those tests that provide the appropriate balance of measures for a monitoring programme.

Figure 2 Scheme of relationships between biological effects techniques.



The ACMP agreed with the Working Group that the preparation of a review of the application and interpretation of biological effects techniques would be welcome. Such a paper could be valuable to many groups, including the ACMP, ICES member countries, IOC and the International Maritime Organization (IMO), that may intend to initiate monitoring programmes. With this in mind, the Working Group will be asked to prepare this document and update it as necessary.

7.1.2 Development of methods

The ACMP noted that the Working Group had discussed the possibilities of several biological monitoring methods based on biochemical analyses (aryl hydrocarbon hydroxylase system, ethoxy resorufin O-de-ethylase (EROD) system, mixed function oxidase (MFO) system) and bioassays (Pacific oyster, fish eggs and larvae). A series of "Biological Methods Leaflets" is under preparation and it is expected that the first leaflet, concerning the Pacific oyster bioassay, will be published after the Bremerhaven Workshop in the ICES Techniques in Marine Environmental Sciences series. Further leaflets will deal with the use of fish eggs and larvae and the biochemical techniques for acetylcholinesterase, the ethoxy resorufin O-de-ethylase system and metallothioneins. Special attention will be devoted to the use of the aryl hydrocarbon receptor and the Working Group will request several experts to review the existing information.

7.2 Plans for the Biological Effects Techniques Workshop based at Bremerhaven

The ACMP reviewed the progress in the development of detailed plans for a sea-going Biological Effects Techniques Workshop in the North Sea, based at Bremerhaven, Federal Republic of Germany, to be carried out in March 1990 in collaboration with the IOC Group of Experts on the Effects of Pollutants (GEEP).

The general objectives of the Workshop are:

- a) to test and intercalibrate biological effects techniques that can be deployed at sea to detect and measure the effects of contamination; and
- b) to relate the results from biological indices to chemical data.

Different kinds of techniques that consider the same organisms or habitat will be deployed simultaneously on known contamination gradients. These will include a northwest transect across the German Bight, with an extension into the Elbe estuary plume, and gradients within the zones of influence of an oil platform and, if conditions permit, an incineration site in the North Sea. At the time of the Working Group meeting, more than 40 proposals for participation in the Workshop had been received and grouped under the following topics:

- 1. Fish - Gross pathology
 - Cell pathology
 - Biochemistry
- 2. Bioassays
- 3. Benthos - Benthic community studies
 - Sediment bioassays
- 4. Chemistry
- 5. Statistics

The ACMP considered that, following the Workshop, an ICES-sponsored meeting should be held, with attendance open to both Workshop participants and external scientists. It is expected that the papers presented at the meeting will be reviewed and submitted for publication as a special volume of an appropriate marine journal.

7.3 Bioavailability of Contaminants in Sediments

In noting the plans of the WGBEC to prepare a paper evaluating the bioavailability of contaminants in sediments, the ACMP agreed that the WGBEC had properly identified bioavailability as a parameter of central importance for biological effects of contaminants and pointed out that biological methods are essential for the quantification of this parameter.

The ACMP welcomed WGBEC's decision to prepare a review article on bioavailability and bioaccumulation. In addition to its usefulness for the Bremerhaven Workshop, this review should be of general importance in discussing biological effects of contaminant levels not only in sediments but in the marine environment in general. The ACMP agreed that a more detailed reference to this review should be included in a future ACMP report.

Reference

Bayne, B.L., Brown, D.A., Burns, K., Dixon, D.R., Ivanovici, A., Livingstone, D.R., Lowe, D.M., Moore, M.N., Stebbing, A.R.D., and Widdows, J. 1985. The Effects of Stress and Pollution on Marine Animals. Praeger Press, p.304.

8 BENTHOS ISSUES

8.1 Procedures for the Monitoring of Benthic Communities around Point-Source Discharges

In Section 7 of its 1988 Report, the ACMP provided guidelines for the use of benthos in monitoring the impact of point-source inputs of contaminants as a consequence of discharges to the sea from land or dumping from ships or structures at sea. In the introduction to these guidelines, the ACMP indicated its intention to include in its 1989 report a number of examples to illustrate the practical application of the guidelines. These examples, developed by the Benthos Ecology Working Group (BEWG), are provided in Annex 1. It should be noted that, although separated from the guidelines in this report of ACMP, it is intended that a more detailed version of the guidelines for monitoring benthic communities around point-source discharges will be published by ICES in its Techniques in Marine Environmental Sciences series and that this will be accompanied by the examples given in Annex 1.

8.2 North Sea Benthos Study

Progress on the preparation of the final report of the North Sea Benthos Study has been made by the Benthos Ecology Working Group during 1989. However, the production of the detailed report of this study, the field survey component of which was only completed in 1986, is not yet complete. It is expected that, once completed, the report will serve as a valuable benchmark against which to compare future data on North Sea benthos with a view to the detection of long-term changes. The ACMP will review the report when it becomes available and report on the conclusions accordingly.

9 FISH DISEASE ISSUES

A number of items from the report of the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) were noted as being of interest to ACMP. National reports contained information on the current status of disease surveys in a number of ICES member countries. Progress was reported on three national studies aimed at clarifying the linkage between pollution and fish disease.

9.1 Results of Disease Surveys

The ACMP noted the results of national disease surveys, as summarized in the following paragraphs.

In Denmark, a sharp increase had been detected in prevalence rates of lymphocystis and epidermal papillomas in dab in the eastern North Sea, particularly in areas previously affected by oxygen deficiency. In the Kattegat, the disease rates also appear to be increasing, possibly as a consequence of oxygen deficiency in late summer. Disease rates in the Skagerrak appear low and stable.

A report from the Federal Republic of Germany provided the latest findings from its bi-annual survey of fish disease prevalence rates in the North Sea (including the Elbe estuary) and the Baltic Sea as a continuation of the eleven years of disease survey work specifically aimed at measuring contamination influences on fish disease levels. It was again shown that the highest prevalence of epidermal papillomas and liver nodules in dab occur in the dumping areas within the German Bight, where the prevalence of lymphocystis also seems to be increasing in contrast to a slight reduction on the Dogger Bank. Additionally in 1988, a remarkable green liver discolouration in dab was found extensively in the western North Sea off the British coast and in the central North Sea on Fisher Bank; the cause is unknown. In the Baltic Sea off the Polish coast, rockling were heavily affected by large open skin ulcers; the reason for this is unknown.

In Finland, a five-year (1987-1991) general survey of fish diseases is being conducted, mainly focussed on the Gulf of Bothnia. Whilst not aimed specifically at polluted areas, some attention is being paid to fish in the vicinity of a pulp mill effluent discharge, where high prevalence rates of fin lesions in perch have been observed. These appear to be similar to those reported from Sweden near chlorinated pulp mill discharges.

In the Netherlands, a ten-year survey (begun in 1981) of fish diseases is being conducted as part of stock assessment cruises, with a view to monitoring the disease levels in fixed positions to identify temporal trends. Some fluctuations have been noted, but the present rates appear mostly stable with no trend evident. Lymphocystis rates were slightly higher in 1988, but the quoted levels are much lower than those found by workers from the Federal Republic of Germany surveying in the same areas, e.g., 3% as opposed to 50%. However, the German teams look very closely for lymphocystis and record even single nodules, which are not included by the Dutch, who also sample at different times of the

year. This emphasises the need for the adoption of standardized procedures, as recommended by ACMP in its 1988 report.

In a separate programme, comprising a five-year field study (1983-1988) with special attention to possible pollution effects on disease prevalence in the Dutch coastal waters, the highest levels of liver nodules and epidermal papillomas in dab were again observed to be in the titanium dioxide waste dumping areas, agreeing with the work of the German team. It was also reported that the prevalence rates of liver nodules correlate quite well with the concentrations of PAHs in the local sediments but not in the tissues of individual dab. No such correlation has been found with PCBs in the sediments. In flounder, the highest prevalence of liver nodules/tumours along the Dutch coast clearly correlates with the major pathway of pollutants discharged by the River Rhine.

In Sweden, disease surveys are being conducted on the east and west coasts in areas affected by pulp mill effluents. In 1988, prevalence rates of liver nodules in dab larger than 25 cm were 24% - 29%, and plaice caught near the discharge pipe of the Varö pulp mill were found to be affected by depressions of the distal parts of the body; this condition is absent in plaice from the clean reference area.

The United Kingdom reported an increased level of disease survey work, both as part of regular stock assessment surveys and through specific monitoring of disease prevalence rates at dump sites in both the North Sea and the Irish Sea. At a dump site in Liverpool Bay, prevalence rates of epidermal diseases in dab were slightly higher on stations away from the dump site and, of particular significance, there was no evidence of the liver nodules in dab that are seen in the North Sea. In Scotland, a repetition was made of the 1987 survey of sewage sludge disposal areas and, overall, the disease rates were the same or lower at the disposal sites than at the corresponding reference sites. However, in comparison with the 1987 results, there was a significant increase in the level of lymphocystis at all sites except one.

Independently of the survey work, a field investigation was mounted after reports from the industry of high numbers of large cod showing "blisters" on their visceral organs. Up to 11% of large cod in the affected area in the southern North Sea displayed visceral lesions. All evidence points to an infectious disease progressing naturally in a specific cod population, but the aetiological agent could not be identified, although there are pathological similarities to "presumptive mycobacteriosis".

In the United States, no monitoring programmes are being conducted for diseases in offshore marine fish populations; the ongoing studies concentrate on the influence of pollution on the health of estuarine fish populations. Examination of fish in the Elizabeth River, which has the highest riverine concentrations of PAHs in the USA, revealed several diseases, but no apparent liver nodules/tumours have been observed. Juvenile spot held on contaminated sediments in the laboratory developed ulcers, fin rot, and cataracts, with large skin ulcers appearing within seven days. A large multi-disciplinary study to assess possible bio-markers of effects or disease susceptibility in marine fish is in

progress. This study includes elements of the immune system, and a very clear and consistent depression of phagocytic activity has been demonstrated in fish from the Elizabeth River; this recovers to normal levels when the fish are transferred to clean sediments.

It is clear from the national reports on disease prevalence rates in marine fish stocks that great improvements have been made in standardization of the format of data presentation. However, the ACMP recognizes that there is still a need for the application of more objective methods for the identification of fish diseases. The standardized methods would allow a better integration of the various fish disease surveys presently being carried out in the North Sea and the Baltic Sea. With regard to this latter area, the paucity of information from the southeastern Baltic Sea countries was noted.

The ACMP took note that a presentation concerning biomarker techniques, particularly measurements of immunocompetence, indicated the usefulness of such methods for studying the influence of pollutants on susceptibility of fish to disease. There was general agreement that such new techniques were required and that they should be developed into standard ICES methods. The ACMP is very interested in this approach, particularly if it allows at-sea measurements of aspects of immunocompetence that could be coupled with observations of contaminant levels.

9.2 Computerization of Data on Disease Prevalence Rates

It was noted that a computer program has been prepared in the Federal Republic of Germany for the analysis of fish disease prevalence data derived from field surveys. Up to now only the data input program is complete, allowing the input of all data relating to disease observations together with some analysis. More detailed analysis techniques will be added later. During the next year, the practicability of the program will be tested under field conditions, and a progress report will be given at the WGPDMO meeting in 1990.

9.3 Progress Reports on National Studies of Pollution and Fish Diseases

A progress report was presented on the coordinated multi-disciplinary research project conducted by several institutes in the Federal Republic of Germany, which started in 1987 and will probably be finished in 1990. Its purpose is to obtain information on the disease status of fish in the German Wadden Sea and on the impact of environmental factors, particularly pollution.

Studies in both the Netherlands (Texel) and the UK (Weymouth) have been initiated to determine whether there are any cause-and-effect relationships between pollutants and disease development in marine fish stocks.

The Dutch experiments are conducted in 4.50 m³ basin mesocosms, and involve exposing flounder to heavily contaminated sediments from Rotterdam Harbour and, as a control, to reference sediments.

In a pilot study, several disease outbreaks occurred in fish exposed to both types of sediments, including the occurrence of lymphocystis, skin ulcers, and fin rot. These latter conditions were more prevalent in fish exposed to the contaminated sediments. However, the most important information gained to date has been on how to handle the mesocosms and sort out problems arising. Now that the experiments appear to be running smoothly, more in-depth studies on the development of changes in fish health will be made, including collaborative studies of immunocompetence assays with the Weymouth Fish Diseases Laboratory (UK).

In the Weymouth studies, the experimental system is much smaller than that in the Netherlands: indoor tanks are supplied with a constant flow of clean sea water at controlled temperature. For the pilot studies, test fish (dab) were exposed to highly contaminated sediments from Liverpool Docks and, for comparison, to a reference (clean) sediment for a period of three months. The sediments were analysed for contaminants prior to and during the experiments. The contaminated sediments contained significantly higher concentrations of metals (Mn, Cu, Zn, Cd, and Pb) than the reference sediments. These concentrations remained fairly stable throughout the experiment. Concentrations of total hydrocarbons were two-fold higher in the test sediment and a range of common organochlorine compounds normally included in monitoring programmes were undetectable or at low concentrations in both sediments. The development and comparison of disease prevalences in the experiment were recorded as possible direct indicators of cause and effect. Possible indirect effects of exposure to the contaminated sediments on disease susceptibility were measured by challenging the exposed fish with a bacterial pathogen, and comparing immuno-pathological changes between the two groups. As with the Dutch experiments, several initial technical problems arose with the experimental system, including disease outbreaks in both groups of dab. Skin ulcers were most common in the group exposed to the contaminated sediment, but, interestingly, almost all ulcers healed rapidly when the fish were removed from the sediments and held in clean sea water. The initial immunological measurements revealed small but significant differences in antibody response between the two groups, with fish on the contaminated sediment having a lesser response. Analysis of fish muscle for metals has indicated no significant uptake from either type of sediment; tests for organochlorine compounds are underway. Further long-term exposure studies with improved experimental designs are to commence soon.

In finalizing its discussion on fish diseases, the ACMP noted that the report on the Second Sea-Going Workshop on Methodology of Fish Disease Surveys, that ACMP had outlined in its 1988 report, has now been published as Cooperative Research Report No. 166. The ACMP encouraged the use of the standardized methods agreed at that Workshop.

The ACMP also endorsed the view that more work on fish diseases should be conducted in the Baltic Sea. The ACMP looked forward with interest to reviewing the results of the national programmes on the linkage between pollutants and fish diseases and would like to receive more information about the biomarkers techniques.

10 ENVIRONMENTAL IMPACT OF MARICULTURE

The ACMP considered the report of the Working Group on Environmental Impacts of Mariculture (WGEIM). On the basis of national reports presented at the Working Group meeting, the WGEIM discussed a number of issues, among which the following were of interest in a pollution-control context: (1) production trends, (2) site selection and monitoring in relation to management of environmental impacts of mariculture, and (3) chemical usage in mariculture.

10.1 Production Trends

In most ICES member countries, finfish mariculture production showed a remarkably rapid growth rate in 1988. The prospects for 1989 seem to be even greater for a few countries. As in previous years, the trend in coastal cage farming is towards larger units installed in more exposed sites, employing lower stocking densities. Shellfish production is relatively stable in most of the major producing countries. Recent production statistics for selected Baltic Sea countries are presented in Section 10.4 of this report.

10.2 Managing Environmental Impact

With the growth of the industry, the management of the environmental impacts of mariculture will be essential, not only because of the possible negative effects of mariculture but also because of the need to safeguard the industry itself. It is with this conviction that the ACMP endorsed the approach taken by the Working Group to the management of environmental impacts of mariculture, recognizing that an assessment and synthesis of many factors (environmental, social, and economic) has to be undertaken prior to the approval of the establishment, as well as during the operation, of a mariculture facility. Several national approaches to achieve such an assessment have been outlined in earlier Working Group reports. In an attempt to visualize the key elements and principal procedures employed in most of the national programmes, the flow diagram in Figure 3 illustrates one way in which such an assessment could be undertaken.

The ACMP agreed with the conclusion of the WGEIM that at the present time the role of the Group in providing advice in such decision-making processes, particularly in relation to the concept of "an acceptable level of environmental change" resulting from a specific environmental impact, is very limited. For most environmental impacts, the ecological basis for establishing "acceptable levels of change" has not been formulated. For this reason, and because issues other than environmental ones may be included, the responsibility for setting "acceptable levels of change" resides with the governmental and regulatory authorities of each member country. The ACMP, therefore, agrees with the Working Group that its role should be restricted to identifying possible environmental impacts, providing methods or approaches for quantifying and monitoring impacts, as well as advice on how to minimize adverse effects.

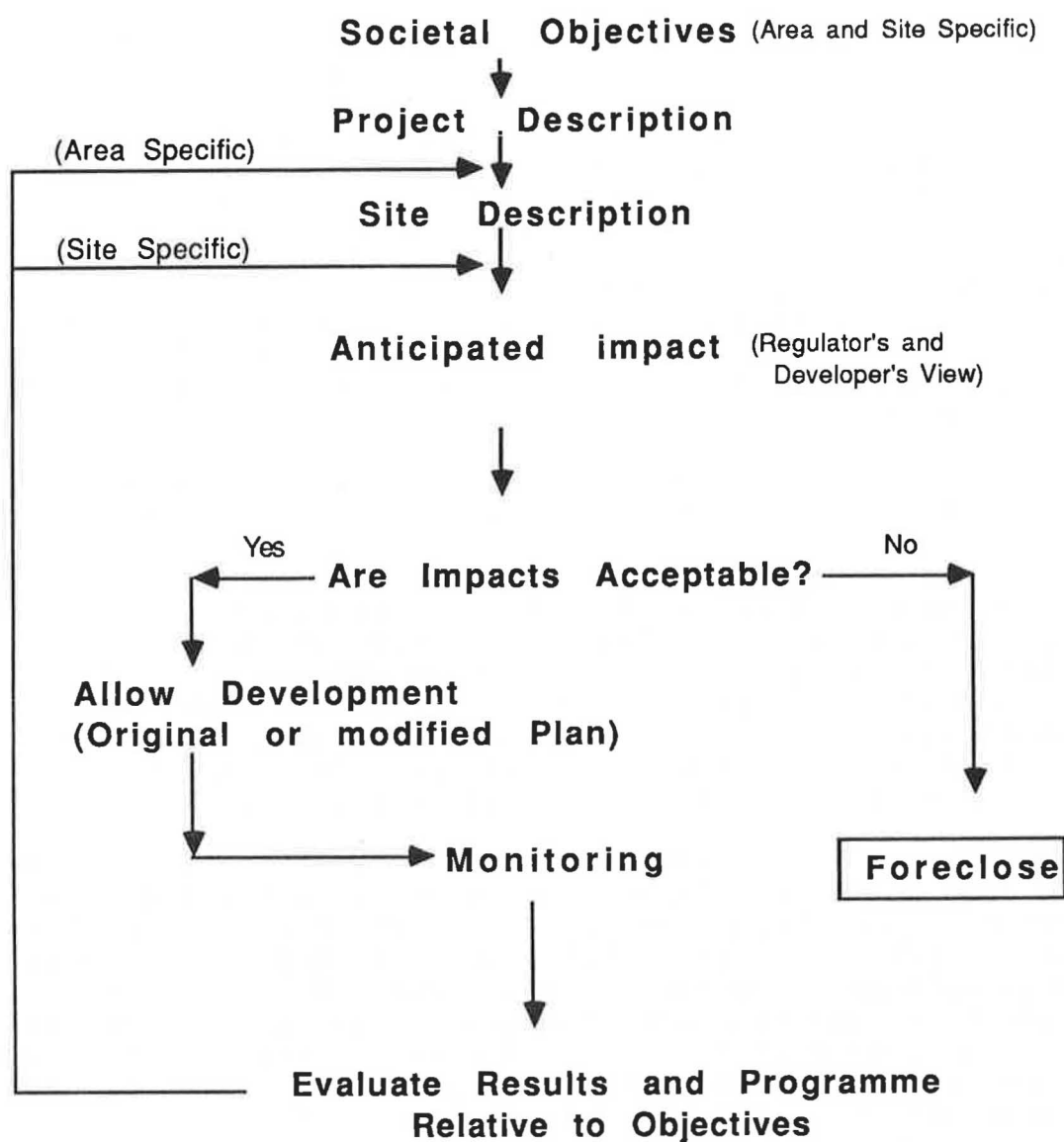


Figure 3 Flowchart on principal procedures for the evaluation of environmental impact of mariculture.

The ACMP recognized that many of the existing and potential environmental effects of mariculture stem from improper siting and the coexistence of mariculture operations and other uses of coastal areas. The necessary constraints on mariculture operation will often be related to environmental quality considerations applicable to other marine activities. Failure to adequately address these issues at the planning stage may jeopardize the long-term viability of mariculture, or coexisting activities, at particular sites and may present continuing managerial difficulties. The ACMP, therefore, supported the principle that, in selecting sites for mariculture operations, preference should be given to sites that could reasonably be designated exclusively for mariculture, at least on a local basis. This approach would allow the development of marine environmental quality criteria that would primarily be determined by the requirements of mariculture itself. It would, of course, be important to include the general criterion that operations within a designated area should not result in adverse effects outside the area.

Some ecological impacts of mariculture have been studied in detail and relevant information can be found in Rosenthal *et al.* (1988).

Several mathematical models have been formulated which can be used, in certain cases, as tools for estimating the impact of new mariculture operations. It should be recognized, however, that current models incorporate assumptions that are based on the current understanding of coastal marine ecosystems, rather than on data derived from individual mariculture sites, and these assumptions are not necessarily valid in all situations.

The ACMP noted from the Working Group report that the governments of some ICES member countries require an environmental impact assessment of aquaculture operations. For example, under European Community (EC) Directive 85/337/EEC, EC member states are required to take measures for the assessment of the effects on the environment of fish farm developments. It was noted that national legislation interpreting this directive may vary between countries in accordance with, for example, site-specific differences that determine how to achieve these objectives.

10.3 Chemical Usage in Mariculture

Chemical use has long been accepted as a necessity in all forms of terrestrial animal husbandry. It is not surprising, therefore, that the aquatic and marine counterparts to the terrestrial farmers have found the use of chemotherapeutic agents and other chemicals to be a critical component of successful aquaculture. Although a culturist can employ non-chemical means to reduce the frequency and severity of disease outbreaks, some diseases are unavoidable and must be combatted with chemotherapeutic agents to ensure the continued viability of the operation.

At the present time, quantitative data on chemical usage in ICES member countries are extremely sparse and of variable quality. Absolute amounts of chemicals can only be given for a few countries and occasionally these can be broken into amounts per tonne of fish produced to avoid distortion. Norway, with a pro-

duction of almost 90,000 t of finfish in 1988, used a total of 18,220 kg of oxytetracycline or 0.21 kg/tonne of fish produced; whereas British Columbia (Canada), with a production of 5,800 t fish used 2,880 kg or 0.48 kg/tonne of fish - over twice the Norwegian dose. This example is used merely by way of chemical-specific illustration and does not reflect the total use of antibiotics per tonne of fish produced. In Finland, the overall production has increased dramatically in the last ten years, but antibiotic usage per tonne of fish produced has decreased to 0.115 kg/tonne. Present trends in mariculture strategies indicate that there is considerable room for developing improved fish health protection strategies that help to reduce the use of antibiotics and other chemicals considerably. Therefore, increasing mariculture production will not necessarily lead to a linear increase in chemical usage.

The ACMP recognized that the increasing use of chemicals for disease control in mariculture, due to expansion of the industry, and the tendency for a higher prevalence of disease in densely stocked units, gave added prominence to the environmental consequences of this practice. The control of effluents from mariculture operations, which frequently contain residual disease-control agents, continues to present technical and managerial difficulties. However, the high cost of these agents, the greater use of vaccines, and improvements in effluent containment should lead to a gradual reduction in amounts used as well as losses to the environment. The WGEIM is preparing a comprehensive technical report on chemical use in mariculture that will include an inventory of substances and quantities used in ICES member countries.

10.4 Nutrient Inputs from Baltic Fish Farms

In response to the request from the Helsinki Commission for advice on issues related to excessive nutrient inputs from fish farms, the ACMP presents the following information, provided by the Working Group on Environmental Impacts of Mariculture.

Mariculture production in countries adjacent to the Baltic Sea is growing the most rapidly in Finland, followed by Denmark and Sweden. Little information on production trends is available from the other countries surrounding the Baltic Sea. The overall production in recent years is depicted in the following table:

Table 4 Fish and shellfish production (tonnes per year) in coastal waters of selected Baltic Sea countries (data compiled from various sources). S = shellfish.

Country	Production (tonnes/year)			
	1985	1986	1987	1988
Denmark	2,450 -	3,400 -	2,950 150 (S)	5,500 400 (S)
Finland	6,637	7,140	8,782	~10,000
Federal Republic of Germany	20	25	35	40
Sweden	?	2,510 231 (S)	3,270 2,556 (S)	3,281 ?

Sweden

In total, there were 277 aquaculture operations for the production of fish, of which 188 were located in marine or brackish water areas. The numbers of mussel-producing operations and oyster units were 5 and 4, respectively. In 1986, the production figures for salmon and rainbow trout in marine areas were as follows: in the Bothnian Bay, 442 tonnes; the Bothnian Sea, 205 tonnes; the Baltic Proper, 1,940 tonnes; and the Skagerrak, 289 tonnes.

Denmark

Fish farming in marine waters consists mainly of cage culture of large rainbow trout. In 1988, net cage production reached about 5,500 tonnes. Mussel and oyster farming is still at a low level, but increased production is expected to take place during the next few years.

Finland

Expansion of fish farming has occurred rapidly during the last decade. The total food fish production in 1988 was over 12,000 tonnes, with approximately 10,000 tonnes produced in brackish water areas along the coastline.

Federal Republic of Germany

Mariculture production along the Baltic Sea coast is negligible (only one net cage farm in the Inner Kiel Fjord, producing 30 to 40 tonnes annually; another land-based farm operates a turbot hatchery with an attached 10 tonnes grow-out facility).

Poland

The information available indicates little production in coastal waters (mainly pilot scale and for research purposes).

Nutrient loads

So far, the most reliable estimates available on nutrient inputs from fish farming are from Finland. These inputs originate from two sources: (a) fish hatcheries producing juveniles for stocking, and (b) grow-out facilities to produce market-sized fish.

The Finnish production of juvenile fish for stocking natural waters is estimated at about 600 tonnes annually. This means that an estimated 7 tonnes of phosphorus and about 45 tonnes of nitrogen loading is derived from this form of aquaculture, of which only a small fraction reaches brackish water areas.

The nutrient loads from food fish farming in both fresh and brackish water in Finland are estimated to be about 140 tonnes of phosphorus and 950 tonnes of nitrogen annually. The contributions of freshwater and marine farming to these nutrient loads are presented in Figures 4a and 4b.

By comparing these figures to the total land-based nutrient load to Finnish waters derived from human activities, it can be concluded that the contribution to the nutrient load from fish farms is small: under 4% for phosphorus and under 2% for nitrogen.

Recent Finnish studies show that the amount of nutrients released to the environment do not necessarily have to increase at the same rate as production grows. With improved husbandry (e.g., feed conversion efficiency) and reduced phosphorus content in feeds, the total phosphorus load from fish farming has increased by only about 23% while fish production has more than tripled (Table 5).

Table 5 Estimation (annual averages) of N and P loadings in relation to feed conversion efficiency, P- and N-contents in feed and total annual fish production in Finland (after Mäkinen, 1989).

Year	Feeding coeff.	P content in feed (%)	N content in feed (%)	P loading tonnes/yr	N loading tonnes/yr	Total production tonnes/yr
1978	2.0	2.0	6.5	115	337	3,205
1979	1.9	1.9	6.5	105	323	3,275
1980	1.9	1.7	6.5	132	460	4,670
1981	1.8	1.5	6.5	124	495	5,383
1982	1.8	1.3	6.5	123	582	6,325
1983	1.8	1.1	6.5	119	691	7,511
1984	1.7	1.1	6.5	140	812	9,493
1985	1.7	1.0	6.5	131	861	10,913
1986	1.7	1.0	6.5	142	933	10,913

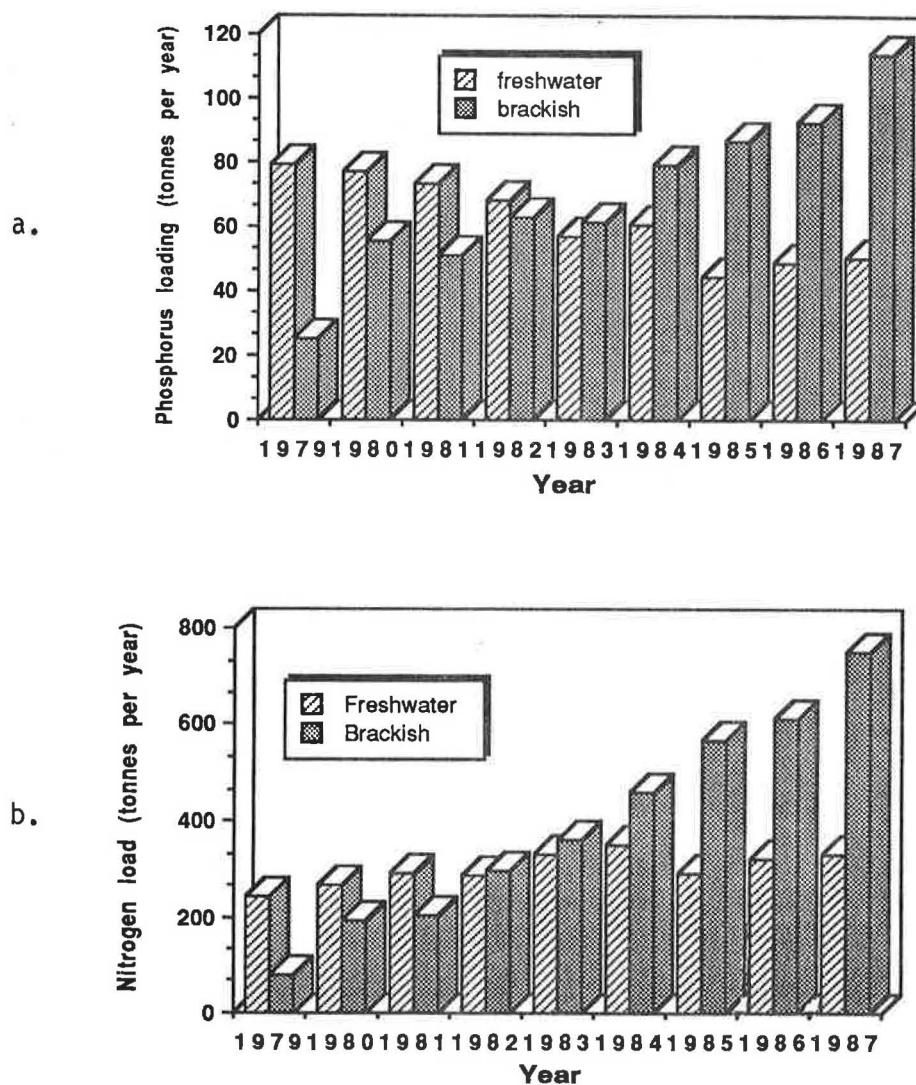


Figure 4 Estimated phosphorus (upper figure) and nitrogen (lower figure) loads from freshwater and brackish water fish farms in Finland.

A recent Swedish study shows that the overall pollution load derived from fish farms can be greatly reduced by improving feed composition and feed conversion efficiency. The results are summarized in Figures 5 and 6.

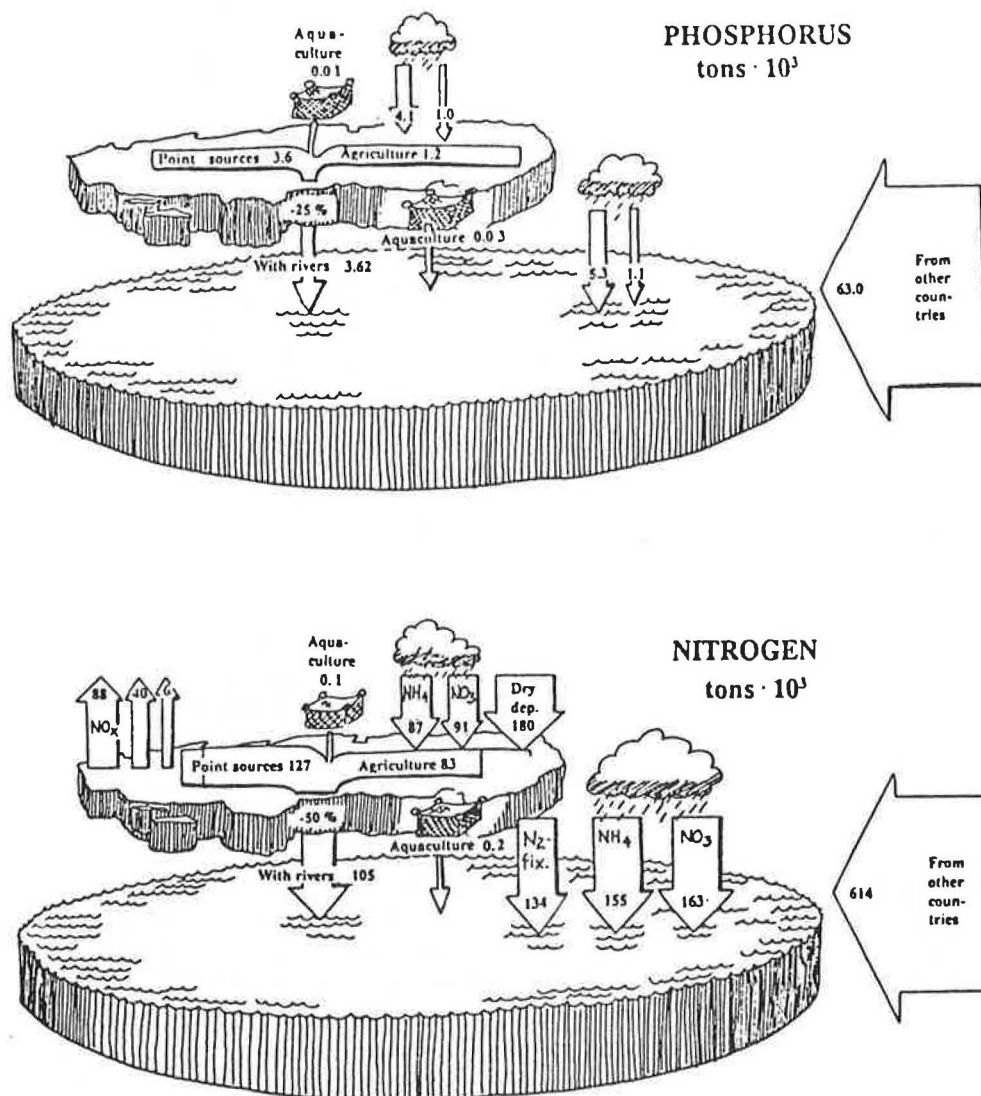


Figure 5 Nutrient input from Swedish aquaculture (fresh water and marine) into the Baltic Sea in relation to other sources for P and N (after Ackefors *et al.*, 1989).

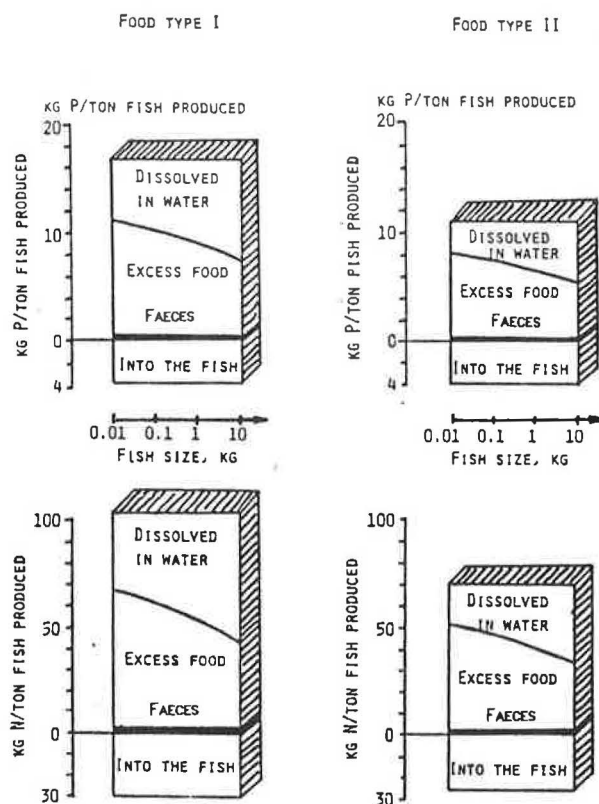


Figure 6 Reduction of nutrient input through improved feed formulation: the Swedish example (after Ackefors *et al.*, 1989).

The ACMP noted that there is still room for significant improvement in this area and recommends to the Helsinki Commission that it encourage research on improved feed formulation. Since the number of land-based systems discharging effluents into coastal waters is increasing, research on further improvements of mechanical filtering systems (swirl pool separator, triangle filter, settling ponds, etc.) that allow effective removal of suspended solids (and, to some extent, nutrients) is strongly recommended.

References

- Ackefors, H. and Emell, M. 1989. Discharge of nutrients from Swedish fish-farming to adjacent sea areas. *Ambio*, in press.
- Mäkinen, T. 1989. Fish culture and environmental impact in Finland. Doc. ICES, C.M.1989/F:10.
- Rosenthal, H., Weston, D., Gowen, R. and Black, E. (Eds) 1988. Report of the *ad hoc* Study Group on Environmental Impact of Mariculture. ICES Coop. Res. Rep. No. 154.

11 ALGAL BLOOMS AND RELATED ISSUES

11.1 Report from the ICES Workshop on the Chrysochromulina polylepis Bloom in the Skagerrak and Kattegat in May-June 1988

The ACMP considered the draft report from the Workshop on the Chrysochromulina polylepis Bloom, that had been held in Bergen on 28 February to 2 March 1989 to bring together the information on the taxonomy, physiology and toxicity of C. polylepis and describe the environmental conditions associated with this bloom, and its effects. The final report will be published in the Cooperative Research Report series in autumn 1989. The following is a brief resumé of the main findings of the Workshop, updated with more recent findings on long-term effects.

The C. polylepis bloom may be regarded as a "case study" illustrating problems to be expected with noxious algal blooms and with the increased sensitivity to such blooms resulting from the increased development of mariculture.

To put this particular bloom in economic perspective, no losses have been reported by Danish fish farms, while a loss amounting to about 10 million ECU (European Currency Units) was suffered by the Swedish and Norwegian aquaculture industry. In Norway, only 800 tonnes of fish, corresponding to 0.6% of the 1988 production, were lost.

The ACMP noted that this bloom was exceptional only in that C. polylepis had not previously been recorded to occur as a toxic bloom over large areas. The algal biomass produced by the bloom was not exceptionally high and Chrysochromulina species are natural components of the normal heterogeneous algal population in the area.

The toxin produced by C. polylepis affects the salt regulating properties of cell membranes. A variety of plants and animals may thus be affected to varying degrees. Sessile organisms or organisms with limited mobility were killed, while larger mobile organisms (necton) escaped.

Some toxicity could be demonstrated experimentally in mussels exposed to the bloom, while no toxicity could be demonstrated in the muscle tissue of fish killed by the bloom. In no case was toxicity to humans registered in connection with the bloom.

Low salinities seem to minimize the osmotic stress on injured organisms and to inactivate and disrupt C. polylepis cells. During the bloom, evacuation of aquaculture pens from bloom exposed areas to brackish water inside the fjord systems was demonstrated to be a viable method for avoiding damage to cultured fish.

Extensive damage to littoral environments exposed to the bloom was recorded by diving surveys immediately after the bloom. Some effects of the bloom on population composition could be detected by scientific survey one year after the bloom. These effects were most noticeable for species with limited mobility of adults and larvae.

The Workshop report registers that nutrient inputs to the area due to local run-off and by the Jutland Current may have been important, perhaps even more due to their imbalance as to N:P ratios, than due to their magnitude. It has been experimentally verified that phosphate limitation induces toxicity of C. polylepis cultures (Prof. E. Paasche, unpubl. Univ. of Oslo). N:P ratios as high as 25:1 (normal ratio 16:1) were registered during the bloom.

While a reduction of anthropogenic nutrient inputs to the area may reduce the probability of noxious blooms, the C. polylepis bloom highlighted the fact that anthropogenically distorted nutrient ratios may be of as great importance as increased nutrient availability for the occurrence of noxious blooms.

It is probably simplistic to assume that any one single factor (nutrient availability, nutrient imbalance, salinity, water stratification, temperature, solar radiation, etc.) by itself may cause a specific bloom. When environmental factors and their temporal development successfully complement the ecophysiological capabilities of an algal species, a monospecies algal bloom may occur.

It is assumed that the specific development of physical and chemical environmental conditions prior to and during the bloom were uniquely well suited to the specific ecophysiological capabilities of C. polylepis, allowing it to develop as a toxic bloom. The probability of a recurrence of a bloom of this species is unknown. However, a recurrence of similar environmental conditions to those prevailing prior to and during the 1988 bloom could enhance the possibility of a C. polylepis bloom. Nevertheless, even with the same environmental conditions, the probability of a recurrence of a C. polylepis bloom may not be great. An equivalent bloom (in terms of biomass) of a non-toxic alga might well pass unnoticed.

The existence of a long time-series of physical and chemical measurements in the Skagerrak-Kattegat area was useful in assessing the environmental conditions prevailing at the time of the bloom. Continued measurements in this series may provide a basis for the estimation of the probability of future C. polylepis blooms.

While a better understanding of the ecophysiological properties of C. polylepis is essential for an estimation of the probability of a recurrence, attention should also be given to ecophysiological studies of other algae potentially able to form noxious or beneficial blooms. Those environmental factors of known importance for noxious blooms should receive special attention in monitoring programmes.

The ACMP considers it to be unfortunate that media attention focused on the C. polylepis and other noxious blooms has created the popular impression that all algal blooms are noxious, notwithstanding the fact that normal blooms form the basis for biological marine resource production.

11.2 Other Issues regarding Algal Blooms

The ACMP noted that the two reports, "Management of the Effects of Harmful Algal Blooms on Mariculture and Marine Fisheries" and "Currently known causes of and species involved in algal blooms with harmful effects on fisheries and mariculture", being prepared by the Working Group on Harmful Effects of Algal Blooms on Mariculture and Marine Fisheries now appear to be treated as a single report and that it seems unlikely that this report will be completed in 1989. The ACMP hopes, however, that the report can be completed in 1990. If this is the case, a brief review of the report will be included in the 1990 ACMP Report.

The ACMP considered the plans of the Phytoplankton Ecology Working Group for its July 1989 meeting, where the main business will be: 1) to define an ICES standard method for primary production measurements, 2) to specify types of data to be incorporated into a data bank on primary production, 3) to initiate an analysis of available data on algal blooms, and 4) to consider the terms of reference for the expanded activities of the Working Group in 1990. The ACMP noted that the report on the results of the Inter-comparison Exercise on the ^{14}C Primary Production Method, carried out in 1987, is expected to be presented for publication as a Co-operative Research Report in the autumn of 1989. The ACMP noted the research priorities in the understanding of phytoplankton blooms identified by the Working Group on Harmful Effects of Algal Blooms on Mariculture and Marine Fisheries. It recommended that the agenda of the Phytoplankton Ecology Working Group be amended so that these priorities can be considered.

12 NUTRIENT TRENDS IN THE OSLO AND PARIS COMMISSIONS AREA

The ACMP noted the following points that had arisen out of discussions at the meetings of the Marine Chemistry Working Group (MCWG), the Working Group on the Statistical Aspects of Trend Monitoring (WGSATM), and the Shelf Seas Oceanography Working Group and an information paper prepared by the ICES Secretariat for the ACMP meeting.

The MCWG will extend the analysis of nutrient trends in the North Sea by an examination of data from Denmark, the Federal Republic of Germany, Norway, and France. The first two data sets are to be extracted from the ICES data bank, the latter two directly from the French and Norwegian scientists responsible for this work. A report on this data analysis, which will be done along the lines of the procedure given in Section 11 of the 1988 ACMP report, is expected to be discussed at the 1990 MCWG meeting.

The Shelf Seas Oceanography Working Group had examined the paper by Dickson et al. (1988) and agreed with the authors' conclusion that there was no evidence of trends in nutrient levels in UK coastal waters over the past 20 years. The Working Group did, however, point out that the conclusions arising from a recent Dutch paper on this topic had indicated that there was evidence of increased nutrient levels in Dutch waters during the 1966-1978 to 1984-1987 period.

The ICES Hydrographer had again reported that, although there was evidence of large data sets on nutrients in coastal areas of the North Sea being compiled by member countries, only a fraction of these data (ca. 10%) was available in the national data centres and in the ICES data bank. To date, submissions to the ICES data bank had been made by the Federal Republic of Germany, the Netherlands, Denmark, England and Scotland, largely on the basis of data collected in annual ICES International Young Fish Surveys. Additional data sets were expected from 1990 onwards from the UK, arising from the UK NERC North Sea project, and from the Netherlands fisheries scientists, cooperating with the Rijkswaterstaat.

A preliminary examination of other Dutch nutrient data sets had been made by the ICES Hydrographer. The aim had been to ascertain whether there had been any trends in nutrient concentrations in Dutch coastal areas, influenced by the Rhine and Scheldt rivers, during the 20-year period covered by the measurements made by both the Rijkswaterstaat and the Texel laboratory. When data for samples of salinity >20 are considered, there is no clear trend in nitrate levels in the Dutch data; whereas there was an apparent 30% increase in nitrate concentrations in both the Rhine and Scheldt rivers and an increase in ammonia in the Scheldt, for this period of time. Thus, increases in nutrient concentrations in rivers, while evident at low salinities, may not be detectable at higher salinities further offshore.

This preliminary examination had suggested that some caution must be exercised in interpreting trends from coastal data only.

The ACMP noted that a further examination of these data will be made by the ICES Hydrographer and that a paper on the Dutch data will be discussed at the ICES Statutory Meeting in 1989.

Reference

Dickson, R.R., Kirkwood, D.S., Topping, G., van Bennekom, A.J. and Schreurs, W. 1988. A preliminary trend analysis for nitrate in the North Sea west of 3° E. Doc. ICES, C.M.1988/C:4.

13 INTERCALIBRATION AND QUALITY ASSURANCE ISSUES

13.1 Quality Assurance and Reference Materials

The ACMP was informed that the marine chemistry working group (MCWG) had made further comments on the use of internal reference materials (IRMs) in the quality control of chemical analyses. The MCWG recognized that the preparation of these materials may present difficulties for many laboratories. Thus, the use of poorly prepared materials could lead to poor quality control. As a result, the MCWG now proposed that those laboratories which feel confident in their ability to produce IRMs should do so, but that those who were unsure of their ability to prepare such materials should continue to use certified reference materials (CRMs) to ensure that their analytical measurements were under statistical control.

On the matter of uncompromized reference materials (URMs), which form the basis of intercomparison exercises, the MCWG emphasised that there was still a need for the OSPARCOM to arrange the production of sufficient quantities of relevant materials for any future baseline/monitoring studies; e.g., the JMG baseline study of trace metals in sea water, scheduled for 1992, would require at least one, and probably two, URMs for the intercomparison component of this study.

The ACMP noted that the justification for the preparation and use of these materials had been made in its 1988 report (Section 12.8). The ACMP further noted that the preparation of URMs could be self-financing once the production of the first of each type had been financed; e.g., the OSPARCOM could arrange for a bulk supply of a URM to be prepared to meet its needs for a particular exercise. Participants in monitoring programmes would then be obliged to purchase sufficient URMs to meet their needs. The money from the sale of the URMs would then be used to finance the preparation of the URM required for the next intercomparison exercise. Alternatively, the production of URMs could be financed from special contributions from the national authorities participating in JMG baseline/monitoring studies.

The ACMP noted that the MCWG had responded to a request to review the paper on quality assurance which had been presented by the Dutch delegate at the 1989 meeting of the JMG in connection with the forthcoming baseline study of metals in sea water.

The MCWG stated that the Dutch proposals for analytical quality assurance procedures were in line with the general philosophy previously approved by the MCWG in relation to the design of monitoring programmes. It welcomed and supported the attention paid by the authors to the necessity for also validating the sampling and storage procedures. This latter aspect was an essential component of assuring the quality of the overall measurement. If the sampling protocol is incorrect and, as a result, unrepresentative, contaminated and badly processed samples are obtained, the overall measurement would be poor irrespective of how well the actual chemical analyses were performed. However, the MCWG considered that the proposal for this aspect required elaboration in more detail and agreed to prepare a paper on this matter for discussion at its 1990 meeting.

The MCWG did, however, criticise the proposal that each laboratory should prepare its own internal sea water reference material for in-house quality control. It considered that the preparation of IRMs for sea water by inexperienced laboratories could lead to both a contaminated bulk material and sub-samples which would give misleading results in relation to quality control charts. Therefore, the MCWG strongly recommended that, in such cases, in-house quality control should be conducted using CRMs, which has the additional advantage that the laboratory would be able to monitor the accuracy, as well as the precision, of such measurements.

The ACMP noted that new certified reference materials had recently been prepared by both the U.S. National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards) and the National Research Council of Canada.

13.2 Intercomparison Programme on Analyses of Polycyclic Aromatic Hydrocarbons

The ACMP was informed that the coordinator, Mr. R. Law, of the first stage of the Intercomparison Programme on Analyses of Polycyclic Aromatic Hydrocarbons (PAHs) had distributed sets of samples to 17 laboratories in ten countries in November 1988 and a further set in January 1989. To date, six sets of results have been returned to the coordinator.

Losses of solvent from the sample containers have been reported by some analysts. Others have reported difficulties in the resolution of individual hydrocarbons. These problems may require the coordinator to repeat the first stage by the issue of a second set of samples. A report on the results of the first stage of this exercise, together with plans for the second stage, will be submitted to ACMP in June 1990.

It should be noted that this exercise is a restricted one since only those laboratories conducting analysis by high pressure liquid chromatography (HPLC) and/or gas chromatography-mass spectroscopy (GC-MS) can participate in this assessment of the measurement of individual hydrocarbons.

13.3 Intercomparison Programme on Analyses of Chlorobiphenyls

The ACMP noted that samples for the first stage of the ICES/IOC/OSPARCOM Intercomparison Programme on Analyses of Chlorobiphenyls (CBs) had been distributed in May 1989 to about 100 participants and that the deadline for the receipt of the results was 30 June 1989. The results are expected to be evaluated in the second half of 1989 and a report issued to ACMP in June 1990, following comments by the MCWG. The ACMP noted that the MCWG proposed to repeat stage 1 of this exercise if the degree of comparability was not deemed acceptable. Laboratories which fail to achieve satisfactory performance after this repeat exercise will not be able to proceed to the second stage of the exercise. The criteria for acceptability of results would be established by the coordinators of the exercise (Drs. J. de Boer and J.C. Duinker), with assist-

ance from the Working Group on the Statistical Aspects of Trend Monitoring (WGSATM), and discussed by the MCWG at its 1990 meeting.

The second stage of this exercise will consist of two parts: (1) an ICES/IOC component dealing with extracts of biological tissue, and (2) an ICES/OSPARCOM component dealing with extracts of sediment.

The ACMP noted that the MCWG had discussed plans for the second stage of the exercise for biological tissue, which was to include two seal blubber extracts and a reference fish oil from the European Community Bureau of Community References (BCR). It also noted that the Working Group on Marine Sediments in Relation to Pollution (WGMS) would be responsible for the design and conduct of the second stage of the sediment exercise and detailed plans would be submitted in 1990. The US National Oceanic and Atmospheric Administration (NOAA) would assist the WGMS in the planning and conduct of this stage of the exercise. The ACMP noted that, of the 100 participants in the first stage, 17 would continue with the sediment-based exercise and 83 with the tissue-based exercise.

The ACMP reminds the Oslo and Paris Commissions that this is a step-by-step exercise in which the main objectives are to assess and correct the errors associated with each analytical stage, in order to lead to an improvement in the analytical capability of participating laboratories for the overall measurement of CBs in biological tissue and sediment samples. Each laboratory must attain a satisfactory performance before it can proceed to the next stage. Participants have accepted at the outset that failure to achieve satisfactory performance at any stage must exclude them from participation in subsequent stages, if the exercise is to be completed successfully within the specified time frame.

13.4 Intercalibration Exercise on the Analysis of Nutrients in Sea Water

In noting the progress in the Intercalibration Exercise on the Analysis of Nutrients in Sea Water, the ACMP was informed that three samples of sea water (containing low, medium and high concentrations of nutrients) had been distributed to 85 participants in May 1989. Following a preliminary evaluation of the results in September 1989, a status report will be submitted to the 1989 ICES Statutory Meeting. A full report on this exercise should be presented to ACMP in June 1990, following a discussion of the coordinating committee's report by the MCWG in February 1990.

13.5 Intercomparison Exercises on Suspended Particulate Matter

The ACMP noted that the Working Group on Marine Sediments in Relation to Pollution (WGMS) had modified its original proposals for the Intercomparison Exercise on the Analysis of Trace Metals in Suspended Particulate Matter (SPM) (see Annex 1 of the 1988 ACMP Report).

The first phase of this exercise will now commence in April/May 1989 with an in-house exercise using a sediment certified reference material, of the participant's choice, to allow the participant to assess his ability to analyse small samples of material. When this has been successfully completed, each participant will receive three vials from the coordinator (Dr J. Skei), in August 1989, containing 5, 15 and 20 mg, respectively, of three different homogenized sediment reference materials. The participants will be requested to analyse three sub-samples of each material, using sample weights of 1, 3 and 5 mg, respectively. All replicates are to be analysed for Cu, Pb, Zn, Cd, Al, Ni, Mn and Co using a method which determines total metal concentrations, e.g., Loring and Rantala (in press). Participants are to submit their results to the coordinator by December 1989. The coordinator will then prepare a draft report for the 1990 WGMS meeting and a final report should be submitted to the ACMP in that year.

The ACMP noted that, once the intercomparisons of analytical techniques for the measurement of trace metals in sediment reference materials and marine SPM on filters has been undertaken, it would be logical to proceed with an evaluation of SPM sampling techniques. This could be carried out by a single laboratory or, preferably, by several laboratories, using a variety of sample collection methods. The ACMP urged the WGMS to develop the experimental design for such an evaluation at its 1990 meeting.

13.6 Guidelines for the Measurement of Low Dissolved Oxygen in Sea Water using in situ Oxygen Sensors

In relation to the request from the Helsinki Commission for advice on the use of in situ oxygen sensors in water masses with low oxygen and where hydrogen sulfide may be present, the ACMP noted that the MCWG had offered the following comments and advice.

- 1) When employing in situ sensors for profiling purposes, in conjunction with CTD apparatus, it is necessary to validate the measurements of oxygen using the traditional Winkler method. Ideally, calibration should be done on each profile by collecting water samples in a repeated cast at depths which reflect high and low dissolved oxygen readings recorded by the sensor. This means, in practice, that at least one water sample is required per profile at a depth where there is a low concentration of oxygen.

It should be noted that oxygen sensors are sensitive to carbon dioxide levels in sea water. Account must be taken of this factor in interpreting dissolved oxygen measurements, especially under conditions of low oxygen.

- 2) If measurements of dissolved oxygen by in situ sensors are conducted in anoxic waters, "poisoning" of the sensor can occur. This renders the sensor inoperable. Therefore, in situ O_2 sensors should not be deployed in such areas, particularly since some sensors can take considerable time to recover from such exposures and valuable shiptime can be wasted. In such areas, it is recommended that dissolved oxygen measurements are made by the Winkler method. Investigators are strongly advised to conduct such measurements in accordance with the procedures given by Fonselius (1983).
- 3) A procedure for the measurement of low oxygen levels in the presence of H_2S has been described in Ingvorsson and Jørgensen (1979).

13.7 Other Matters Arising from the MCWG Report

The ACMP noted that the MCWG had completed a set of reviews of measurements of petroleum hydrocarbons in water, biota and sediments. These reviews, which examine the key steps in such measurements (i.e., sample collection, isolation of hydrocarbons from the sample matrix and quantitative analysis, with or without prior separation of the hydrocarbons), are to be submitted to ICES for publication in the Journal du Conseil.

The ACMP noted the following points emerging from these reviews:

- 1) The influence of different methods of sample collection on the results obtained are largely unknown.
- 2) Different extraction methods and solvent systems can yield large differences in the results of sea water analyses. Wide variations have also been noted in sediment analyses, where different extraction and clean-up techniques have been employed.
- 3) The method for total petroleum hydrocarbon analysis based on measuring the UV fluorescence of aromatic components has been shown to generate comparable results for sea water and sediments. The precision attainable with UV fluorescence analysis of petroleum hydrocarbon residues in sea water is such that an order of magnitude change in concentration can be detected at low levels of contamination (several tens of nanograms crude oil equivalents per litre) among a group of analysts using a common work-up procedure. At somewhat elevated levels of contamination, precision improves to the point where approximately $\pm 20\%$ changes in concentration become detectable.

- 4) Analytical methods involving separation and individual determination of single hydrocarbons are highly developed (capillary gas chromatography, high performance liquid chromatography, gas chromatography in combination with mass spectrometry). However, purchase of the instrumentation requires a larger financial outlay than for, e.g., UV fluorescence spectrometry, and the analyses are more time-consuming. This has led to the widespread use of the simpler technique as a screening method, followed by the application of chromatographic methods to selected samples.

In the first ICES hydrocarbon intercomparison exercise, involving a fine sandy intertidal sediment sample, no extraction or analytical method was imposed. The best agreement was obtained for measurements based on UV fluorescence.

Depending upon the question(s) to be addressed, a selection can be made from a variety of methods. Guidelines will be developed intersessionally by the MCWG which would make it possible to judiciously select an appropriate method to analyse hydrocarbons in the most suitable matrix to answer a given question. These guidelines will critically evaluate the advantages and shortcomings of different methods and the type of information which they can or cannot provide. They will also discuss which matrix, e.g., water, particles, organisms, or sediments, needs to be analysed for each purpose.

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14 STUDIES OF CONTAMINANTS IN SEDIMENTS

The ACMP considered the "Guidelines for differentiating anthropogenic from natural trace metal concentrations in marine sediments", prepared by the WGMS. The ACMP noted that these revised guidelines were based on a debatable definition of the normalization concept which, furthermore, does not apply to substances such as chlorinated hydrocarbons that do not have both a natural and an anthropogenic source. The ACMP noted that the submitted guidelines document was limited to the case of trace metals in sediments. The ACMP decided to amend the document in order to respond better to the urgent request of the Oslo and Paris Commissions for advice on normalization of the concentrations of a wide variety of contaminants in marine sediments.

14.1 Normalization Techniques for Sediment Quality Assessment

14.1.1 Introduction

Normalization in this discussion is defined as a procedure to compensate for the influence of natural processes on the measured variability of the concentration of contaminants in sediments. Most contaminants (metals, pesticides, hydrocarbons) show high affinity to particulate matter and are, consequently, enriched in the bottom sediments of estuaries and coastal areas. In practice, natural and anthropogenic substances entering the marine system are subjected to a variety of biogeochemical processes. As a result, they become associated with fine-grained suspended solids and colloidal organic and inorganic particles. The ultimate fate of these substances is determined, to a large extent, by particulate dynamics. They therefore tend to accumulate in areas of low hydrodynamic energy, where fine material is preferentially deposited. In areas of higher energy, these substances are "diluted" by coarser sediments of natural origin and low contaminant content.

It is obvious that the grain size is one of the most important factors controlling the distribution of natural and anthropogenic components in the sediments. It is, therefore, essential to normalize for the effects of grain size in order to provide a basis for meaningful comparisons of the occurrence of substances in sediments of various granulometry and texture within individual areas or among areas. Excess levels, above normalized background values, could then be used to establish sediment quality.

For any study of sediments, a basic amount of information on their physical and chemical characteristics is required before an assessment can be made on the presence or absence of anomalous contaminant concentrations. The concentration at which contamination can be detected depends on the sampling strategy and the number of physical and chemical variables that are determined in individual samples.

The various granulometric and geochemical approaches used for the normalization of trace elements data as well as the identification of contaminated sediments in estuarine and coastal sediments has been extensively reviewed by Loring (1988). Two normal-

ization approaches widely used in oceanography and in atmospheric sciences have been selected here. The first is purely physical and consists of characterizing the sediment by measuring its content of fine material. The second approach is chemical in nature and is based on the fact that the small size fraction is usually rich in clay minerals, iron and manganese oxi-hydroxides and organic matter. Furthermore, these components often exhibit a high affinity for organic and inorganic contaminants and are responsible for their enrichment in the fine fraction. Chemical parameters (e.g., Al, Sc, Li) representative of these components may thus be used to characterize the small size fraction under natural conditions.

It is strongly suggested that several parameters be used in the evaluation of the quality of sediments. The types of information that can be gained by the utilization of these various parameters are often complementary and extremely useful considering the complexity and diversity of situations encountered in the sedimentary environment. Furthermore, measurements of the normalizing parameters selected here are rather simple and inexpensive.

This report presents general guidelines for sample preparation, analytical procedures, and interpretation of physical and chemical parameters used for the normalization of geochemical data. Its purpose is to demonstrate how to collect sufficient data to normalize for the grain-size effect and to allow detection, at various levels, of anomalous concentrations of contaminants within estuarine and coastal sediments.

14.1.2 Sampling Strategy

Ideally, a sampling strategy should be based on a knowledge of the source of contaminants, the transport pathways of suspended matter and the rates of accumulation of sediments in the region of interest. However, existing data are often too limited to define the ideal sampling scheme. Since contaminants concentrate mainly in the fine fraction, sampling priority should be given to areas containing fine material that usually correspond to zones of deposition.

The high variability in the physical, chemical and biological properties of sediments implies that an evaluation of sediment quality in a given area must be based on a sufficient number of samples. This number can be evaluated by an appropriate statistical analysis of the variance within and between samples. To test the representativity of a single sediment specimen at a given locality, several samples at one or two stations should be taken.

The methodology of sampling and analysis should follow the recommendations outlined in the "Guidelines for the Use of Sediments as a Monitoring Tool for Contaminants in the Marine Environment" (ICES, 1987). In most cases, the uppermost layer of sediments, collected with a tightly closing grab sampler (level 1 in the Guidelines), is sufficient to provide the information concerning the contamination of the sediments of a given area compared to sediments of uncontaminated locations or other reference material.

Another significant advantage of using sediments as monitoring devices is that they have recorded the historical evolution of the composition of the suspended matter deposited in the area of interest. Under favourable conditions, the degree of contamination may be estimated by comparison of surface sediments with deeper samples, taken below the biological mixing zone. The concentrations of trace elements in the deeper sediment may represent the natural background level in the area in question and can be defined as baseline values. This approach requires sampling with a box-corer or a gravity corer (levels 2 and 3 in the Guidelines).

14.1.3 Analytical Procedures

Typical analytical procedures to be followed are outlined in Table 6. The number of steps that are selected will depend on the nature and extent of the investigation.

14.1.3.1 Grain size fractionation

It is recommended that at least the amount of material less than 63 μm , corresponding to the sand/silt classification limit, be determined. The sieving of the sample at 63 μm is, however, often not sufficient, especially when sediments are predominantly fine grained. In such cases, it is better to normalize with lower size thresholds since the contaminants are mainly concentrated in the fraction less than 20 μm , and even more specifically in the clay fraction ($< 2 \mu\text{m}$). It is thus proposed that a determination be made, on a sub-sample, of the weight fraction less than 20 μm and that less than 2 μm with the aid of a sedimentation pipette or by elutriation. Several laboratories are already reporting their results relative to the content of fine fractions of various sizes and these results may be useful for comparison among areas.

14.1.3.2 Analysis of contaminants

It is essential to analyse the total content of contaminants in sediments if quality assessment is the goal of the study, and it is thus recommended that the unfractionated sample be analyzed in its entirety. The total content of elements can be determined either by non-destructive methods, such as X-ray fluorescence or neutron activation, or by a complete digestion of the sediments (involving the use of hydrofluoric acid (HF)) followed by methods such as atomic absorption spectrophotometry or emission spectroscopy. In the same way, organic contaminants should be extracted with the appropriate organic solvent from the total sediment.

An individual size fraction of the total sediment may be used for subsequent analysis, if required, to determine the absolute concentrations of contaminants in that fraction, providing that its contribution to the total is kept in perspective when interpreting the data. Such size fraction information might be useful in tracing the regional dispersal of metals associated with specific grain-size fractions, when the provenance of the material remains the same. However, sample fractionation is a tedious procedure

that introduces considerable risk of contamination and potential losses of contaminants due to leaching. The applicability of this approach is thus limited.

14.1.4 Normalization Procedures

14.1.4.1 Granulometric normalization

Since contaminants tend to concentrate in the fine fraction of sediments, correlations between total concentrations of contaminants and the weight percent of the fine fraction, determined separately on a sub-sample of the sediment by sieving or gravity settling, constitute a simple but powerful method of normalization. Linear relationships between the concentration and the weight percentage of the fine fraction are often found and it is then possible to extrapolate the relationships to 100% of the fraction studied, or to characterize the size dependence by the slope of the regression line.

14.1.4.2 Geochemical normalization

Granulometric normalization alone is inadequate to explain all the natural trace variability in the sediments. In order to interpret better the compositional variability of sediments, it is also necessary to attempt to distinguish the sedimentary components with which the contaminants are associated throughout the grain-size spectrum. Since effective separation and analysis of individual components of sediments is extremely difficult, such associations must rest on indirect evidence of these relationships.

Since contaminants are mainly associated with the clay minerals, iron and manganese oxi-hydroxides and organic matter abundant in the fine fraction of the sediments, more information can be obtained by measuring the concentrations of elements representative of these components in the samples.

An inert element such as aluminium, a major constituent of clay minerals, may be selected as an indicator of that fraction. Normalized concentrations of trace elements with respect to aluminium are commonly used to characterize various sedimentary particulate materials (see below). It may be considered as a conservative major element, that is not affected significantly by, for instance, early diagenetic processes and strong redox effects observed in sediments.

In the case of sediments derived from the glacial erosion of igneous rocks, it has been found that contaminant/Al ratios are not suitable for normalizing for granular variability (Loring, 1988). Lithium, however, appears to be an ideal element to normalize for the grain size effect in this case and has the additional advantage of being equally applicable to non-glacial sediments.

In addition to the clay minerals, Mn and Fe compounds are often present in the fine fraction, where they exhibit adsorption properties strongly favouring the incorporation of various contaminants. Mn and Fe are easily analysed by flame atomic absorption spectrometry and their measurement may provide insight into the behaviour of contaminants.

Organic matter also plays an important role as scavenger of contaminants and controls, to a major degree, the redox characteristics of the sedimentary environment.

Finally, the carbonate content of sediments is easy to determine and provides additional information on the origin and the geochemical characteristics of the sediments. Carbonates usually contain insignificant amounts of trace metals and act mainly as a diluent. Under certain circumstances, however, carbonates can fix contaminants such as cadmium and copper. A summary of the normalization factors is given in Table 7.

14.1.4.3 Interpretation of the data

The simplest approach in the geochemical normalization of substances in sediments is to express the ratio of the concentration of a given substance to that of the normalizing factor.

Normalization of the concentration of trace elements with respect to aluminium (or scandium) has been used widely and reference values on a global scale have been established for trace elements in various compartments: crustal rocks, soils, atmospheric particles, river-borne material, marine clays and marine suspended matter (cf., e.g., Martin and Whitfield, 1983; Buat-Menard and Chesselet, 1979).

This normalization also allows the definition of an enrichment factor for a given element with respect to a given compartment. The most commonly used reference level of composition is the mean global normalized abundance of the element in crustal rock (Clarke value). The enrichment factor EF is given by:

$$EF_{\text{crust}} = (X/Al)_{\text{sed}} / (X/Al)_{\text{crust}}$$

where X/Al refers to the ratio of the concentration of element X to that of Al in the given compartment.

However, estimates of the degree of contamination and time trends of contamination at each sampling location can be improved upon by making a comparison with metal levels in sediments equivalent in origin and texture.

These values can be compared to the normalized values obtained for the sediments of a given area. Large departures from these mean values indicate either contamination of the sediment or local mineralization anomalies.

When other variables (Fe, Mn, organic matter and carbonates) are used to characterize the sediment, regression analysis of the contaminant concentrations with these parameters often yields useful information on the source of contamination and on the mineralogical phase associated with the contaminant.

A linear relationship between the concentration of trace constituents and that of the normalization factor has often been observed (Windom *et al.*, 1989). In this case and if the natural geochemical population of a given element in relation to the normalizing factor can be defined, samples with anomalous normalized concentrations are easily detected and may indicate anthropogenic inputs.

According to this method, the slope of the linear regression equation can be used to distinguish the degree of contamination of the sediments in a given area. This method can also be used to show the change of contaminant load in an area if the method is used on samples taken over intervals of some years (Cato, 1986).

A multi-element/component study, in which the major and trace metals, along with grain size and organic carbon contents, have been measured, allows the interrelationships between the variables to be established in the form of a correlation matrix. From such a matrix, the most significant ratio between trace metal and relevant parameter(s) can be determined and used for identification of metal carriers, normalization and detection of anomalous trace metal values. Factor analyses can sort all the variables into groups (factors) that are associations of highly correlated variables, so that specific and/or non-specific textural, mineralogical, and chemical factors controlling the trace metal variability may be inferred from the data set.

Natural background levels can also be evaluated on a local scale by examining the vertical distribution of the components of interest in the sedimentary column. This approach requires, however, that several favourable conditions are met: steady composition of the natural uncontaminated sediments; knowledge of the physical and biological mixing processes within the sediments; absence of diagenetic processes affecting the vertical distribution of the component of interest. In such cases, grain-size and geochemical normalization permits compensation for the local and temporal variability of the sedimentation processes.

14.1.5 Conclusions

The use of the granulometric measurements and of component/reference element ratios are useful approaches towards complete normalization of granular and mineralogical variations, and identification of anomalous concentrations of contaminants in sediments. Their use requires that a large amount of good analytical data be collected and specific geochemical conditions be met before all the natural variability is accounted for, and the anomalous contaminant levels can be detected. Anomalous metal levels, however, may not always be attributed to contamination, but rather could easily be a reflection of differences in sediment provenance.

Geochemical studies that involve the determination of the major and trace metals, organic contaminants, grain size parameters, organic matter, carbonate, and mineralogical composition in the sediments are more suitable for determining the factors that control the contaminant distribution than the measurement of absolute concentrations in specific size fractions or the use of potential contaminant/reference metal ratios alone. They are thus more suitable for distinguishing between uncontaminated and contaminated sediments. This is because such studies can identify the factors that control the variability of the concentrations of contaminants in the sediments.

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TABLE 6

A TYPICAL APPROACH FOR DETERMINATIONS OF PHYSICAL AND CHEMICAL
PARAMETERS IN MARINE SEDIMENTS

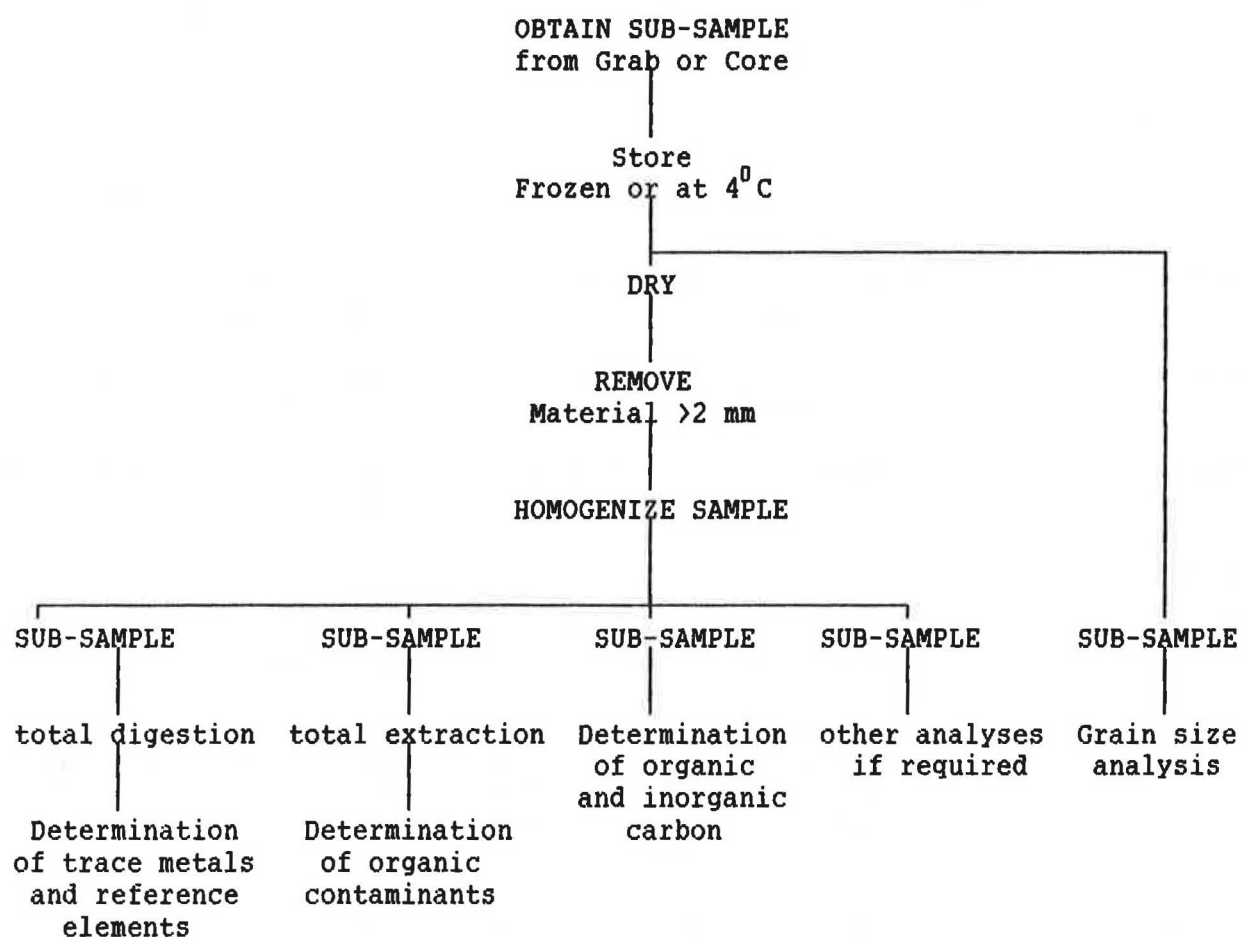


TABLE 7

SUMMARY OF NORMALIZATION FACTORS

Normalization factor	Size (μm)	Indicator	Role
<u>Textural</u>			
			Determines physical sorting and depositional pattern of metals
Sand	2000-63	Coarse-grained metal-poor minerals/compounds	Usually diluent of trace metal concentrations
Mud	<63	Silt and clay size metal-bearing minerals/compounds	Usually overall concentrator of trace metals
Clay	<2	Metal-rich clay minerals	Usually fine-grained accumulator of trace metals
<u>Chemical</u>			
Si		Amount and distribution of metal-poor quartz	Coarse-grained diluter of contaminants
Al		Al silicates, but used to account for granular variations of metal-rich fine silt + clay size Al-silicates	Chemical tracer of Al-silicates, particularly the clay minerals
Li, Sc		Structurally combined in clay minerals and micas	Tracer of clay minerals, particularly in sediments containing Al-silicates in all size fractions
Organic carbon		Fine-grained organic matter	Tracer of organic contaminants. Sometimes accumulator of trace metals like Hg and Cd
Fe, Mn		Metal-rich silt + clay size Fe-bearing clay minerals, Fe-rich heavy minerals and hydrous Fe and Mn oxides	Chemical tracer for Fe-rich clay fraction. High adsorption capacity of organic and inorganic contaminants
Carbonates		Biogenic marine sediments	Diluter of contaminants. Sometimes accumulate trace metals like Cd and Cu

14.2 Sediment Studies in the Baltic Sea

The ACMP examined the report of the Sub-Group on Baltic Sediments which was set up under the ICES Working Group on the Baltic Marine Environment in order to prepare a critical review of contaminant and geochemical data from sediment studies carried out in the Baltic Sea, and to consider the possibilities of whether the monitoring of harmful substances in sediments should be conducted on an international basis. The Sub-Group had met twice in the course of the year. At a meeting held in September 1988 in Tallinn, the contents of the "Critical Review" were agreed upon and authors and possible data originators were identified. At the meeting held in Sopot in April 1989, the progress in the work was reviewed and, although a large number of the agreed chapters of the Critical Review had already been drafted, nevertheless, major gaps were still found to exist. They are mainly due to delayed responses from scientists and a lack of expertise in certain fields of the members of the Sub-Group present at the meetings. Relevant trace element data for the preparation of "Baltic Sea Sediment Maps" are now available. Data on organochlorines, petroleum hydrocarbons, and nutrients in sediments are scarce. The ACMP noted that it had been agreed by the Sub-Group that a first draft of the Critical Review should be presented at the 1990 meeting of the Working Group on the Baltic Marine Environment.

The main purpose of the Critical Review is to give background information which will allow the Helsinki Commission to decide whether or not to include the monitoring of harmful substances in marine sediments in the Baltic Monitoring Programme (BMP). In spite of the slow progress in completing the Critical Review, sufficient information is already available to allow a recommendation to be made as to the inclusion of sediments in the Baltic Monitoring Programme. Because sediments provide a medium in which long-term trends of contaminant levels could possibly be detected, and because contaminant budgets can be calculated only if sediment data are available, the ACMP endorsed the Sub-Group proposal that a recommendation should be forwarded to the Helsinki Commission that Baltic Sea sediments should be investigated on a multilateral basis under the framework of the BMP. It should, however, be noted that the slow rate of accumulation and the extent of mixing of the sediments by bioturbation and/or by trawling makes it advisable to monitor sediments on the basis of rather extensive baseline studies repeated at intervals of five years or more. All significant sedimentation areas of the Baltic Sea should be covered. In the first phase, some metals (Hg, Cd, Pb, Cu, Zn), phosphorus and nitrogen compounds should be included. Selected organochlorines and petroleum hydrocarbons can, at this stage, only be considered on a tentative basis due to analytical problems. A broad range of background parameters, required to characterize the sediments and allow further normalization, should also be included. An intercalibration exercise has already been run in 1984 to assess the methodological capability of the Baltic Sea laboratories. However, combined "pilot studies/intercalibration exercises" in advance of the proposed studies have been suggested in order to optimize the sampling and analytical procedures.

Considering these problems and the fact that the sampling strategy requires better information on sedimentation processes, dis-

tribution patterns of sediments, and existing data on contaminant content, which will be available in the Critical Review, the ACMP endorsed the Sub-Group suggestion that the extensive baseline study should not be started before 1993.

The ACMP noted that the proposed baseline studies have followed, to a large extent, the methodological guidance provided by ACMP on the basis of advice from the Working Group on Marine Sediments in Relation to Pollution. The ACMP, in endorsing the proposed plans and time schedule, encouraged the Sub-Group to release rapidly a draft of the Critical Review and to finalize the document in 1991.

14.3 Release of Contaminants from Sediments

The ACMP noted that, in accordance with its request, the Working Group on Marine Sediments in Relation to Pollution discussed during its 1989 meeting the possible release of contaminants from highly contaminated sediments. The ACMP noted that excessive amounts of organic or inorganic contaminants in the sediments represent a potential environmental risk and that it is important to make a quantitative assessment of the sediments as a source of contamination.

The results of two experimental studies were presented and discussed. The first, carried out by the Norwegian Institute for Water Research, referred to a laboratory experiment using a continuous flow system containing highly contaminated sediments, allowing evaluation of the rate of release of contaminants from the sediment. Additionally, bioavailability tests using eel and mussels were made in connection with the flux experiment. The experimental design seems appropriate for the objectives of the studies. It was found that the rates of release of metals and chlorinated compounds were low unless the contaminated sediment is resuspended. Contaminants released from the sediments were rapidly taken up by mussels and fish. The toxicological significance of this uptake could not be determined from the report.

The second study referred to was carried out to examine the release of mercury during the resuspension of mud and also during the dumping of dredged material. Two muddy patches in Liverpool Bay, where mercury concentrations reached levels around 2 mg/kg, were selected for the experiments. The results indicate that mercury was released as a pulse immediately on resuspension or dumping and then readsorbed within the next few minutes. The desorption/adsorption cycle could, in the field, allow the release of mercury from the sediment and its transport away from the resuspension or dumping zone.

The ACMP endorsed the view expressed by the WGMS that, in the field, resuspension would occur irregularly, generally during storms. It would, thus, not be simple to take measurements to obtain an overall picture of the release of contaminants. The ACMP also agreed with the WGMS suggestion concerning the use of caged mussels as the first stage of an assessment of release.

This suggestion was partly supported by the results of a comparative study of contaminant concentrations in sediments and bivalves from the same location, conducted by the U.S. National Oceanic and Atmospheric Administration (NOAA) in its National Status and Trends Program. During this study, both bivalves (mussels and oysters) and fine-grained sediments were collected at 117 sites in coastal and estuarine areas that are relatively highly contaminated. The results were that both mussels and sediments simultaneously reflected levels of contamination for most of the organic and inorganic pollutants. Contaminant levels in oysters, on the other hand, did not parallel those in sediments. This study concluded that sediments are the preferred matrix to describe spatial distributions of contaminants, but that year-to-year temporal trends are much more readily described through the analysis of mussels.

The ACMP recognized the importance of the problem discussed by the WGMS and stressed the need for research in this field. In the case of sediments characterized by a low exchange capacity, even low levels of contamination may be responsible for critical release of the contaminants during resuspension events. The ACMP also recognized the problems of potential release of contaminants if sediments, deposited under anoxic conditions, are subsequently subjected to oxic conditions. This may happen when dredged sediments are discharged on land, deposited at uncontaminated marine sites or when they are dispersed in the water column. It may also be encountered in estuaries and fjords where seasonal anoxic conditions are observed or in highly contaminated areas when better environmental conditions are restored. The redox potential is a master variable controlling the chemical behaviour of most of the trace elements and the metabolic activities of benthic microorganisms. The ACMP noted that information on mobilization of contaminants exists but is dispersed in individual studies, for example, in relation to the disposal of dredged material. Considering the importance of this subject, it is anticipated that the topic will be discussed further by the WGMS in 1990. These discussions should include a careful examination of the various biological and chemical processes occurring when changing from anoxic to oxic conditions.

15 EFFECTS OF EXTRACTION OF MARINE SEDIMENTS ON FISHERIES

The ACMP noted the report of the Working Group on the Effects of Extraction of Marine Sediments on Fisheries, which reported on progress in the preparation of an overview paper on the effects of marine extraction and the development of a draft Code of Practice to foster cooperation between the extractors and the fishing industry. The Working Group had acknowledged that they had yet to fully meet their terms of reference, as it was necessary to finalize work on both documents.

The Working Group report examined the state of marine sediment extraction and its impacts on the marine environment, as well as efforts to map superficial marine sediments by ICES member countries in 1988. The report also provided an overview of recent results of national research programmes aimed specifically at monitoring and quantifying the effects of sediment extraction activities on fisheries. The ACMP considered that it is necessary to address the question of how the environmental impact of sediment extraction can be simply monitored and quantified.

The draft Code of Practice considered the various steps to be carried out in the pre-prospecting and prospecting stages, the consultations needed before licensing an extraction, and finally the issues to be covered in the permit for the extraction itself. The draft Code of Practice is nearing completion, but requires an introduction illustrating the manner in which extraction operations and their products may potentially affect biological processes and production.

The ACMP again emphasized the undesirability of returning fines to the water column or the seabed, as this will lead to alteration of the previously existing substrate. Accordingly, the ACMP advises that all nationally issued permits include a statement to this effect as a condition of licensing. Return of fines to the bottom will "blanket" the bottom substrate, thus effectively impeding the industry's own efforts. Changes in substrate character affect benthic community structure and succession, and thus the type of food available for finfish and shellfish. Particular substrate types are frequently specific for the attachment of demersally attached eggs, as well as settlement and recruitment of larval and juvenile stages. Sessile organisms may become partly covered or buried by fines. High ratios of particulate inorganic matter (PIM) to particulate organic matter (POM) in suspended material may result in clogging in filter feeding animals, delayed gut passage time, reduced assimilation rates and, accordingly, result in slow growth. It should be borne in mind that fines and other particulate by-products can adhere to eggs, particularly demersal eggs, and clog the gills of fish larvae, thus limiting respiration efficiency. Finally, resuspension of bottom material rich in organic content can place an elevated oxygen demand on the environment. This may be associated, to a lesser or greater extent, with oxygen depletion at the sediment-water interface as well as in the water column, depending on current velocity.

16 NET RIVERINE FLUXES

The request from the Helsinki Commission for information on approaches to the estimation of net riverine fluxes of contaminants was presented and discussed. The ACMP concluded that, in all essential respects, the advice provided in its previous year's report (1988 ACMP Report, pp. 87-88) was appropriate for responding to the HELCOM request. It was further noted that, since the Baltic Sea is a semi-enclosed marginal sea, it would also be possible to estimate net fluxes from the Baltic Sea to the North Sea through measurements of water exchange and composition in the straits between Denmark and Norway/Sweden. It was noted that this is one of the declared aims of the SKAGEX investigation. While flux studies will require considerable investment in physical oceanographic and chemical measurements, they may well prove to be the most effective manner of determining net contaminant fluxes from the Baltic Sea.

17 STUDIES IN THE BALTIC SEA

17.1 Report of the Working Group on the Baltic Marine Environment

The ACMP considered the report of the Working Group on the Baltic Marine Environment (WGBME). The ACMP noted that there is at present a long period of stagnation in the Baltic deep basins, with a lack of oxygen and the presence of hydrogen sulfide. In some basins, zoobenthos has been killed below 80 m water depth. The last large water inflow from the North Sea was observed in the winter of 1975-1976; however, it is not clear to what extent the present stagnation is an effect of natural phenomena or of anthropogenic influences.

During the past forty years, winter phosphate and nitrate concentrations have shown a marked increase in the surface water of the Baltic proper and an increasing trend of nutrient concentrations has been observed below the pycnocline (BMEPC, 1987). Increasing primary production has also been recorded. For this reason, it is believed that the anthropogenic contribution to oxygen depletion in the deep water is significant.

Concerning toxic metals in the Baltic Sea, the ACMP noted that concentrations of mercury and lead in the Baltic waters are in the same range as those in the open North Atlantic. The concentrations of cadmium, copper and nickel in open Baltic waters are, however, higher than those in the waters of the open North Atlantic. This can partly be explained by the admixture of river water, which contributes to a large extent to Baltic Sea water. Trace metal concentrations in Baltic fish are, however, comparable with those occurring in North Atlantic and North Sea fish. This was well documented in the 1985 Baseline Study of Contaminants in Fish and Shellfish, which also revealed that concentrations of DDT and its metabolites in cod and herring from the Baltic Sea are still high compared with concentrations in these species of fish from the North Sea. PCB concentrations also seem to be rather high, but very little is known about the concentrations and environmental effects of other organic contaminants in the Baltic Sea.

The ACMP also took note of an overview on contamination of the Baltic Sea by petroleum hydrocarbons. Petroleum hydrocarbons in water were determined on an obligatory basis during the second stage of the Baltic Monitoring Programme (BMP) using the UVF technique together with an "Ekofisk standard". The UVF technique was commonly applied on the understanding that this was a screening technique. In cases where unusually high concentrations were found by UVF, other relevant techniques, e.g., GC-MS, were to be applied to examine the components in detail. In recent years, no significantly contaminated area has been recorded. However, some tanker accidents have occurred, e.g., the "Antonio Gramsci" accident in the Gulf of Finland, and some smaller instances of oil contamination, including deliberate oil disposals at sea.

On the basis of UVF records taken from the 1970s, including the recent measurements undertaken within the BMP, it can be concluded that there is no evidence of increasing oil contamination in the Baltic Sea and that contamination of the Baltic Sea is no greater than that in the North Sea with respect to oil. Most com-

monly reported values for the open sea areas are between 0.2 and 2 µg/l (UVF, Ekofisk standard, see Figure 7).

In addition, a very even distribution of petroleum hydrocarbons has been observed in Baltic Sea waters. This could be due to airborne input of "UVF active" combustion products. Another explanation could be that there is a relatively evenly distributed pool of UVF active and petroleum hydrocarbon related substances which are degraded only slowly in relation to other components of oil.

It is worth noting that additional studies, applying more powerful GC-MS techniques, have been started in the Baltic Sea countries. Concentrations of individual compounds have been shown to occur at the ng/l level. For example, Dahlmann and Theobald (Deutsches Hydrographisches Institut, Hamburg, 1988) analyzed the composition of the non-polar fraction of a typical water sample from the Baltic Sea and found 40 compounds with concentrations between 0.2 (4-M-phenanthrene) and 11.8 ng/l (n-C₂₉), including n-alkanes from C₁₄ to C₃₀, aromatic compounds of petroleum origin (weathered oil, combustion products) and products of natural origin (pristane).

Studies on oil contamination of sediments and on the effects of the oil on biota are not as well developed as the studies on water contamination. More effort should be devoted to this subject, especially in developing the necessary analytical methods.

The ACMP noted that the Study Group on Baltic Sea Modelling had held its first meeting in connection with the 16th Conference of Baltic Oceanographers, in Kiel in September 1988, and that the Study Group intended to continue its work mainly on the basis of a Workshop expected to be held in late April 1990 at ICES headquarters. The aims of this Workshop are:

- to describe the state-of-the-art regarding marine modelling,
- to present the state of modelling in the Baltic Sea, and
- to define what is possible to achieve by joint efforts on modelling in the Baltic Sea area.

The ACMP was informed of the Swedish/Finnish proposals and preparations for a "Gulf of Bothnia Year 1991". The ACMP noted that the main topics of the programme of the Gulf of Bothnia Year will be "inputs from land", "biogeochemical cycles", "toxic substances" and "modelling", and that the other Baltic Sea countries may take part in a variety of investigations.

The ACMP also endorsed the proposal that the WGBME investigate the technical and scientific possibilities of using "ships of opportunity" to provide surface data from installed sensors which may continuously record relevant environmental background parameters.

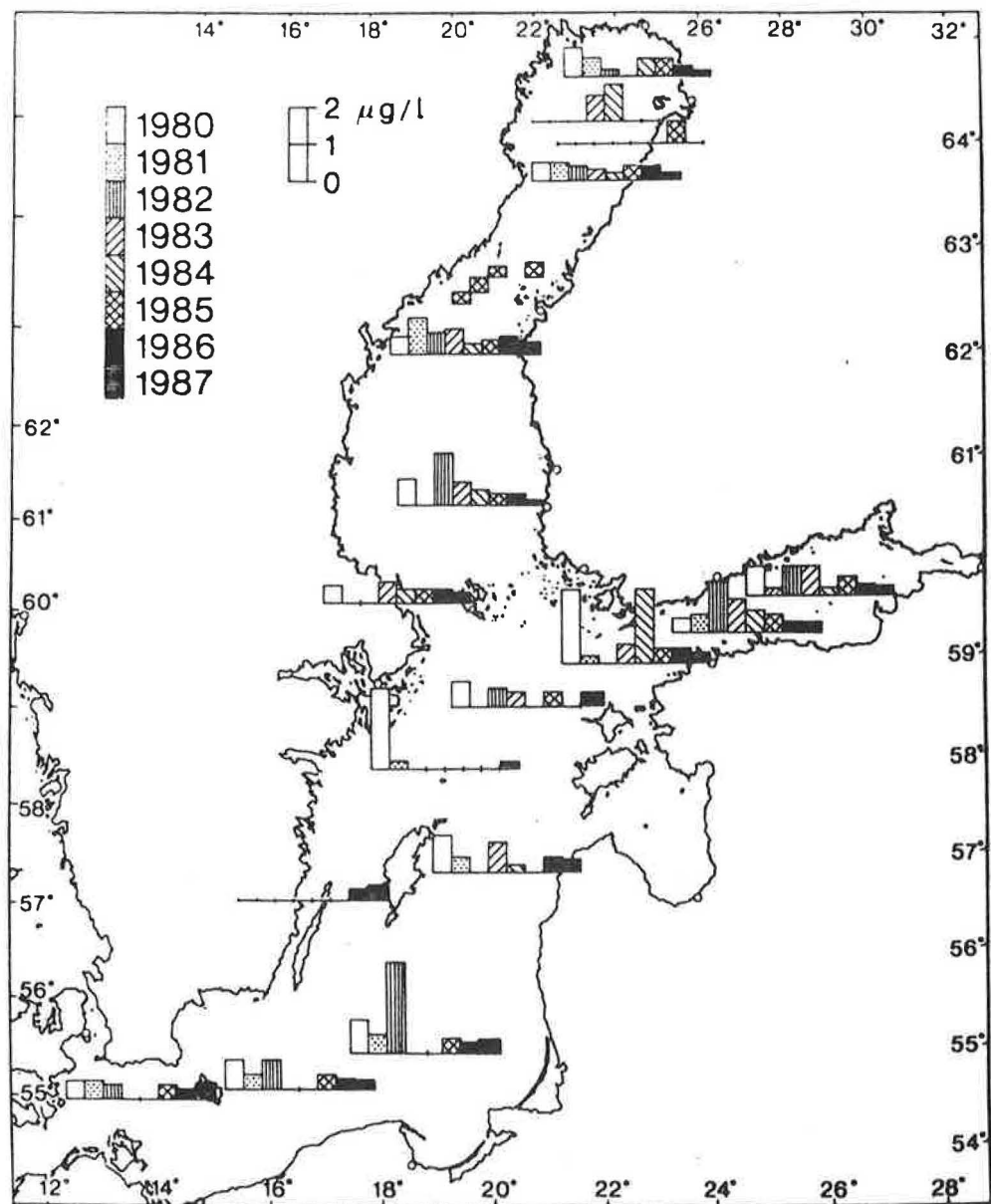


Figure 7 Total hydrocarbon concentrations in the time period 1980-1987 (Poutanen, 1988.)

17.2 Report on PEX Studies

The ACMP took note of the main report (ICES, 1989) on the results of the Joint International Multi-Ship Investigation of Patchiness in the Baltic Sea (PEX '86). The physical, chemical and biological parameters measured showed a pronounced patchiness, with spatial scales from hundreds of meters to hundreds of kilometers and a time scale from hours to weeks. During the period of the investigations (25 April - 8 May 1986), considerable changes occurred. The physical factors determined to a great extent the distribution of the biological parameters. During the bloom, the consumption by autotrophic organisms was, however, most important for the distribution of the chemical parameters.

Following from the results of PEX, it is evident that due to the "patchiness noise" in each of the sub-areas of the Baltic Sea, the physical and chemical oceanographic conditions are not necessarily always adequately represented by the stations presently used in the BMP. Hence, the ACMP supported the recommendation of the WGBME that participants in the BMP should be encouraged to submit all data from stations visited in the same sub-area as the obligatory "representative" BMP station and, if necessary, collect additional oceanographic data relevant to the conditions at the monitoring station concerned. Such additional data could be generated by, for example,

- measurements around the monitoring station over an area with a radius of about 10 n.m.;
- transects through the monitoring station; and/or
- time series measurements at the monitoring station.

Although PEX was considered successful in many respects, the methods applied did not provide the data quality desired. Problems identified included the comparability of sampling depths, and the accuracy in the determination of some parameters, e.g., nutrients. Sometimes large correction factors were needed to compensate for these variances. On the basis of the experiences with the PEX data, there is a general agreement that better quality control is urgently needed. There are also indications that many highly suspect data are stored in data banks. In this connection, the ACMP endorses the recommendation of the WGBME on the necessity for quality assurance of measurements and quality control of data for all types of studies in the Baltic Sea and, especially, for those data to be exchanged between countries and/or delivered to international data bases. The recommended procedures include:

- to follow exactly the procedure for using CTDs as described in the report of SCOR WG 51;
- to perform routine calibration checks for all series of measurements, including tests of instruments and methods against standards, for physical, chemical, and biological determinands;
- to organize intercalibration workshops to be held at least every fifth year; and

- to ensure that all institutes participating in joint Baltic studies and/or the BMP should investigate the reasons for discrepancies shown by intercalibration results and take appropriate measures to improve the quality of such measurements.

To this end, the ACMP recommends that the HELCOM data centre should apply data quality checks on the data they receive from Baltic Sea countries, in a manner similar to that employed by the ICES data centre.

17.3 Baltic Fish Chapter for Assessment of the Baltic Sea

The Helsinki Commission has asked ICES to prepare a chapter on fish stocks in the Baltic Sea, for the Second Periodic Assessment of the Baltic Sea Environment, in which data on fish stocks over the past ten years should be presented and information provided on the effects of contaminants on fish stocks in the Baltic Sea area. The information on contaminant effects on stocks made available to ACMP by the Working Group on Assessment of Pelagic Fish Stocks in the Baltic and the Working Group on Assessment of Demersal Fish Stocks in the Baltic up to now is, however, scanty. Restricted catches of demersal species have been associated with oxygen deficiency in some areas of the southernmost Baltic Sea, the Danish Straits, and in the Kattegat. Also, the fishing period has been reduced for the same reason. For a more complete and precise assessment of the effects of contaminants on the Baltic fish stocks, the ICES working groups on Baltic fisheries may have to collect more material on this subject, in cooperation with the WGBME.

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18 ISSUES CONCERNING SEALS

Previous advice on seal population levels in the Baltic Sea and possible effects of environmental contaminants in the Baltic Sea were given in the 1986 ACMP report and in the 1987 ACMP report. In the light of the disease epidemic that affected seals around Northern Europe in 1988, both issues were again addressed by a joint meeting of the Working Group on Baltic Seals and the Study Group on the Effects of Contaminants on Marine Mammals, held in Helsinki on 15-18 May 1989. The ACMP examined the report of that meeting and agreed to include a substantial section of the meeting's findings in its report.

18.1 The Size of Seal Populations and the Impact of the Phocine Distemper Virus Epidemic

18.1.1 Harbour seals (*Phoca vitulina*)

Since mid-April 1988, more than 17,000 harbour seals have been found dead at various sites around the coasts of northern Europe. It is generally accepted that the primary cause of death for most of these animals was infection with a previously undescribed morbillivirus tentatively named as Phocine Distemper Virus. Most diagnoses of the disease have been based on the presence of characteristic pathological and clinical symptoms or of antibodies to the closely related Canine Distemper Virus in serum. In a few cases, it has been possible to detect the presence of virus antigen in tissue using immunofluorescent techniques. It will not be possible to assess the full impact of the epidemic on most seal populations until aerial surveys are conducted during the moult period in August 1989. However, preliminary estimates of the previous abundance and numbers of dead animals found in 1988 are given in the following paragraphs.

Baltic Sea

There were approximately 300 harbour seals in the Baltic Sea before the start of the epidemic. There has been no unusual mortality among the group of about 80 seals at Öland and of 4-5 seals at the south end of Gotland. But there had been 60-70% mortality among the harbour seals in the southwestern Baltic Sea and only about 50 animals now remain at the largest colony. Reproductive rates amongst the seals in the southwest Baltic Sea appear to be reasonably good, but up to 50% of the pups have been found dead within the first months after pupping between 1984 and 1987. The low size of this population (less than 300) and the severe mortality suffered during the epidemic in 1988 mean that the status of this population is now critical.

Kattegat and Skagerrak

Until 1988, the harbour seal population in the Kattegat and Skagerrak had been increasing at an exponential rate of 0.12; it had been anticipated that, if this rate continued, aerial surveys in August would have revealed 8215 animals. However, since April 1988, 4847 animals have been found dead in the area and only 2900 live animals were counted in the annual aerial survey after the

period of highest mortality. The overall mortality was estimated to be 60%; about 95% of the pups born in 1988 were thought to have died. In the whole area, approximately equal numbers of animals of each sex were found dead. Tagging studies have indicated that most bodies were washed ashore, usually on the Swedish side, within three weeks of death. Since the beginning of February 1989, only two animals have been found dead.

Norway

950 dead animals had been found in Norway out of an estimated population of 4300. Most of the dead animals (500) were from the Oslofjord area. This was more than the estimated local population size and it was considered that some of these bodies had been washed northwards from the Skagerrak. No dead seals had been found north of Trondheim, although there was a substantial harbour seal population of 1200 to 1400 animals in this area. There were no recent reports of dead seals.

Limfjorden and Wadden Sea

850 dead seals had been found in the Limfjord area; this was more than the highest previous count from aerial surveys. 8550 dead harbour seals had been found in the Wadden Sea area out of an estimated minimum population of 9500 at the end of the pupping season in 1988. Although some of these corpses could have drifted across the North Sea from the east coast of England, it was considered that this was unlikely to have been a major source because such bodies would have taken about three weeks to travel across and should have washed up in the western Wadden Sea, where relatively few bodies were recovered. Since January 1989, 20 to 40 times more dead seals than normal had been found in Schleswig-Holstein. Twenty-five percent of the seals brought into the rescue centre at Pieterburen during the winter did not have antibodies to the virus; most of these were young animals. Seals with clinical symptoms of virus infection were still being reported from the Netherlands, Schleswig-Holstein, and Denmark early in 1989.

United Kingdom

Over 3000 dead seals had been reported from the UK coast since the end of July 1988. Of the 1183 animals for which there was a positive identification as to species, only 185 were grey seals although the population of this species was estimated to be more than 90,000. This suggests that about 2500 dead harbour seals were found from a population of at least 25,000 at the start of the epidemic. 1765 of these were from the North Sea coasts of England and Scotland and 750 from the North Atlantic coasts of England, Scotland, Wales, and Northern Ireland. Very few dead seals (48) had been reported from the Shetland Islands and none of these had shown clear clinical symptoms of virus infection or virus antibodies. It was believed that mortality had been substantially under-estimated because of the extensive areas of poorly populated and rocky shoreline, where bodies were unlikely to be found, and the prevailing offshore winds. There had been very few reports of dead seals during the winter, but the numbers had increased since the end of March from all around the coast, including an animal with clinical symptoms from Shetland.

France

The small group of animals in the Baie de Somme appeared to be unaffected by the virus. Five dead animals had been found in the Dunkirk area, but none had symptoms of the disease; however, an animal with symptoms of the disease, as shown by histological analyses, had recently been found dead on the south coast of Brittany.

18.1.2 Grey seals (*Halichoerus grypus*)

Four dead grey seals with symptoms of virus infection had been found in the southwestern Baltic Sea. These were all old animals suffering from the adreno-cortical hyperplasia previously reported in Baltic seals (Bergman and Olsson, 1986), which is believed to involve immune system depression. There were estimated to be 1,200 - 1,500 animals on the Swedish Baltic coast. There was some evidence of a slight increase in numbers counted in northern areas in recent years. The summer population in Finnish waters was estimated at 600 - 700 animals, with a Soviet population of 200 - 300. The entire Baltic population was, therefore, estimated to be at least 2,000. The status of this population remains critical.

No dead grey seals with symptoms of the disease had been found in Norway, the Federal Republic of Germany or France, but three seals with symptoms (including one pup) had been found in the Kattegat. One dead animal from the small Netherlands Wadden Sea population of about 80 animals had been found with pathological symptoms in May 1989.

In the United Kingdom, 185 of the animals reported dead were positively identified as grey seals and the total number of dead grey seals was estimated to be about 500. However, very few of these had shown symptoms of the disease and only one animal had been confirmed to have virus antigen. More sick and dead animals with disease symptoms had been reported since the end of March 1989, including some pups born in 1988. Samples of blood from 70 breeding females and 3 pups taken at a number of Scottish colonies in 1988 had shown a very high (97%) prevalence of antibodies to distemper virus. No trace of antibodies had been found in 60 adult females and 80 pups sampled between 1977 and 1987. Pup production at a number of colonies on the North Sea coast was 20-30% lower than expected in 1988. This could have been due to abortion of fetuses or death of females caused by the disease, or by some extraneous factor.

18.1.3 Ringed seals (*Phoca hispida*)

No ringed seals showing symptoms of the disease had been seen in the Baltic Sea. However, one ringed seal brought into the rescue centre at Pieterburen had developed clinical symptoms although it later recovered. Antibodies to distemper virus have been found in ringed seals from west and east Greenland sampled since 1985 (Dietz *et al.*, 1989).

Trends in reproduction

The proportion of adult female ringed seals taken in the Finnish hunt that show occlusions of the uterine horns, which render them sterile, appears to have declined in the youngest age classes from 1977-1979 to 1980-1988. However, the sample sizes for the younger age classes in 1977-1979 were very small and the Working Group decided that no firm conclusions could be reached about changes in the populations from these data.

The proportion of animals aged 1-4 years taken in the Finnish hunt in the Bothnian Bay had increased from <10% in 1978-1979 to 20%+ in 1982-1988, but this could be due to an increased production of young, increased adult mortality, or a combination of these two factors.

Helle had estimated a maximum pregnancy rate of 70% among animals without occlusions sampled in May in the years 1986 to 1988, if it is assumed that all animals with large corpora albicantia had been pregnant. However, because there was considerable overlap in the sizes of corpora albicantia of ovulation and pregnancy, it was impossible to provide an unbiased estimate of the pregnancy rate.

Trends in contaminant levels

Although there was some evidence of a decrease in PCB levels in the blubber of ringed seals from 1980 to 1986, this had not been observed in Swedish grey seal samples from the Bothnian Bay. A decline in PCB levels in herring had been observed in many parts of the Baltic Sea following the ban in emissions in the early 1970s. However, these declines had not continued during the 1980s in the Bothnian Sea and the northern part of the Baltic proper.

Other sources of mortality

The Finnish hunt for ringed seals had ceased after the 1988 season, when 31 animals had been killed. However, the Working Group recognized that the incidental entanglement of young ringed seals, and grey seals, still posed a continuing threat to the seal populations in the Baltic Sea.

Status of the Baltic ringed seal stock

Results were available from aerial surveys conducted using a modified strip transect technique in the Bothnian Bay during April and May 1988. The population on the ice at this time was estimated to be 2341 ± 562 , which is similar to results from surveys conducted by Finnish scientists in 1984 and 1987. The results of Soviet surveys in the Gulf of Finland conducted in 1988 were not yet available, but previous surveys in this area in 1983 had provided a maximum estimate of 4000. The fact that no further decline in ringed seal numbers had been detected in the 1988 aerial survey, and the possible change in the number of animals with occlusions, were encouraging signs. However, none of them provided evidence of a significant improvement in the status of the stock.

The ACMP endorsed the concern expressed by the Working Group that any recovery of this severely depleted stock will be slow because of the high proportion of sterile animals. It was important to determine whether seals which had been rendered sterile by occlusions in the uterus could recover. This could be examined by bringing a limited number of females with occlusions into captivity and studying the changes in their uterus at regular intervals with an endoscope.

18.1.4 Implications of the epidemic for the future of European seal stocks

The Working Group concluded that the threat to the surviving harbour seal population in the Kattegat and Skagerrak in 1989 would be less than in 1988 because only the pups of the year were likely to be vulnerable to the virus. As a result, the probability of an infected animal carrying the virus to ringed and grey seals in the Baltic Sea was less in 1989 than in 1988.

Data from the UK indicated that only a small percentage of animals born in 1987 and 1988 had yet been exposed to the virus, possibly because they were widely dispersed by the time the virus reached the UK. As a result, between one-quarter and one-half of the surviving seal population was probably still vulnerable to infection in 1989. The same is probably true in the western Wadden Sea. Elsewhere, all age classes appeared to have been equally exposed and the main risk was to pups born in 1989.

The Working Group noted that the surviving European harbour seal stocks are unlikely to increase at any greater rate than that which was observed before the epidemic. If animals which had survived infection had damaged lungs, or decreased resistance, then the rate of recovery could be substantially lower than this.

The prospects for European grey seal stocks are still unclear.

18.1.5 Experimental and field evidence linking contaminants with the epidemic

In its 1987 report, the ACMP had noted that a number of organochlorine compounds have been implicated in observed cases of reproductive failure and immune system problems amongst seals.

It is apparent that the primary cause of the wide-scale mortality amongst harbour seals in the North Sea, Baltic Sea, and northeast Atlantic in 1988 was infection by a morbillivirus. Organochlorines and some heavy metals are known to have an immunosuppressive effect on other mammals under experimental conditions; the Working Group, therefore, considered it possible that these pollutants had contributed to the severity of the epidemic.

The ACMP considered that, at this stage, it is difficult to draw any firm conclusions regarding the possible influence of contaminants. Although only a limited number of samples from dead seals had been analysed to date, none had shown abnormally high levels of any contaminant measured. However, since the threshold level for the effect, if any, of these compounds on the immune system

of seals is not known and since all of the implicated compounds had yet to be analysed, this was not conclusive proof that contaminants were not involved. In this context, the Working Group had noted that studies planned in the UK to compare organochlorine levels in the blubber of seals which died in the epidemic and in those which survived on an area-by-area basis might resolve some of these problems. In addition, the studies planned by the UK and the Netherlands on the effects of organochlorines on the immune system under field and laboratory conditions should indicate whether immunosuppression could have occurred.

18.1.6 Future actions

The ACMP agreed that the Joint Group should be reconvened at a suitable future date to continue its review of the results of studies carried out as a result of the epidemic. The ACMP will provide a final report on the seal epidemic of 1988-1989 when a more complete picture of the outcome is available.

The ACMP welcomes the decision of the Finnish government not to issue any more licences to hunt ringed seals in 1989 and it urges the relevant authorities to refrain from issuing further licences until there is clear scientific evidence that the ringed seal stocks in the Baltic Sea have recovered.

References

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19 OVERVIEWS ON CONTAMINANTS IN THE MARINE ENVIRONMENT

Four documents were considered under this item. The first of these was an article on planar and coplanar chlorobiphenyls, prepared by a member of the MCWG. This deals primarily with measurement technology and toxicology of individual planar, mono- and diortho-chlorinated biphenyl congeners in the environment. The ACMP considered that it contained valuable information on this topic, but was directed principally at a scientific audience. The ACMP suggested that this report, augmented with additional information, be submitted for open publication and an abbreviated version, couched in less technical language, be prepared for inclusion as an overview in a future ACMP report.

The second document presented information on hexachlorobenzene (HCB) and lindane (γ -hexachlorocyclohexane (γ -HCH)). This had been prepared under the MCWG and was found to contain a useful summary of the properties, sources, occurrence and effects of these compounds. After some debate, it was agreed that this material was valuable but required some modification in its form of presentation, and the author was requested to submit an amended version.

The third and fourth documents, respectively, were an overview on mercury and an update on a previous overview on chlorinated dibenzodioxins and dibenzofurans. The mercury overview was adopted, in revised form, for inclusion in this ACMP report. It is presented below. The additional information on polychlorinated dibenzo-p-dioxins and dibenzo-p-furans is also provided below as an addendum, or update, to the ACMP overview on these chemicals contained in its 1984 report.

Overviews on chromium and chlorophenols in the marine environment are being prepared by the MCWG for inclusion in a future ACMP report.

19.1 An Overview of Mercury in the Marine Environment

19.1.1 Abstract

Mercury is a volatile element whose global circulation is dominated by transfers involving the atmospheric reservoir. In the oceans, where concentrations range from 0.05 to 2.5 ng·l⁻¹, chlorocomplexes are the most abundant mercury-containing chemical species. Mercury has a great affinity for particulate matter, especially particulate organic matter. This reactivity is reflected by the short residence time of this element in the ocean (~350 years). Its oceanic distribution is controlled by the balance between the input flux (mainly from the atmosphere) and the intensity of the removal from the water column. The stability of monomethyl mercury gives this metal a particular characteristic: that of accumulation by organisms. Human intervention in the mercury cycle is mainly perceptible in increased emissions from land into the atmosphere. The anthropogenically related flux is now the same order as the natural flux. Human health may be affected by the consumption of seafood containing high concentrations of mercury.

19.1.2 Introduction

As has been the case for a number of transition elements during the 1970s, knowledge of the concentrations, biogeochemical behaviour and fluxes of mercury in the marine environment has improved as a result of the application of more reliable sampling and analytical techniques. The quantity and quality of the data published in the last few years have led to a better understanding of the behaviour of mercury in the marine environment.

In this paper, the nature and distribution of mercury in the marine environment is first examined. Then the chemical and biological processes which control the transfer of this metal between geochemical reservoirs are described. Finally, an attempt is made to assess the current global mercury budget.

19.1.3 Forms of mercury in the marine environment

Dissolved mercury can exist in a wide variety of chemical forms, including inorganic species and organometallic compounds. The relative abundance of different complexes of mercury with inorganic ligands has been calculated by Dyrssen and Wedborg (1980) for oceanic and estuarine waters (Table 8). It can be seen that chlorocomplexes account for practically all of the dissolved mercury in oceanic and most estuarine waters. In oxygenated water, only a small amount of Hg^0 ($<10^{-6}$ of total inorganic Hg) is predicted from the thermodynamic chemical models (Fitzgerald, 1986).

Organic acids (amino, fulvic) and the methyl radical can combine with Hg. In sea water, organomercury compounds exist in non-equilibrium and their relative contribution to total mercury appears to be low (Fujita and Iwashima, 1981). They may be more abundant in coastal waters where dissolved organic matter concentrations are higher. Stumm and Morgan (1981) indicated that methyl mercury is very stable in sea water. Wallace *et al.* (1982) concluded, from a study of the biogeochemical fate of mercury in controlled experimental ecosystems, that the affinity of mercury for organic matter was the most important feature governing its chemical speciation during their experiments. According to these authors, colloidal and high molecular weight dissolved mercury forms may account for 90% of the total mercury present in the water column. Evidence has also been obtained for the ability of phytoplankton to volatilize mercury in sea water in microcosm experiments (Fitzgerald, in press).

In suboxic waters, elemental mercury may be a major species (Iverfeldt, 1984). Under anoxic conditions, insoluble cinnabar (HgS) precipitates; but under highly reducing conditions, the formation of more soluble polysulfides (HgS_2^{2-}) occurs (Gavis and Ferguson, 1972). In reducing environments, methylmercury sulfide is unstable and may lead to the formation of HgS (Wollast *et al.*, 1976).

Mercury has a great affinity for suspended particulate matter, especially for organic particles (e.g., Wallace *et al.*, 1982); however, the nature of the mercury-particle association is little known. Trost (1970), for example, observed greater adsorption onto organic matter than onto clays. Wallace *et al.* (1982) pre-

sented experimental evidence of the sorption of mercury to particulate organic matter consistent with Freundlich or linear adsorption isotherms.

19.1.4 Distribution of mercury in the marine environment

Open ocean waters

If only results obtained using ultra-clean sampling and laboratory protocols are considered, concentrations of mercury in oceanic waters range between 0.05 and 2.5 ng·l⁻¹ (Olafsson, 1983; Dalziel and Yeats, 1985; Gill and Fitzgerald, 1985, 1987a, 1987b and 1988).

Mercury measurements are experimentally expressed in operational terms as reactive, or easily reducible mercury in acidified samples, and total mercury. Reactive mercury comprises inorganic species and labile organomercury associations. The difference between reactive and total mercury measurements is attributable to stable organomercury compounds (especially methylmercury) that require strong oxidation (UV, bromination, etc.) to be decomposed. According to Gill and Fitzgerald (1987a, 1987b), concentrations in surface waters of the oceans range from 0.1 to 2 ng·l⁻¹ with the bulk of the mercury (> 88%) consisting of reactive forms. The same authors suggest that surface concentrations in the Northwest Atlantic Ocean are higher than those in the Pacific Ocean at the same latitude. This situation appears to result from the comparatively larger mercury input from the atmosphere to the waters of the Northwest Atlantic. Indeed, the mercury content of rain is elevated in the North Atlantic compared to the North Pacific (Gill and Fitzgerald, 1987b). Inter-hemispheric distributions of reactive mercury in the sea surface layer and in the atmosphere tend to point to the emission of mercury from the sea surface to the atmosphere related to the upwelling of nutrient-rich water (Fitzgerald *et al.*, 1984). These findings lead to the conclusion that oceanic effluxes of mercury may significantly affect the global cycling of the element (Kim and Fitzgerald, 1986).

Recently, the first reliable vertical feature of mercury concentrations in the open ocean has been established (Gill and Fitzgerald, 1988). The vertical distribution is characterized by a concentration maximum (up to 2.4 ng·l⁻¹) in the vicinity of the main thermocline. This feature possibly results from lateral advection of mercury-rich water masses formed in contact with the atmosphere at higher latitudes. Below the thermocline concentrations drop, indicating the existence of a removal process in deeper waters. These authors state: "In general, vertical mercury distribution appears to be governed by an external cycling process (that)... reflects a rapid competition between the magnitude of the input source and the intensity of the (water column) removal process".

The occurrence of a biological mechanism for scavenging and removing mercury from the surface layer has been demonstrated (Wallace *et al.*, 1982). Contrary to other metals of the same chemical group (cadmium and zinc), mercury is not as extensively involved in net recycling processes as the other metals and this

is reflected in its short residence time in the ocean (about 350 years, according to Gill and Fitzgerald, 1988). As these last authors remark, this does not mean that remineralization does not occur. It implies rather that the scavenging of regenerated mercury is very effective in maintaining low concentration levels in the deep ocean.

In regions of changing chemical redox potential, high mercury levels have been measured (Iverfeldt, 1988). Release of mercury from particles at the redoxcline (degradation of organic matter, reductive dissolution of Fe and Mn oxides) may be responsible for the observed enrichment.

Near continental margins, diagenetic reactions in the sediment may affect mercury concentrations in the water column. The redox conditions in the superficial sediments would determine the direction of transport: anoxic conditions producing scavenging in the sediments and oxic conditions promoting releases to the water column. This hypothesis, proposed by Gill and Fitzgerald (1988), is supported by recent results on dissolved mercury concentrations in pore water of oxic coastal sediments (Gobeil and Cossa, 1988). These authors calculate a significant biologically mediated mercury flux from the sediment to the overlying water. On the other hand, seasonal build-up of mercury and sulfide in bottom water through diffusive supplies from the anoxic water-sediment interface has been suggested (Lu *et al.*, 1986). This latter observation is consistent with earlier measurements made by Bothner *et al.* (1980), according to which mercury mobilization is occurring in anoxic sediments. Establishing whether or not all these observations are valid and consistent requires a better understanding of the chemical mechanisms involved (methylation, formation of polysulfide complexes, etc.) during the early diagenesis of mercury in marine sediments.

Coastal waters

In coastal waters, especially in estuaries, it is essential to distinguish between dissolved and particulate mercury because of the higher concentrations of suspended particles in these areas.

Dissolved mercury concentrations in coastal waters do not differ markedly from open ocean levels (Bloom and Crecelius, 1983; Schmidt and Freiman, 1984; Copin-Montégut *et al.*, 1986; Cossa and Noël, 1987). Serritti *et al.* (1982) and Ferrara *et al.* (1986) found, however, higher dissolved levels in the Tyrrhenian Sea (1.4 to 19.7 ng·l⁻¹). Levels of mercury in the offshore Mediterranean Sea also appear to be elevated as a result of the increased abundance of this element in the geology of some of the adjacent land areas.

According to Cossa and Noël (1987) and Fileman (in prep.), the relative importance of reactive mercury compared to total mercury is lower in coastal waters (60-70%) than it is in the open ocean (88%).

In estuaries, dissolved mercury concentrations lie between 0.5 and 10 $\text{ng}\cdot\text{l}^{-1}$ (Nelson, 1981; Figuères *et al.*, 1985; Cossa and Noël, 1987; Fileman, 1987; Cossa *et al.*, 1988). Mobilization and removal of dissolved species have both been observed, but a general model of mercury behaviour in estuaries is not yet available.

The high mercury concentrations found in unfiltered water samples reflect the importance of the suspended load of coastal waters (Davies, 1980; Gobeil *et al.*, 1983; Cossa and Noël, 1987). Large variations in the mercury content of particles have been observed and are probably the result of differences in the nature of the particles (terrigenous, biogenic, authigenic minerals) and/or anthropogenic influence. The concentrations of mercury in particles vary from 0.1 to 2.0 $\mu\text{g}\cdot\text{g}^{-1}$ (Essink, 1980; Donard, 1983). The latter author showed that, in the Gironde estuary, the mercury concentration decreases from 1 $\mu\text{g}\cdot\text{g}^{-1}$ in the river to 0.3 $\mu\text{g}\cdot\text{g}^{-1}$ in the turbidity maximum zone; mineralization of particles in the turbidity maximum may be responsible for this observation. This hypothesis is supported by the results of Rae and Aston (1982), who found a strong correlation between mercury and organic carbon contents of the suspended particulate matter in the Wyre estuary.

Sediments

In spite of the potential importance of remobilization of mercury from marine sediments, it appears clear that, following its deposition with settled particles, most of the mercury remains associated with the solid phase and is buried in the sediments. Pre-industrial concentrations of mercury in marine sediments range from 0.02 to 0.06 $\mu\text{g}\cdot\text{g}^{-1}$, except in zones of cinnabar deposits and hydrothermal activity (Young *et al.*, 1973; Cox and McMurtry, 1981; Baldi and Bargagli, 1982).

In coastal zones, many studies of the vertical distribution of mercury in recent sediments in the context of geochronological dating indicate that, during the past 100 years, mercury deposition has increased. The highest concentrations were commonly found in coastal areas near chlor-alkali plants (Thompson *et al.*, 1980; Smith and Loring, 1981); however, lower but more diffuse and widespread contamination has also been reported (Young *et al.*, 1973; Skei and Paus, 1979). According to Young *et al.* (1973) "the anthropogenic input rate of mercury in this coastal marine reservoir seems roughly to have matched the natural input rate in recent years".

19.1.5 Bioaccumulation

Mercury concentrations in marine biota vary widely, from 0.01 to several dozen $\mu\text{g}\cdot\text{g}^{-1}$ of dry tissue weight (d.w.) (Table 9). Bioaccumulation is the result of the stable association between biochemical compounds, particularly proteins, and methyl mercury. The methylated fraction of total mercury increases with trophic level; in fish tissue, the monomethyl mercury compounds represent 70-90% of the total (see review by Fowler, 1982).

Mercury is the only metal which indisputably biomagnifies through the food chain (e.g., Lindberg *et al.*, 1987). Mercury concentrations in fish are related to trophic level and fish age. The mechanism for this biomagnification is not clearly understood. The trophic level approach examines bioaccumulation as a function of diet (Bernhard and Andreae, 1984), but methyl mercury is also absorbed from sea water, uptake being much more rapid than excretion. Accordingly, older fish should have a higher Hg content. Fowler (1982) states "As the older (fish) are also often the top-level carnivorous fish, the end result of high Hg concentrations in older fish is similar to that found when mercury levels in fish are ranked strictly according to trophic level."

In marine mammals very elevated concentrations have been observed (Table 9). Elevated mercury concentrations in the tissues of marine mammals have often been associated with poor health, proximity to urbanized areas or starvation (Eisler, 1981).

19.1.6 Methylation/demethylation

Jensen and Jernelov (1969) gave the first demonstration of biological methylation of mercury in sediments. In marine sediments, pH, Eh and chloride concentration are factors influencing the rate of methylation. According to Wollast *et al.* (1976), most methylation occurs in the "oxidizing anoxic" zone (where neither oxygen nor sulfide is present), but it may also exist under oxic conditions (Compeau and Bartha, 1987). Sulfide concentration in sediment seems to be the major controlling factor for methylation of mercury in estuarine sediments (Craig and Moreton, 1986) and there is an optimum sulfide concentration at which the methyl mercury formation is maximized. In the presence of high sulfides, methyl mercury spontaneously breaks down. Methylation has also been shown to occur in the water column (Topping and Davies, 1981) and in the intestines of fish (Rudd *et al.*, 1980). The biochemical mechanism of methylation has been explained by Wood *et al.* (1968), who demonstrated bacterial mediation. However, chemical methylation is also possible (Jewett and Brinkman, 1974; Weber *et al.*, 1985); more recently, Nagase *et al.* (1986) have shown methyl mercury formation during refuse incineration with the resulting emission of methyl mercury into the atmosphere.

Methyl mercury is subject to biochemical decomposition. Demethylating microbes are widespread in water and sediments (see review by Summers, 1984). Methylating and mineralizing mechanisms may occur simultaneously and may reach steady state. Any small imbalance between the two processes determines whether the environment is a source or a sink for methyl mercury (Wollast *et al.*, 1976). Dimethyl mercury, that is released from marine sediments, is relatively unreactive in the water column and can escape into the atmosphere because of its volatility.

19.1.7 Transport pathways and tentative budget

Figure 8 shows the major paths between geochemical reservoirs. Natural and anthropogenic emissions of mercury from land are mainly in the form of mercury vapor (Hg^0). Gas exchanges [Hg^0 , $(\text{CH}_3)_2\text{Hg}$] occur between the troposphere and sea water (Lindqvist

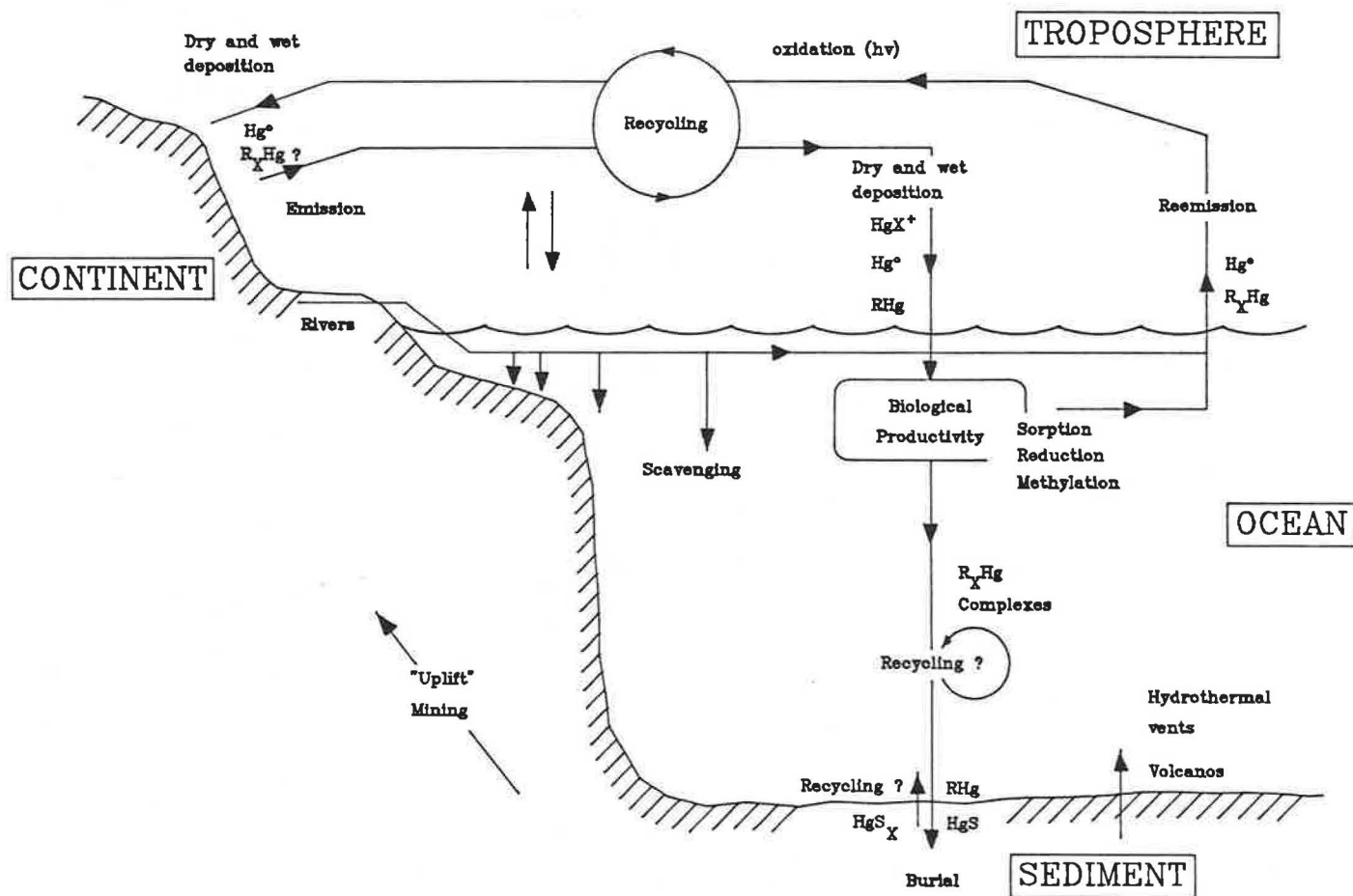


Figure 8 Pathways of mercury in the environment.

and Rodhe, 1985). Evasion or invasion of volatile mercury across the sea surface may occur depending upon the latitude and the season (Fitzgerald, 1986). Photo-oxidation in the atmosphere transforms these species into more soluble (ionic) forms that are deposited in wet or dry precipitation onto the ocean surface. Rivers constitute a relatively minor source of mercury to the ocean, mostly in the form of particulate matter which settles in nearshore areas. Riverborne dissolved mercury transport is negligible compared to atmospheric influxes.

In euphotic zones, biological productivity (phytoplankton and bacteria) affect dissolved mercury levels by sorption, reduction and/or methylation. Some of the particulate mercury formed in this way is transferred to higher trophic levels and subsequently transported to the sediments by faecal pellets, moults and other organic or inorganic detritus.

In sediments, methyl mercury, polysulfides or other chemical species may be remobilized; HgS is buried in the anoxic layer of the sediment. Hydrothermal and mining activities constitute complementary pathways for the introduction of mercury to the global cycle.

Since 1975, several attempts have been made to produce a global mass balance model (Garrels *et al.*, 1975; MacKenzie and Wollast, 1977; N.A.S., 1979). Nevertheless, an accurate estimation is not yet possible because of the lack of reliable basic data. According to Fitzgerald (1986), the estimate by Lindqvist and Rhode (1985) is probably the most accurate, although it is only an order of magnitude estimate. It is presented in Table 10 (with complementary data on riverine and sedimentary fluxes). As Fitzgerald (1986) concludes, "...recent data suggest that mercury flows through the atmosphere are smaller than many previous estimates. Thus, impact from ocean sources of mercury and the interference of man-related emissions on the atmospheric cycle of mercury could be quite substantial."

19.1.8 Toxicity

Human Health

As has been observed in Minamata disease, methyl mercury is a poison for the central nervous system (Clarkson *et al.*, 1984). The primary pathway to humans is fish consumption. Dose-effect relationships for methyl mercury compounds in humans have been evaluated (Nordberg and Strangert, 1982). Their calculations indicate that, for an adult, a daily intake of 50 μg gives a risk of less than 1% for the symptom of paresthesia, whereas an intake of 200 $\mu\text{g}\cdot\text{day}^{-1}$ would give a risk of about 8% for this symptom. The World Health Organization (WHO, 1972) has proposed a tentative maximum weekly intake of 300 μg total mercury (200 μg for methyl mercury) for adults. Additional restrictions have been proposed for protecting the health of pregnant women and children (WHO, 1980). Although the use of mercury in agriculture and industry has been regulated and curtailed in many countries, humans in high risk groups should be regularly tested for exposure.

Environmental health

Although mercury is the only metal which indisputably biomagnifies within marine food webs, evidence of its toxicological effects has been limited. Most of the effects have been shown to occur at the $\mu\text{g}\cdot\text{l}^{-1}$ level, i.e., one thousand times the natural levels and one hundred times the contaminated levels encountered. "While mercury levels in biota, especially in aquatic species, may be elevated in certain areas resulting from more diffuse sources of mercury in the environment, no direct widespread biological effects have been unequivocally linked to these elevated tissue levels", concludes the group report on mercury by a Workshop on Trace Metals in the Environment (Hutchinson and Meema, 1987).

19.1.9 References

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Table 8 Relative abundance (%) of inorganic mercury species in oceanic water ([Cl] = 0.7 M) and estuarine water ([Cl] = 0.2 M). Data from Dyrssen and Wedborg (1980) cited by Lindqvist and Rodhe (1985).

Compound	Oceanic water	Estuarine water		
		pH 6	pH 7	pH 8
HgCl_4^{2-}	65.8	-	-	-
$\text{HgCl}_3\text{Br}^{2-}$	12.3	-	-	-
HgCl_3^-	12.0	0.1	0.1	-
HgCl_2Br^-	4.3	-	-	-
HgCl_2	3.0	91.1	34.1	0.1
HgClBr	1.1	-	-	-
HgOHCl	0.2	8.5	49.4	6.2
HgCl^+	-	0.2	0.1	-
$\text{Hg}(\text{OH})_2$	-	0.2	16.4	93.7

Table 9 Range of mercury concentrations usually found in marine biota.

	Concentration ($\mu\text{g}\cdot\text{g}^{-1}$, d.w.)	Reference
Phytoplankton		
- North Atlantic	0.1 - 1	Windom (1973)
- North Sea	1.0 - 10	Baeyens <i>et al.</i> (1979)
- Minamata Bay	up to 67	Kumagai and Nishimura (1978)
Macrophytes	0.02 - 1.23	Cited by Eisler (1981)
Molluscs		
- Various regions	0.02 - 2.60	" "
- Minamata Bay	up to 85	" "
Crustaceans	0.06 - 1.70	" "
Annelids	0.01 - 0.35	" "
Fish (muscle)	0.05 - 1.20	Bernhard and Andreae (1984)
- Cod ¹	0.15 - 2.30	" "
- Haddock ¹	0.10 - 0.30	" "
- Hake ¹	0.15 - 4.25	" "
- Sardine ¹	0.03 - 2.00	" "
- Halibut ¹	0.15 - 0.25	" "
- Plaice ¹	0.05 - 2.50	" "
- Tuna ¹	0.15 - 7.50	" "
- Minamata (13 species)	up to 309	Cited by Eisler (1981)
Birds¹ (muscle)	0.25 - 3.80	" "
Mammals		
- Muscle ¹	0.03 - 6.11	" "
- Liver ¹	0.50 - >1000	" "

¹ Data conversion to per unit of dry weight material (d.w.), in cases where the original concentrations were expressed per unit of fresh material, is achieved by multiplying by 5.

Table 10 Estimates of fluxes of mercury to and from the global atmosphere ($10^5 \text{ kg} \cdot \text{a}^{-1}$) from Lindqvist and Rhode (1985). Flux from rivers is calculated on the basis of the St. Lawrence River dissolved mercury concentration (Cossa *et al.*, 1988). Flux to the sediment from MacKenzie and Wollast (1977).

Process	Flux	Range of uncertainty	Method of assessment
Present anthropogenic emissions	2.5	2-10	Watson (1979), Mackenzie and Wollast (1977)
Present background emissions	5.5	<15	By balance
Total present emissions	8	2-17	Assuming balance between emission and deposition
<hr/>			
Wet deposition	4	2-10	From estimates of Hg concentration in rain water
Dry deposition	4	<7	Average concentration of soluble Hg $<0.1 \text{ ng} \cdot \text{m}^{-3}$; deposition velocity $<0.5 \text{ cm} \cdot \text{s}^{-1}$
Total present deposition	8	2-17	
<hr/>			
Pre-industrial deposition (and emission)		2-10	Data from Danish peat bogs and Greenland ice cores
<hr/>			
River input	0.5	0.2-1.5	Dissolved Hg concentration in rivers: $0.6 - 5 \text{ ng} \cdot \text{l}^{-1}$
<hr/>			
Sedimentary flux	3.5		

19.2 Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzo-furans: An Update

19.2.1 Introduction

Since the preparation of the previous overview by ACMP on polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (ICES, 1984), there has been significant progress in the analytical methodology associated with the determination of these compounds and a continuing, almost exponential, growth in the number of studies reported relating to their use, occurrence and distribution.

This overview updates the initial report and gives reference to more recent publications providing a more critical assessment of the impact of PCDDs and PCDFs in the marine environment.

19.2.2 Overviews, reviews and symposia

There is a series of annual symposia on PCDDs and related compounds; the First International Symposium was held in Rome in 1980 and the eighth was held in Sweden in 1988. The Symposium Proceedings are published in *Chemosphere* (e.g., Masuda *et al.*, 1987) and currently contain over 100 papers which cover analytical methodology, pharmacokinetics, biochemical effects and animal toxicology; environmental fate and levels; destruction methodology, incineration technology and municipal waste; human tissue levels; observations in man; epidemiology; and risk assessment. Hutzinger and Blumich (1985) have reviewed the sources and fate of PCDDs and PCDFs, including their formation during chemical manufacture and the improper disposal of contaminated waste products, and during the incineration of chemical waste, natural materials and fires involving PCBs. Tiernan *et al.* (1985) have extensively reviewed the sources and fates of PCDDs, PCDFs and related compounds in the human environment. More recently, Eduljee (1988) reviewed the sources and fate of PCDDs and PCDFs in the environment in a more "popular" style, written for the wider scientific community.

Eisler (1986), in a synoptic review of the hazards of PCDDs to fish, wildlife and invertebrates, comments on the paucity of reliable data and the need to identify populations possibly at risk through exposure to PCDD/PCDF congeners.

19.2.3 Properties

The physico-chemical properties of PCDDs and PCDFs continue to be investigated. Webster *et al.* (1985) studied octanol:water partition coefficients, solubilities, vapour pressures and Henry's constants as a prelude to developing a model for the fate of PCDDs. Adams and Blaine (1986) have determined the water solubility of 2,3,7,8 tetrachloro dibenzo-p-dioxin (2,3,7,8 TCDD). Sarna *et al.* (1984) have determined the octanol:water partition coefficients of PCDDs and PCDFs using different reverse-phase C_{18} liquid chromatography columns. Shin *et al.* (1988) have reported newly determined experimental data for aqueous solubility, octanol:water partition coefficients and Henry's law constants. Existing information is reviewed and updated for 15 of the con-

geners. Koroki *et al.* (1987) have synthesized and determined the mass spectral properties of a number of hydroxy, dihydroxy PCDFs and sulfur-containing PCDF metabolites. Koroki *et al.* (1984) have also synthesized 51 PCDFs and confirmed their structure by mass spectrometry and proton magnetic resonance spectroscopy.

19.2.4 Analytical methodology

The development of refined, and increasingly reliable, techniques for the determination of the ultra-trace quantities of PCDDs/PCDFs, and particularly the most toxic congeners 2,3,7,8 Tetra-CDD and 2,3,7,8 Tetra-CDF, has been given considerable attention in recent years. Although there are some methods which involve little clean-up, but maximize the resolution available on High Resolution Mass Spectrometry (MS) or Tandem MS (Cuiv, 1986), most analytical techniques include a separation procedure to isolate the planar PCDD and PCDF materials. Although florisisil has been used to separate planar chlorobiphenyls (CBs) (Kamops, 1979), most separations have used carbon columns either on polyurethane foam (Huckins *et al.*, 1980) or, more successfully, on glass fibres coated with active carbon (Smith *et al.*, 1984; Lawrence *et al.*, 1986; Huckins *et al.*, 1988). This technique has been fully automated under microprocessor control (O'Keefe *et al.*, 1985). Tanabe *et al.* (1987) reverted to a more simple approach by saponifying the tissue with alcoholic KOH at the extraction stage and isolating the dioxins and furans on an active carbon column, eluting with 1000 mL of toluene. More recently, Cresser and al-Haddad (1989) have reported the use of porous graphitic carbon (PGC) in a high pressure liquid chromatographic system. The porous graphitic carbon, developed in Edinburgh (Chromatographite Ltd.) by Professor J.H. Knox, is currently marketed by Shandon (UK) Ltd. The sample extract is cleaned up by saponification with alcoholic potassium hydroxide and/or absorption chromatography and then chromatographed by liquid chromatography (LC) with n-hexane. The PCDDs/PCDFs are removed, once the non-planar organochlorines, and non-planar and planar PCBs have been removed, by reversing the flow. The reverse flow volume can be reduced by eluting with toluene rather than hexane.

Riehle *et al.* (1988) have reported on the selectivity of a smectic liquid-crystalline silicone phase for the congener-specific separation of PCDDs and PCDFs by capillary gas chromatography (GC). Ligon and May (1984) have reported full chromatographic resolution of the 2,3,7,8 Tetra-CDF, 2,3,4,7,8 Penta-CDF and 1,2,3,7,8,9 Hexa-CDF using two-dimensional GC.

Alford-Stevens and Budde (1988) have reported a method of identification of PCBs, PCDDs and PCDFs by calibrating on a single isomer to represent each level of chlorination. The whole determination was automated by auto-injection, analysis and auto-confirmation and quantification. Taguchi *et al.* (1988) have reported high resolution MS-Simultaneous loss monitoring (MS-SIMS) for all PCDDs (Cl_xDD, x = 4-8) and PCDFs (Cl_xDF, x = 4-8) using an alternative lockmass system for enhanced sensitivity, easier control and greater resolution. Stalling *et al.* (1985, 1986) evaluate the complex PCDD and PCDF residue data by pattern recognition using principal component analysis. This chemometric ap-

proach using SIMCA (soft independent modelling by class analogy) has been applied to data from environmental samples of fish, birds and eggs from the Great Lakes.

In reviewing the data from the analysis of PCDDs/PCDFs reported in scientific publications, Clement *et al.* (1986) found that a significant number of papers contained irregularities and omissions in the information reported. Most data were for analysis of the most toxic congener, 2,3,7,8 Tetra-CDD, only. Since the 2,3,7,8 Tetra-CDD congener was either absent or below the detection limits, it was suggested that, by inference, all dioxins/furans might be considered absent. This may be compared to data where all or a variety of PCDD/PCDF congeners are detected in wildlife (see Table 11). This is a particularly pertinent point in view of the use of "TCDD Toxic Equivalent Factors" proposed by Safe (1987) and Tanabe (1988; Tanabe *et al.*, 1987), whereby less toxic compounds may be present at significantly higher concentrations than the most toxic material and exert an additive, biological effect.

Clement (1986) made a list of recommendations for PCDD/PCDF analysis (Table 12), which would be appropriate not only for round robin studies but also for good laboratory practise.

19.2.5 Occurrence of PCDDs and PCDFs

Eisler (1986) has reviewed the dioxin hazard to fish, wildlife and invertebrates. The report is centred primarily on 2,3,7,8 Tetra-CDD and most data that are collated refer to reports prior to 1984 and generally concentrate on data obtained in the freshwater environment. Hallet and Brooksbank (1986) have reported the trends of Tetra-CDD and related compounds in the Great Lakes ecosystem. Czuczwa and Hites (1986) found a predominance of the octachloro congener of dioxin, and relatively high concentrations of heptachlorodioxins and heptachlorofurans in Niagara river sediments, similar to Lake Ontario sediments. The PCDD and PCDF congener profiles in the sediment were similar to those found on urban air particulates. O'Keefe *et al.* (1985) have reported 2,3,7,8 Tetra-CDD in a variety of fish species, from $3.2 \text{ ng} \cdot \text{kg}^{-1}$ (detection limit) to $107 \text{ ng} \cdot \text{kg}^{-1}$, on a wet weight basis.

Apart from the Great Lakes ecosystem, the other main area that has now been studied in some detail is the Baltic Sea. In 1986, Nygren *et al.* reported low levels of a series of PCDDs and PCDFs in herring, salmon, guillemots and seal blubber. Subsequently, the same group undertook a more detailed study between 1983-1985 (Rappe *et al.*, 1987b). These authors reported values for five CDDs and six CDFs. The values, on a wet weight basis, for salmon muscle from the Urne River ranged from $49.0 \text{ ng} \cdot \text{kg}^{-1}$ for 2,3,4,7,8 Penta-CDF to non-detected (detection limit = $0.1 \text{ ng} \cdot \text{kg}^{-1}$). Herring muscle from Karlskrona ranged from $6.8 \text{ ng} \cdot \text{kg}^{-1}$ for 2,3,4,7,8 Penta-CDF to non-detected, and for herring muscle from Luleå, on the Baltic Sea coast, the range was $8.8 \text{ ng} \cdot \text{kg}^{-1}$ for 2,3,4,7,8 Penta-CDF to undetected for some of the other congeners.

The results of a comparative study of PCDDs and PCDFs in four species of seals (ringed seal, common seal, grey seal, and harp seal) from the Baltic Sea, the Kattegat/Skagerrak area, and the Spitzbergen area showed that detectable and comparable levels

were only found for tetra- and pentachlorinated congeners (Olsson *et al.*, 1988). The results did not indicate substantial species or spatial differences, except for higher concentrations in ringed seals from the Baltic Sea. Further comparisons of concentrations of Tetra- and Penta-CDD and Tetra- and Penta-CDF were made between the above-mentioned species of seals and harp seals from the Arctic Ocean and crabeater seals from the Antarctic (Bignert *et al.*, 1989). Crabeater seals showed lower concentrations of all five congeners reported than seals from the Northern Hemisphere.

Norstrom *et al.* (1985) reported on the use of lobster digestive gland as a means of studying sources of environmental contamination with PCDDs and PCDFs (Clement *et al.*, 1986).

Studies of crustaceans, both from the Canadian Pacific coast and the US Atlantic coast, have shown the presence of a greater number of other congeners, e.g., 1,2,4,7,8 Penta-CDD and 1,2,3,6,7,9 and 1,2,3,6,8,9 Hexa-CDD, with the concentration in the hepatopancreas being up to 100 times higher than in the crab muscle tissue. In Sweden (Rappe *et al.*, 1987a), the digestive glands taken from crustaceans around kraft bleachmills were analysed for a series of PCDDs and PCDFs; the results showed considerably higher concentrations than found previously. A summary is given in Table 13. Miyata *et al.* (1987) used the blue mussel as a bio-indicator of PCDD contamination in Osaka Bay, northern Japan. The average values for PCDDs ranged from 7.6 to 250 ng·kg⁻¹ (wet weight).

The sources of the PCDDs and PCDFs were further investigated by Swanson *et al.* (1988). However, the results indicated that, while minor amounts of the dioxins and furans were formed during the bleaching of the pulp, the patterns of congeners were quite different from those associated with samples from the incineration process. Compared with other sources of PCDDs and PCDFs, the amounts formed in pulp bleaching were estimated to be quite small. Paasivirta *et al.* (1987) have studied the distribution of PCDDs, PCDFs and aromatic chloroethers in Baltic wildlife primarily to determine the impact of the effluent from the pulp and paper industries.

Further studies by Rappe *et al.* (1987b) have shown measurable quantities of PCDDs and PCDFs in fish and mussels near pulp mills (Masuda *et al.*, 1987; Nygren *et al.*, 1986). Oehme *et al.* (1988) determined the levels of seven PCDDs and nine PCDFs in seven Arctic seals caught at Spitzbergen. The major dioxins measured were 1,2,3,7,8 Penta-CDD, ranging from 2.6 - 30 ng·kg⁻¹ (wet weight), and Octa-CDD, ranging from 13.0 - 37 ng·kg⁻¹. The most abundant PCDF was the 2,3,7,8 Tetra-CDF, with values between 11.0 and 21.0 ng·kg⁻¹. Although the concentrations were generally low, the overall 2,3,7,8 Tetra-CDD equivalent ranged from 8.2 to 47.5 ng·kg⁻¹. Reiersen and Iversen (1988) have reported measurements of dioxins up to 200 to 4,500 ng·kg⁻¹, with the highest concentration at 20 µg·kg⁻¹, Tetra-CDD equivalent in cod livers from the Frierfjord, Norway. These values are exceptionally high and, if confirmed, would reflect a case of severe dioxin contamination.

19.2.6 References

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Table 11 Incidence of chlorinated dibenzo-p-dioxins and dibenzo-furans in Ontario sports fish.

Location	Dibenzo-p-dioxins		Dibenzofurans	
	2,3,7,8 TCDD	Other	Total tetra	Other
Lake Ontario	0/28	18/27	25/27	27/27
Lake Huron	3/23	1/25	15/25	8/25
Lake Erie	1/12	1/15	5/12	2/15

(Detection limit: $1 - 3 \times 10^{-12}$ by weight).

From: Clement et al. (1986).

Table 12 Summary of recommendations for CDD/CDF analysis.

1. All CDD/CDF congeners should be determined
2. Supporting data should be included whenever possible (i.e, percentage lipid, interferences, precursors)
3. Methods are needed for toxic congener analysis
4. More effort is needed in sampling (i.e, where samples collected, how collected, homogenization procedures, report sampling conditions)
5. Spike levels should always be reported
6. Methods should be described in detail or reference made to other published papers, not reports
7. GC-MS conditions must be described; specifically - electron energy, SIM dwell time, characteristic ions used, how scan RT windows determined for congener groups
8. Individual sample spike recoveries and limit of detection should be given, not just averages
9. Methods of calculating recoveries and limits of detection (LOD) should be described
10. LOD must take into account percentage recovery, instrument sensitivity and levels of interferences
11. More than one label should be spiked to determine total congener groups
12. Methods of quantitation must be clearly described
13. Feedstock must be analysed for incinerator mass balance
14. Sample chromatograms and number of isomers observed are useful data
15. Standardized use of nomenclature is recommended.

Ref: Clement (1986).

Table 13 Levels of PCDDs and PCDFs in samples of crab muscle and hepatopancreas and sediments from the Swedish west coast.

	Crab muscle ng·kg ⁻¹	Hepatopancreas ng·kg ⁻¹	Sediments ng·kg ⁻¹
2,3,7,8 TCDF	31	590	890
2,3,7,8 TCDD	17	170	120
Total penta CDFS	130	490	130
Total penta CDDs	86	270	170
Total hexa CDFS	70	280	17
Total hexa CDDs	134	465	92

Summary of the table from Rappe et al. (1987b).

19.3 New Contaminants

The ACMP noted the WGEAMS discussion on methods and approaches to determining the hazards associated with chemical substances. While the ACMP concurred with the emphasis on the toxicological properties of substances as a primary means of assessing their potential hazards to living marine resources, it stressed that such an approach will require a much larger investment in both acute and sub-lethal toxicity evaluations.

The ACMP concurred that a better balance of research investment between the measurement of biological effects in the environment and toxicological evaluations of individual chemicals needs to be achieved, with comparatively greater effort being devoted to the latter. It looked forward to receiving further reports on this topic from WGEAMS.

20 ACID RAIN STUDIES

The ACMP reviewed the 1989 report of the ICES Study Group on Toxicological Mechanisms Involved in the Impact of Acid Rain and its Effects on Salmon. This Study Group was convened in part to respond to the question raised by ACMP as to whether the dissolved organic carbon content of Nova Scotian rivers is sufficiently different from that of rivers in Scotland and Norway to imply differences in the cause of salmon mortalities. In addition, the ACMP had requested further justification for the 1988 conclusions that were made on the effectiveness of liming as a mitigation measure.

In its review of the report of the Study Group, the ACMP paid particular attention to the three sections of the report addressing its questions.

The first of these summarizes the characteristics of acid rain and freshwater acidification, including short overviews on precipitation chemistry, vegetation influences, the effects of geology, soil, and flow paths, and land-use effects. The second section deals with aluminium chemistry. The speciation of aluminium in freshwater environments is particularly complex. The relative composition of aluminium compounds is a function of pH, temperature, and the nature of the dissolved organic material. Aluminium has the capacity to be readily complexed by a variety of dissolved organic compounds. In any evaluation of the role of aluminium in acid rain impacts, it is essential to separate total aluminium into at least two fractions: the so-called non-exchangeable aluminium (predominantly organically complexed) and the exchangeable aluminium (mainly soluble inorganic forms of aluminium). It is the latter fraction that is important in the disruption of biological ion exchange systems.

In the third section, the toxicities to Atlantic salmon of hydrogen ion (H^+) concentration and exchangeable aluminium, respectively are discussed in some detail. In waters rich in dissolved organic matter (i.e., low exchangeable aluminium), H^+ toxicity is critical at pH levels below 5.0. At these high H^+ levels, the uptake of Na^+ and Cl^- across the gills is partially blocked. This leads to circulatory collapse and fish death.

In waters within which aluminium is not complexed with organic material (i.e., freshwater characterized by elevated concentrations of exchangeable aluminium), toxicity occurs at pH levels between 5 and 6. In this range, the addition of exchangeable aluminium to H^+ converts sub-lethal acid exposure to lethal. The exchangeable aluminium causes Na^+ and Cl^- losses which lead to respiratory failure. The large respiratory disturbance caused by exchangeable aluminium results from multiple effects.

There are a number of interacting factors that can mitigate the toxic effects of H^+ and exchangeable aluminium. These include elevated concentrations of dissolved calcium and the organic content. The latter factor is particularly important in understanding the differences between Canadian and Scandinavian salmon mortality observations. At the same pH level, the total aluminium concentration can be higher in Nova Scotian rivers because of greater complexing by the generally higher concentrations of dis-

solved organic matter. However, at a given pH level, the exchangeable aluminium can be higher in Scandinavian rivers. This results in fish mortality at higher pH levels in Norway and Sweden compared to Nova Scotia. Geological features with a naturally high fluoride concentration can complicate the issue. Fluoride ion generates aluminium complexes which are included in the estimate of exchangeable aluminium, but are not toxic to salmon. Thus, waters with relatively high concentrations of aluminium and fluoride will lead to an overestimate of exchangeable aluminium toxicity.

The section on toxicity concludes with a summary of the relative sensitivity of different life history stages of Atlantic salmon. The eggs are insensitive to H^+ and exchangeable aluminium due to the protection provided by the chorion and perivitelline fluid. The newly hatched alevins, the fry, and the smoltification process are particularly sensitive. The parr and adult fish are more resistant.

The differences between North American and Scandinavian rivers in the responses of Atlantic salmon populations to hydrogen ion and exchangeable aluminium toxicity are concluded to be due to differences in water chemistry rather than due to differences in resistance by impacted salmon stocks. The differences in water chemistry are summarized in Table 14 below.

Table 14

Area	pH	Ca^{2+} (mg/l)	DOC ¹ /TOC ² (mg/l)	Total Al (μ g/l)	Exchangeable Al (μ g/l)
<u>North America</u>					
Nova Scotia	4.7-6.0	0.8-1.6	6.0-18.4 ¹	110-331	8-37
Maine, Vermont	6.6-6.8	1.7-6.2	1.9-10.8 ¹	104-140	21-22
<u>Europe</u>					
Norway	4.9-6.6	0.4-2.2	1.0-4.9 ²	11-187	0.5-131
UK (Wales)	6.0-6.8	2.7-7.1	1.5-10+ ³	80-170	3-10

¹ Dissolved organic carbon.

² Total organic carbon.

³ Humic substances.

The report estimates losses of production of Atlantic salmon in Norway, Sweden, and Wales due to acid rain. These estimates are provided in the responses to the questions summarized below. The final part of the report deals with a wide range of mitigation measures which raise pH levels and calcium concentration. Summary responses to the four questions addressed by the Study Group are provided in the following paragraphs:

Question A

Examine the basis of the toxicological impact of acid rain on water quality of the habitat of salmonid species, particularly the factors that interact to ameliorate or worsen the effects of low pH.

Question A - Summary Statement

High concentrations of strong acid anions in wet and dry materials deposited from the atmosphere have resulted in changes in the water quality of lakes and streams, yielding conditions that are toxic to fish. The most important toxic substances are hydrogen ion (H^+) and aluminium. H^+ , aluminium, and dissolved organic matter interact chemically, and Ca^{2+} modifies their effects on fish, so that the mechanisms of toxic action are very complex. Both H^+ and soluble inorganic forms of aluminium, termed exchangeable aluminium, affect the gill function of fish. The transport of ions essential for osmotic balance, primarily Na^+ and Cl^- , and the exchange of gases necessary for metabolism, oxygen and carbon dioxide, is disrupted. Mortality results from either circulatory system collapse resulting from osmotic imbalance, or tissue anoxia resulting from lack of oxygen, or both. Ambient Ca^{2+} mitigates the toxic effects of osmotic imbalance, but not anoxia. Organic matter, and probably F^- , complex aluminium, reducing its toxic effect.

Question B

Resolve the question of the apparent differences in either water chemistry or stock sensitivity in rivers in northeastern North America relative to rivers in other regions of interest to ICES, e.g., Scandinavia and the UK.

Question B - Summary Statement

The differences in river pH at which salmon stocks decline or disappear in North America relative to Scandinavia can be accounted for by differences in concentration of exchangeable aluminium. Atlantic salmon stocks may exist that vary with respect to acid tolerance, but no data are available to demonstrate this. Although total aluminium concentrations are similar in Atlantic salmon rivers of similar pH in both regions, North American rivers contain much higher concentrations of dissolved organic matter. Therefore, most of the total aluminium in these rivers is in the organo-aluminium complex form, which is not toxic to fish.

The Study Group concludes that loss of Atlantic salmon from acidic rivers in Nova Scotia has resulted primarily from H^+ toxicity, whereas in Scandinavian rivers, it has resulted from both H^+ and exchangeable aluminium toxicity.

Question C

Provide estimates of the number of salmon lost due to acidification in the North-East Atlantic Commission Area of NASCO.

Question C - Summary Statement

Estimated loss of Atlantic salmon due to acidification in the NASCO North-East Atlantic Commission Area was obtained from data on areas affected, smolt production, smolt to adult survival, and mean adult weight. The total number of adult salmon lost was estimated to be between 106,000 and 332,000 individuals, having an approximate weight of 400-1,242 t. These losses were principally in Norway and Sweden, although very minor losses were also reported from Wales.

Question D

Describe the effectiveness of mitigation measures and the extent to which the measures are in current use.

Question D - Summary Statement

The Study Group recognized that the only satisfactory permanent solution to the problem of acidification of Atlantic salmon rivers is the elimination of the multiple sources of acidity. Feasible short-term mitigation measures are liming, stocking, and the preservation of genetically diverse stocks. Liming of Atlantic salmon rivers has been used successfully in Europe and North America as a mitigation method to reduce juvenile salmon mortality and increase production.

If liming or stocking techniques are employed to mitigate losses of Atlantic salmon resulting from habitat acidification, such techniques should be implemented before native stocks (genomes) have been substantially reduced. Mitigation will assist in the preservation of the indigenous stocks and result in production of adult salmon suited to survival in the rivers being stressed.

The ACMP recommends that the full text of the report dealing with questions A, B, and D should be made available in the published literature and commends the Study Group participants on the clarity and thoroughness of their report.

21 THE APPLICATION OF ACMP ADVICE IN A MANAGEMENT CONTEXT

In accordance with the intention expressed by ACMP in its 1988 report, this article concludes the current phase of ACMP discussions on managerial issues.

Summary

It is the opinion of ACMP that a consensus view on a conceptual framework for environmental protection is necessary for its own work, and should also be of value to the recipients of ACMP advice. The article which follows gives a detailed explanation of the key elements of this framework. It follows that the ACMP would strongly encourage open dialogue on this topic with a view to stimulating the gradual introduction of control strategies, applicable to all anthropogenic influences on the marine environment, that would facilitate the application of its advice within the management context intended; that is, management of the marine environment in a manner which will afford protection to the environment as a whole.

It is most improbable that strategies for assessing and controlling human impact on the environment will be effective if they permit the development of an unrestricted array of new practices, products, and waste materials. There are already indications that statutory regulatory mechanisms are as vulnerable to "overloading" as the environment itself. Furthermore, it is obvious that environmental quality which will allow sustained development can not be achieved through case-by-case assessments alone, or through control strategies that are subject to constant change. The need for re-appraisal of existing strategies, and agreement on the future role of science in the environmental protection process, is urgent.

For the above reasons, the ACMP has outlined a management framework within which justification of a practice becomes the primary requirement and which clearly identifies the contribution of science to subsequent elements of the framework.

A justified practice will be one for which the combined benefits to the whole of society are considered to outweigh the combined deficits or detriment, environmental effects being only part of the latter. The second element of the framework would place scientifically derived limits on the environmental changes that are permitted to occur; in the case of contaminants emitted by a practice, these limits would constitute upper bounds to increased levels of exposure for Man and critical components of the environment. The third element of the framework, in certain respects the most critical, demands actions that will minimize environmental changes resulting from the practice as far below the limits as practical, taking into account technological capabilities as well as economic, social, and political considerations. This is the on-going process of optimization of human activities to ensure their compatibility with sustained use of the environment as advocated by the World Commission on Environment and Development (1987) and others.

Taken together, the elements of the framework comprise an integrated approach to environmental management that provides for ad-

equate control of a practice throughout its lifespan. An inherent feature of the framework is that it allows the application of a variety of regulatory tools, such as, for example, emission controls and use-related environmental quality objectives, provided they are developed and applied in accordance with the basic principles of the framework.

A simplistic representation of the strategy underlying the framework is shown in Figure 9. It indicates that the "acceptability" of a practice will depend not only on its yielding a "net benefit" but also on the possibilities for optimization of the practice. The practical application of the framework is illustrated in Figure 10. This shows the interrelationships between the elements of the framework as well as the relevant considerations of the associated control process.

Finally, in presenting these proposals, the ACMP wishes to stress its belief that, in parallel with scientific activities aimed at improved understanding of existing environmental problems, there must be greater efforts to develop new and improved environmental management systems that will reduce the potential for future problems. This article is ACMP's contribution to this process.

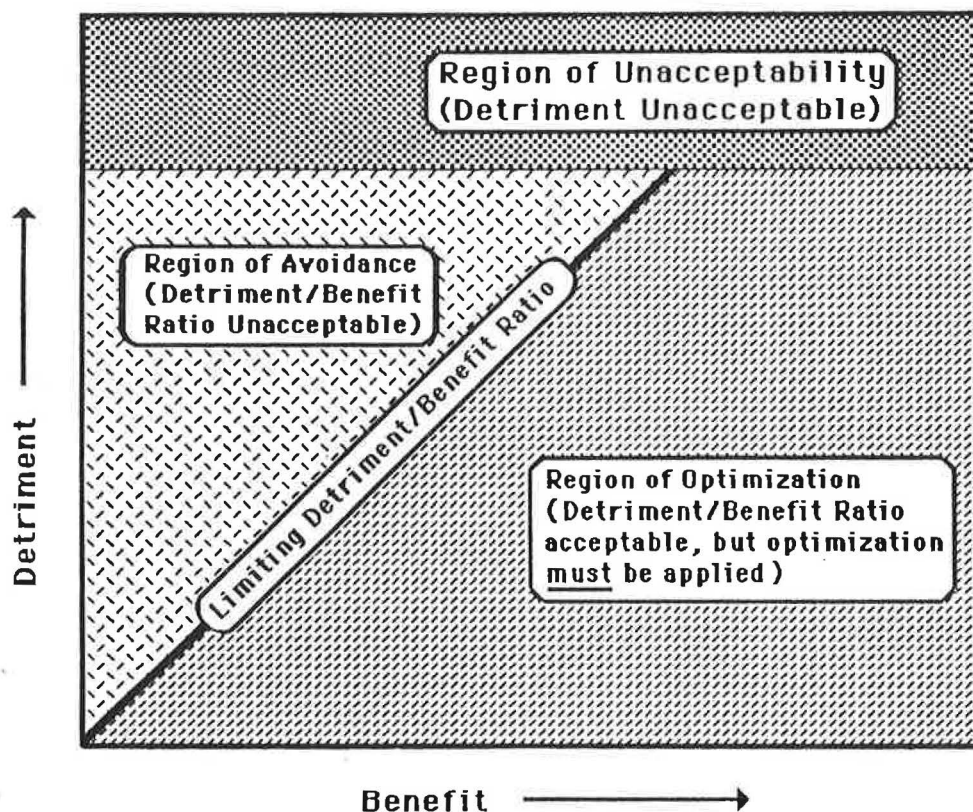


Figure 9 Simplistic Representation of the Environmental Protection Strategy Advocated.

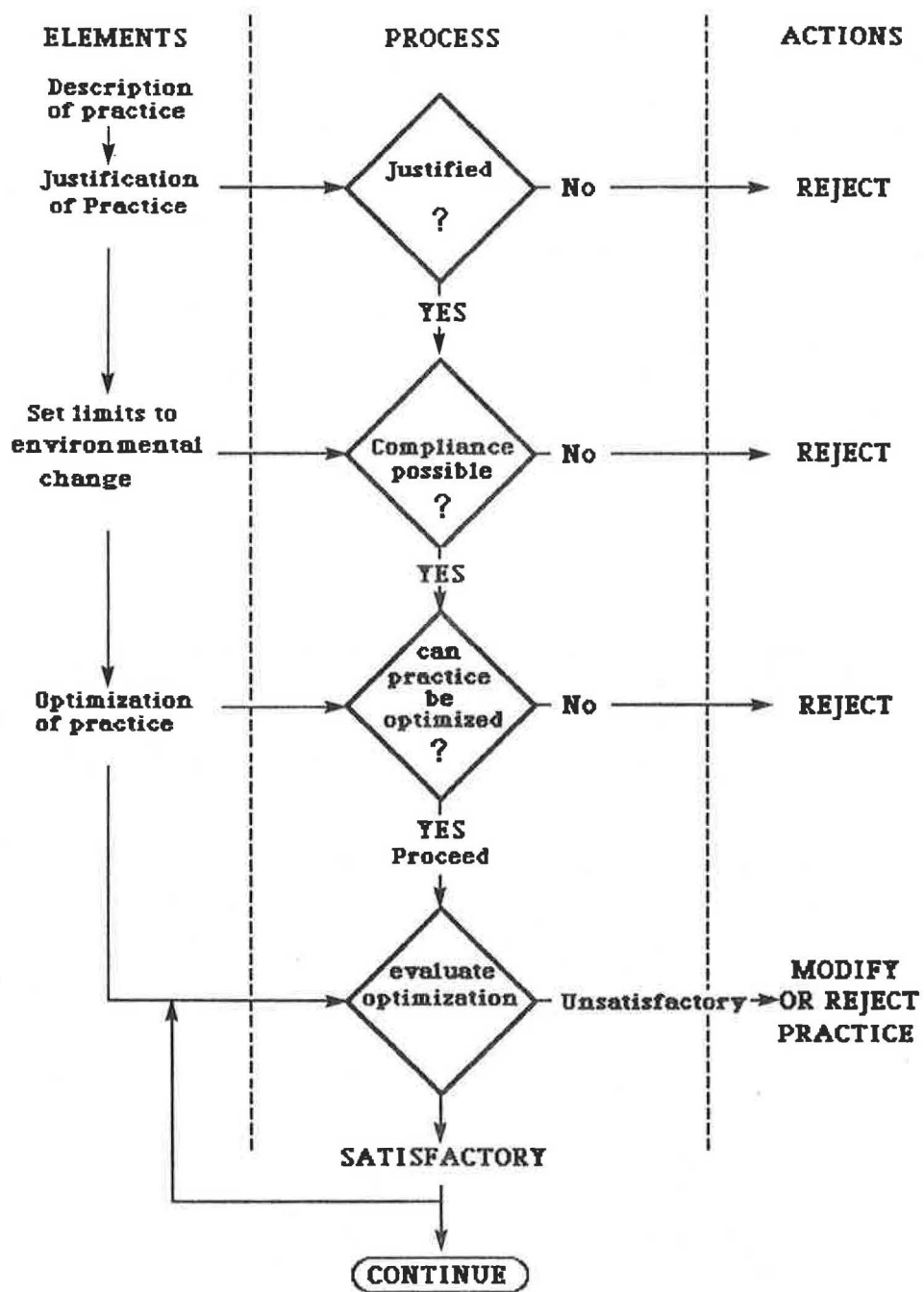


Figure 10 Proposed environmental management framework.

THE APPLICATION OF ACMP ADVICE IN A MANAGEMENT CONTEXT

Introduction

In its 1986 report, the ACMP produced a discussion of certain principles underlying the application of advice which the Committee offers in the field of marine environmental assessment. The decision to include such a discussion was based on the recognition that scientific and technical advice plays an important role in the management of substances introduced to the marine environment and that there are disparities between national approaches to the interpretation and use of this advice. The ACMP regards this situation as potentially divisive in an era of co-operative pollution control activity. Furthermore, there is a need for a more open debate on the principles of environmental protection and, in particular, the approaches to be used for contaminant management, hazard assessment and other elements of marine pollution control.

The reaction of ACMP's audience to the 1986 article, coming largely from intergovernmental bodies unaccustomed to managerial advice from scientific sources was, to some extent, predictable. Several commentators saw the role of ACMP as one confined to scientific issues and had difficulty in accepting that regulatory matters should be the concern of ACMP. Others were more receptive and expressed the view that the issues raised should be the subject of detailed debate in the international environmental management field. It was clear from the responses that these reservations stemmed largely from a new, and extremely cautious, approach aimed solely at the regulation of inputs to the marine environment. Having carefully considered the responses, and in the light of current developments, the ACMP considers that the evolution of regulatory frameworks remains an important and necessary aspect of environmental protection strategies, and the Committee reaffirms its belief that continued discussion of the principles involved can lead to a more balanced, and ultimately more effective, approach to the protection of human health and the environment as a whole. These frameworks can, and should, reflect the caution appropriate to the control of potentially hazardous substances. The ACMP has agreed that formulation of a consensus view on these matters is necessary for its own work and should also be of value to the recipients of ACMP advice. It has, therefore, prepared a further article which expands on some of the principles outlined in its earlier reports.

The present article continues with the theme that, in the long term, protection of health and environment from the harmful effects of contaminants depends on the application of three interactive management principles. The first of these - the Principle of Justification - states that no practice should be adopted by society unless it can be clearly shown that the benefits of the practice outweigh its detrimental effects. The second - the Principle of Compliance - requires that limits of exposure be established covering products, raw materials, and wastes associated with each practice, and that these limits of exposure should be applied to the protection of employees in relevant industries, the public in general, and other living resources. Such exposure limits should be observed at all times. The third - the Principle of Optimization - states that any exposures resulting from an

adopted practice should be kept as low as reasonably achievable; in other words, the control measures applied should be aimed at ensuring the least detriment in relation to the benefit gained.

While these principles have not been applied formally outside the field of radiological protection, they contain elements that to a greater or lesser extent have been used by national authorities to protect human health and the environment from the adverse effects of various practices and substances. Their value from a conceptual viewpoint is that they provide a framework, as well as a practical mechanism, for integrating social values with political, economic, and scientific factors in the management of practices that impact on the environment. They also help to determine the types of scientific information that are most relevant to the control process and to clarify the context in which such information should be used. This is one of the reasons why the ACMP attaches so much importance to the discussion of these principles.

In the following text there will be repeated references to two distinct categories of effect which may result from harmful substances in the environment - stochastic and non-stochastic effects; therefore, these terms require explanation at an early stage. Non-stochastic effects are those, usually attributed to a specific cause, which may have a threshold above which the probability of harmful effects is unity and the severity increases with exposure. Below the threshold, no harm will occur (clearly, this does not apply at limiting levels of exposure to essential substances). The association between exposure and the degree of harm in a non-stochastic regime may be correctly described by a dose-effect relationship. Stochastic effects are those in which there is a probability of harm that is proportional to exposure but it is not possible to specify which individuals within a population will suffer such harm. No threshold can usually be assumed and the manifestation of effects is essentially random. In the stochastic regime, the probability of harm is related to exposure by a dose-response relationship.

As a final introductory comment, certain components of the assessment procedures outlined in the article may appear to require a formidable investment in time and scientific research. This is by no means always the case. The tasks of defining contaminant pathways, exposures and release rates can often be simplified by the use of conservative assumptions; in a number of cases, suggestions are made as to how this might be done. Conservative assumptions will have the effect of further reducing exposures. This is the situation with other approaches to environmental management, such as use of the "black list" and "grey list" classifications and related control procedures. Conservative assumptions will also tend to introduce a strong element of caution into the process of environmental protection. The approach described in this article endorses such precautionary measures while having two inherent advantages over alternative methods. First, it takes into account the indigenous character of the local environment. Second, it offers an implicitly holistic basis for management which permits more sensible and sound comparisons among all the various options for waste disposal, e.g., marine and land-based methods.

THE PRINCIPLE OF JUSTIFICATION AND ITS APPLICATION

Justification is the term applied to an environmental management procedure which seeks to ensure that the advantages of any practice adopted by Man outweigh the disadvantages. We should emphasize at the start that it is not, at present, a procedure which is applied other than in the field of radiation protection and certain aspects of medical practice. In this context, the International Commission on Radiological Protection (ICRP) expresses the principle of justification in the following form:

"No practice shall be adopted unless its introduction produces a positive net benefit."

If the principle is to be applied to the more general field of environmental and human health protection, two aspects need to be considered. The first of these relates to the precise nature of the "practice" to which the principle should apply. The second concerns procedures for the application of the principle to a broad spectrum of activities involving potential hazards to Man and the environment. Dealing with these issues will require some logical interpretation of the principle defined above.

Basic Tenets

Many decisions about human activities are preceded by an implicit balancing of costs and benefits that determines whether or not a chosen activity is "worthwhile". Ideally, acceptance of a proposed activity or practice should be based on an analysis which includes consideration of potential dangers to the environment and human health. The aim of such an analysis is to ensure that the total detriment (sum of all risks and damage) is small in relation to the benefits resulting from the introduction of the activity, i.e., there will be a "net benefit" to the relevant society. Many broad issues need to be addressed, involving economic, social, political, and scientific considerations as well as the nature and extent of the detriment.

There can be little question that the intent of the justification principle is laudable. It serves to ensure that the adoption of a "practice" (which requires definition) is based on a conviction that its benefits to society outweigh any adverse consequences. Clearly, such a conviction should follow from a careful assessment of the components of a practice, such as job opportunities, material requirements, processes, products and by-products, including wastes. Application of the principle must, therefore, be carried out in a multi-disciplinary manner with political, socio-economic, and technical inputs.

It would appear that there are few practices receiving current investment to which the justification principle has been formally and consciously applied. Nevertheless, decisions to invest in certain practices must have involved many of the relevant considerations, but perhaps not on an integrated basis. A simplistic example of this might be the development of synthetic organic pesticides. Pre-marketing trials on these materials would have

shown that they were effective against agricultural pests, that they had clear cost-benefit advantages to previous methods of pest control and, in all probability, involved limited hazards to human health and the environment. Whether the assessment of effects on non-target organisms was as rigorous as might have been warranted is open to question. Indeed, there are specific examples which suggest that concerted efforts need to be made to predict the environmental consequences of open-system uses of chemical substances. These include the use of DDT for a wide variety of insect control purposes which had unforeseen effects on bird reproductive success, and the use of chlorofluorocarbons which now seem responsible for atmospheric effects that are of indirect human health significance. There is little doubt from these examples that rigorous application of the justification principle would be difficult and would not eliminate all the uncertainties associated with a particular practice. On the other hand, if justification were to be required for new chemical products, it may at least help to satisfy those who feel that the burden of proof regarding the safety of such products lies with the intended producer.

Definition of the Practice

So far, we have considered only the rationale which supports application of the justification principle in the management of human activities. Before investigating the various ways in which justification might actually be applied, it is necessary to define the meaning of the word "practice". Intuitively, the original intent was most probably that it should apply to any fundamentally new process that involved the use or production of substances having hazardous properties in addition, of course, to its positive attributes. This, it could be argued, would include processes such as silicon chip fabrication, bio-engineering or even, perhaps, some recent forms of mariculture. It might also apply to the process of electrical production through nuclear energy and, indeed, this would have constituted a valuable assessment of the consequences of nuclear power investment in the 1940s. We are dealing here with new technologies and, in retrospect, it is not difficult to identify examples of technologies for which justification would have been appropriate prior to investment. The question remains, however, as to whether justification would have predicted the adverse consequences of several human and industrial activities that we now know to exist.

An alternative meaning of the word "practice" might be any manufacturing process, agricultural method, or technique for resource recovery which leads either to a new product or to a more efficient industry. These "practices" fall within the realm of newly applied technologies. While the processes involved with such practices may have consequences that are felt mainly at the local level, their products may have very widespread effects on Man and the environment. Waste production is often a feature of these practices and one which may contribute significantly to the overall detriment associated with a particular operation.

Application of Justification

While the justification principle has yet to be applied to any practice on a formal basis, its application at the technology

level would be rational and most consistent with the original intent of ICRP. At this level, justification would clearly not apply to technologies that are already employed.

For most developed and industrialized countries, the introduction of justification at the highest level of the technological hierarchy would not be easy. The productivity-related incentive programmes operated by many governments would not readily accommodate an assessment procedure that carried the possibility that some new technology, with good marketing potential, might not be utilized. Clearly, acceptance of the need for this level of justification would require a fundamental change in social values as stressed by the World Commission on the Environment and Development (1987). While this may seem unrealistic in the short term, it is an aspiration shared by a number of environmental organizations and may ultimately receive broad public support.

Whether the justification principle should be applied at lower hierarchical levels, such as the construction of industrial installations using new processes, remains unclear. In such cases, the balancing of benefits and detriments would be placed in a more geographical context that might make the application of the justification principle easier and more acceptable to the public. In this respect, the environmental impact assessment, as used in a number of countries and recently introduced for specific projects under European Community legislation, has features that constitute components of justification. These assessments are applied to individual installations, or localized activities, but are most often limited to examining the scale of effects and their acceptability. Some of the benefits of proposed activities, such as job creation and increased business for service industries, may also be included in the assessment. Rigorous application of justification at this level would, however, require that all such benefits be documented and, in some manner, balanced with the potentially adverse effects of the activity. A major component of the justification process, frequently omitted from environmental impact assessments, would be the benefits and detriments to society of the products, the importance of these products as components of other industries, and the problems or hazards associated with spent product destruction, recycling, or disposal.

We have not so far addressed the matter of public participation in the justification process. It would be incorrect to assume that justification of a practice, at either the technology or the project level, should involve an exclusively numerical approach to the balancing of benefit and detriment. Indeed, encouraging public participation in a qualitative evaluation would probably be more successful, particularly since the process must include political, social, and economic factors in addition to scientific ones. Nevertheless, the hierarchical level at which public participation occurs has great significance to the future acceptance of a particular technology and, thus, to any subsequent commercial applications of this technology. The clear implication here is that once a new technology has been accepted by society at large, society must be prepared to share the detriments as well as the benefits.

Summary

Ideally, the justification principle should be applied to newly developed technologies, the applications of which have evident potential for environmental damage or effects on human health. Pending the predictably slow evolution of policies and programmes that would permit application of the principle at this level, the principle could and should be applied to major new industrial projects. In the latter context, justification should involve comprehensive examinations and comparisons of the benefits of the proposed operation and its potential hazards to the environment as a whole and to human health. The comparison should be made after the activity has been subjected to optimization procedures (to be discussed below) and should employ techniques that will determine whether the benefits outweigh the costs or vice versa. Furthermore, the mechanism should be such as to inform the public, and to encourage public participation. While it may be naive to expect the principle to be applied uniformly at the project level, there would be considerable benefit in its application through the medium of currently employed environmental impact assessments. Formulation of guidelines on the types of project that should be subjected to justification, and on mechanisms for implementing the principle on an international basis, would be a valuable step in improving approaches to overall environmental protection and management, particularly those related to the marine environment.

The next Section explores some practical approaches to the establishment of exposure limits for those substances which, following justification of the source, are to be introduced to the marine environment.

THE DERIVATION AND APPLICATION OF EXPOSURE LIMITS

All substances can be harmful to living organisms, only the critical exposure varies. It follows, therefore, that the marine environment receives potentially harmful substances of many kinds as a consequence of natural processes and human activities. These introductions occur through atmospheric, river and stream transport, and deliberate disposal of waste through pipelines and ocean dumping. The deliberate input of substances to the sea needs to be subject to very careful regulation to prevent the occurrence of adverse effects (e.g., marine pollution as defined by the UN Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) and within various international agreements). This requirement, in turn, dictates that maximum rates of introduction of potentially deleterious substances need to be defined. The first step in such a process is to establish the species and amenities to be protected. The next is to define the environmental levels of contaminants corresponding to the boundary between "harmless" and "harmful". Both of these requirements involve social, political and scientific considerations; here, we explore the scientific aspects of the process.

Basis for Setting Exposure Limits

Relationship between effects, toxicity, and exposure

To illustrate the role of exposure in producing effects on Man or marine organisms, deleterious effects can be related to toxicity and exposure in a simplistic manner, as follows:

$$\text{Exposure} = f(\text{source strength, environmental physics, biogeochemistry}) \quad (1)$$

and

$$\text{Effect} = f(\text{toxicity, exposure}) \quad (2)$$

where effect represents a change or consequence in the health or viability of Man or marine organisms; toxicity is the intrinsic potential of a contaminant to adversely affect health; exposure represents the character or composition of the environment in which the organism lives and with which it interacts; source strength is the rate of introduction of the contaminant; and physics and biogeochemistry represent the processes and transformations that produce the distribution of the contaminant in the environment, i.e., distribution as a function of space, time, and medium (aqueous, particulate, biological, etc.).

Equation 1 implies that if the nature and magnitude of all relevant physical, geochemical, and biological processes are known, it is possible to relate chemical distributions directly to the source function. It is also possible to deal with non-biological effects, such as interference with physical amenities, through the substitution of other characteristics of the contaminant for toxicity in Equation 2.

Any procedure for the prevention of deleterious effects on organisms, Man or amenities requires that we be able to specify the safe limits of exposure to environmental contaminants. Regulatory action to enforce compliance with such limits is an integral part of the environmental and health protection process.

Establishing exposure limits

The first task is to determine the limits of exposure that must not be exceeded if we wish to avoid pollution. The conventional approach is based upon individual exposures, i.e., the limiting exposure is defined on the basis of tests on individual organisms, or small groups of organisms. It must, however, be appreciated that if the risk of damage is proportional to exposure, limits based on individual exposures may not preclude effects on individuals within large populations.

Except in the field of radiological protection, conventional practice in the control of environmental pollution is generally based upon individual-related assessments. When individuals are found to be at risk by being too highly exposed to contaminants, preventive action is taken. Examples of such action are the removal from the market of fish containing high levels of mercury and the building of higher chimney stacks for the emission of noxious substances. While the latter provide greater protection to the most highly exposed individuals near to the source, they

increase exposure for distant individuals. Thus, a better approach would be to combine individual-related assessments with source-related assessments that consider the collective harm to the exposed population in environmental and health protection mechanisms.

Confusion between individual-related and source-related assessments often leads to the erroneous conclusion that a source is justifiable as long as the individual risks are low. One untenable argument that follows from this conclusion is that individual risks that are small enough to be insignificant in the individual-related assessment can (and should) be ignored in the overall assessment of the impacts of the source. This clearly does not apply where the risk of harm is proportional to exposure and there is no distinct threshold below which adverse effects do not occur. However, in cases where there is a threshold for adverse effects, and individual exposures are well below this level, this argument is valid.

Considering the variety of chemical contaminants, we must recognize that harm may arise from both stochastic and non-stochastic effects. Nevertheless, as we shall see, it is reasonable to use an individual-related assessment in order to set initial exposure limits (to prevent non-stochastic effects and to limit stochastic effects in critically exposed populations to acceptable levels) and to apply source-related assessments through the application of optimization. In setting exposure limits using the individual-related assessment, we will use only the term dose-response relationship although, in practice, this may embrace both dose-effect and dose-response relationships. The reason for this is that information on the effects of chemicals can usually be derived only from experiments using relatively high dose rates and small populations of animals, e.g., results of tests to measure the median lethal concentration (LC_{50}) or no observed effect concentration (NOEC). Under such conditions, a distinction between stochastic and non-stochastic regimes may be difficult to make. Before dealing with the nature of dose-response relationships, we will first describe a technique that can help to simplify the setting of exposure limits.

The critical pathway approach

The possibilities for harmful effects from the introduction of substances into the environment are manifold. However, it is often the case in practice that, for a given contaminant in a given situation, only a few pathways of exposure and one or two target organisms or amenities are potentially the most affected. This facilitates an assessment known as the critical pathway approach in which especially sensitive or "critical" targets are identified and exposure limits are set that protect these targets. Following a careful review of the receiving environment, particular sequences of events leading to the exposure of critical targets are selected as those presenting the most serious set of consequences. This should ensure that all other routes of exposure, and consequent effects, will be at least as well controlled as those involving the critical pathways and targets. The critical pathway typically includes initial dilution, dispersion, accumulation, removal, or degradation by physical, chemical, and biological processes and other changes that either promote or re-

duce exposures to the introduced material and its degradation products.

Dose-effect criteria and their role in setting exposure limits

If we are to build greater confidence into the environmental protection system, we must have appropriate limits of exposure for potential critical targets. Then, using the critical pathway approach, we can apply these limits to specific environmental situations. In defining limits, it will be important to ensure that they provide the degree of protection necessary to avoid unacceptable risks to human health, environmental resources, and amenities.

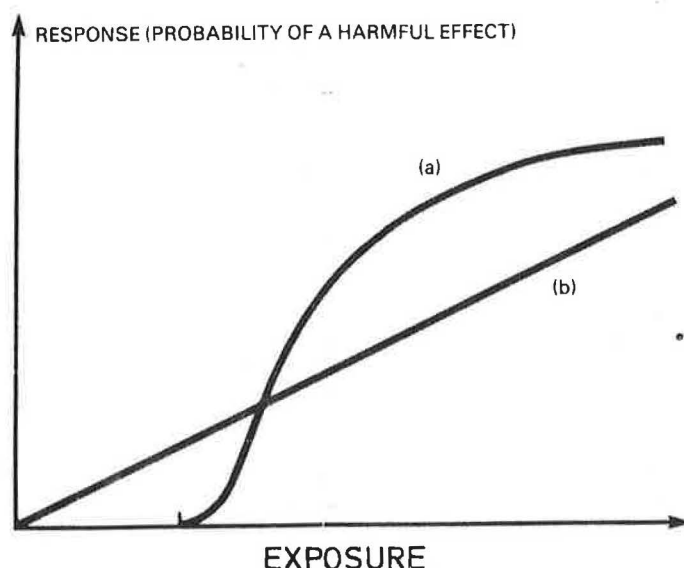
It will not, however, be possible to eliminate risk altogether and, in some instances, a compromise will have to be reached between the cost of reducing the risk of damage and the benefits that such reduction would afford. This compromise is best achieved through the process of optimization. Therefore, in the first instance, the setting of exposure limits should be based primarily upon the protection of the individual from non-stochastic effects.

Definition of an acceptable degree of exposure requires quantitative assessment of the relationship between exposure and effect. The effect in question, when applied to living resources, may be death or a degree of impairment of function that imposes a lower probability of survival than would otherwise be expected, i.e., sub-lethal effects. The crucial question that arises in setting an exposure limit for a particular substance is what level of effect, represented by a particular point on a dose-response curve, is acceptable. Clearly, it is most reasonable to choose an exposure value at which non-stochastic effects cannot occur. This might be obtained, for example, from the results of short-term No Observable Effects Concentration (NOEC) tests applying an appropriate safety factor, e.g., a factor of ten to protect those organisms which are more sensitive than the ones tested. In cases where stochastic effects are suspected, such as mutagenicity, it could be argued that exposures should be minimized through the use of restrictive exposure limits, especially if based on some selection of an acceptable level of risk.

It is important to stress that the protection we afford to marine life differs from that we afford to Man. In general, society is not concerned about the protection of a few individual organisms, but it is firmly committed to the preservation of populations. This should certainly include the preservation of genetic diversity within plant and animal populations. In the latter context, it is vital to ensure that diversity is not threatened by, for example, the selective removal of varieties that may be abnormally sensitive to a particular contaminant.

The dose-response relationship should be established for various periods and levels of exposure but, in practice, this will be restricted by the limitations of experimental procedure. It will, therefore, usually be necessary to make assumptions about the form of the relationship at low doses and low dose rates. At these low levels, it can be assumed that the response curve conforms to one of two basic types, as illustrated in Figure 11. A

relationship that exhibits a low threshold will, in most cases, be indistinguishable from the linear response curve with no threshold. For contaminants for which a threshold can be expected, such as essential elements that occur naturally, it may be possible to determine the likely threshold value based upon a knowledge of natural concentrations. Where a threshold can be experimentally determined, an exposure limit can be set below this threshold, that is, at a non-stochastic no-effect level.



(after Lindell, 1978)

Figure 11 Dose-response relationships.
 (a) non-linear dose-response relationship with threshold value of the dose below which there is no response.
 (b) linear dose-response relationship without threshold (direct proportionality between dose and response over the entire dose range).

In many cases, testing will not reveal a threshold and it must be assumed that the dose-response curve is linear and that no threshold exists. While this may tend to overestimate contaminant potency, exposure limits established on this basis will embody substantial margins of safety in respect to non-stochastic effects and should afford reasonable protection until better data become available. Such limits need to be cautionary, but should not demand unrealistic margins of safety for every conceivable uncertainty. Furthermore, they should be treated with some flexibility and not regarded as rigid lines of demarcation below which there is no effect and above which effects automatically ensue. Again, the reason we can adopt such an approach is that the optimization principle can be used to reduce exposures below the exposure limit where the benefits of so doing outweigh the associated penalties.

Application of exposure limits to environmental protection

Once exposure limits have been derived, these values can be used to determine upper limits for release rates to specific environments. In principle, the limits will be used to apportion the total input of a contaminant to a given area between a number of

individual inputs. We have deliberately qualified the foregoing statement by the words "in principle" because there are several reasons why the limiting rate for a specific environment should not be approached. Reasons include the possibility of additive effects of different contaminants (such effects are rarely more than additive) and the cumulative effects of releases to many coastal environments on offshore basins, e.g., regional or marginal seas. Thus, the calculated receiving capacity for an area should not be fully exploited unless, as a result of applying the optimization process, this is clearly the preferred option.

This approach to regulating contaminant inputs requires a knowledge of physical, chemical, and biological processes within the receiving environment as well as the various uses of the area. For most coastal environments in developed areas of the world, there are already considerable quantities of information that can be used. To identify potential target organisms or amenities, an understanding of accumulation by organisms likely to be consumed by Man, and a list of other interests to be protected, is required. These targets need to be considered in relation to the equilibrium distribution of the contaminant resulting from unit rates of introduction. This information can then be used to identify the critical targets which are likely to be most exposed. Many of the contaminants being considered for release will already occur in the receiving environment. Survey work to identify existing fluxes and distributions will greatly improve understanding of critical target exposures in such instances.

Where conservative substances are to be released into coastal embayments, simplistic representations of water exchange can often be used to approximate equilibrium concentrations. These enable calculation of the rates of release that will result in concentrations equal to the exposure limits in the greater part of the receiving system. For reactive or non-conservative substances, estimates of partitioning between aqueous and specific particulate phases may be used to provide a measure of concentrations likely to be found in sediments and other particulate material. Similarly, the concentrations in living organisms can often be approximated through the application of contaminant and organism-specific concentration factors (IAEA, 1985).

Summary

The planned introduction of substances to the marine environment should be preceded by a risk assessment aimed at establishing suitable exposure limits for the substances concerned. A critical pathway approach, linked to the environmental characteristics of the receiving system and to the properties and behaviour of the substance, can provide an estimate of release rates that will not result in exposures harmful to critical targets. For management purposes, exposure limits established in this manner afford the opportunity to apply optimization procedures which will reduce exposures below the exposure limit where the benefits of doing so outweigh the associated penalties. The exposure limit is thus an upper bound to optimization. The practical aspects of optimization are discussed in the following section.

THE PRINCIPLE OF OPTIMIZATION AND ITS APPLICATION

In its earlier article on the principles of ACMP assessments and the assimilative capacity concept (ICES, 1987), the ACMP emphasized that the application of the principles of justification and compliance with exposure limits alone will not always provide sufficient protection from the harmful effects of toxic substances, particularly those having stochastic effects. It was correspondingly advocated that a third principle, referred to here as "optimization", be applied. This principle is often quoted as the "ALARA" principle by which exposures are kept As Low As Reasonably Achievable. The principle is a fundamental component of the System of Dose Limitation outlined by the International Commission on Radiological Protection (ICRP) and should be similarly applicable to human health and environmental protection in respect to non-radioactive substances.

Objective and Application of Optimization

The purpose of optimization is to reduce exposures to hazardous materials to the extent practical, that is, within limits imposed by social and political acceptability and cost. Its application is analogous to the selection of the Best Practical Environmental Option (BPEO), i.e., that offering the least detriment in relation to the benefits gained. Unlike justification, optimization applies not only to the entire practice but also to components of a practice. Frequently, there will be various alternatives for dealing with a particular operation, or sequence of operations, and these can be evaluated to choose that which offers the least detrimental and most socially acceptable manner of reducing exposures. For example, identifying the best option for waste disposal might involve a comparison of ocean disposal with land burial, land spreading, recycling, etc., on as realistic a basis as possible to select the option that, overall, offers the least detriment considering technical, social, and economic aspects.

Having optimized the avenue for waste disposal, optimization can again be applied to select the actual methods of disposal, or disposal conditions, such that disturbance and detriment are minimized. At this second level, social, economic, and technical factors should again be taken into account. Thus, each sequence of operations in a particular practice can be "optimized" to reduce the exposure consequences of the entire practice. Optimization should be applied to all controllable sources of exposures to hazardous substances irrespective of whether the recipient is an individual or a population. However, it is mainly applicable to protection from stochastic effects. This situation arises because in the stochastic effect regime, the probability of harm is proportional to exposure and, therefore, all exposures impose some measure of risk. Non-stochastic effects generally have a quantifiable threshold and reducing exposures below this threshold may be of limited benefit, especially if the substance concerned is essential at some level of exposure below the threshold for harmful effect.

Exposure limits are designed to protect individuals from non-stochastic effects and limit the risk of adverse stochastic effects to some acceptable level. For substances having only non-stochastic effects, we only need to ensure that there exists a reasonable margin of safety between the threshold for effects and the exposure limit to allow for uncertainties and variance in both environmental concentrations and individual susceptibilities to exposure. For substances having stochastic effects, such as organochlorine compounds and polycyclic aromatic hydrocarbons, there are obvious benefits in reducing the exposures below those imposed by the exposure limit because this results in further reduction of the risk (probability) of adverse effects actually occurring. The extent to which this further reduction is warranted frequently depends primarily on the effort and expenditure society is willing to commit to reducing exposures. This, in theory, should depend on the magnitude of the risk involved in relation to other forms of risk and their acceptability to individuals and society. However, experience suggests that society may not always perceive the risks associated with exposure to chemical substances in the same light as other risks, especially those with which it is more familiar such as driving cars and flying (Allman, 1985). Nevertheless, similar decisions are relatively common in other areas of human activity. For example, several governments have legislated the wearing of protective headgear by motorcyclists in order to reduce the frequency of deaths from motorcycle accidents. Others have banned the sale of certain types of cross-country vehicle that had a record of involvement in serious accidents. In both cases, there has been an appreciation that risks to members of the public, and corresponding medical costs to society, needed to be reduced to bring them into closer alignment with other forms of risk to which members of the public are subjected.

Risk

Risk, in a general sense, is taken to mean the probability that a given individual will incur a particular detrimental effect from exposure to a substance. Detriment is defined as the mathematical expectation of the amount of harm in an exposed group of people which combines the "risk" of harmful effects and their severity. These effects include all those of a "biological" nature - sometimes referred to as the objective health detriment - plus any other adverse consequences related to the comfort and well-being of the members of the exposed group. Thus, if the individual risk is 10^{-5} per year, it follows that in a population of one million people, each member of which is at the same level of risk, ten individuals will be unlucky each year.

Source-related Assessment

These mathematical considerations lead to the concept of the source-related assessment in which the detriment associated with exposure to a hazardous substance is expressed as the integral of exposure across a group of individuals - referred to here as collective exposure. Whereas the limits of exposure are based upon protection of the individual from unacceptable levels of harm, optimization is based upon minimizing collective exposures. Thus, the optimization process consists of considering the relative effort required to reduce the collective exposure. In one of its

simplest forms, optimization can be employed in evaluating which, of a series of alternative options for a particular practice, offers the lowest collective exposure and, consequently, the lowest overall detriment. However, these various options, as well as other specific actions potentially available for reducing the exposure commitment, will have various price tags and a variety of associated impacts on society.

In radiological protection, emphasis was initially placed on cost-benefit analysis to obtain a suitable compromise between no dose reduction and extreme cost. Distasteful though it may seem, life at risk does have a price and forms the basis of insurance practices. Thus, in such instances, there is a fixed monetary benefit in "saving" a life (i.e., preventing a potential death). All this becomes rather involved and sophisticated and applies to only one aspect of the optimization calculation. The other aspect is the monetary cost of achieving a particular level of protection. In general, the more that is spent, the lower becomes the collective exposure and the associated detriment.

Useful as this approach is, it is not entirely satisfactory. This can be exemplified by reference to recent discussions on management of radioactive waste within the international forum. One criticism has been the calculation of collective dose integrals over large time and space scales at exceedingly low levels of individual dose. When it comes to estimating collective doses to very large numbers of individuals, such as the entire global population, and then integrating the collective dose commitment over very long periods of time, such as 10^6 years or more, the numerical value of the dose commitment can be extremely large. Yet, the maximum dose to any individual may be very small indeed. Few rational individuals would dispute that a risk of fatality of, say, 10^{-9} per year from a practice would be equivalent to stating that the practice was perfectly safe. However, when this risk is multiplied by the world's population in the next century ($\sim 10^{10}$) and integrated over a thousand years, then it would appear that 10^4 casualties would be expected. The public not unnaturally asks "How can this be if the practice is said to be perfectly safe?" It is upon such apparent paradoxes that the anti-nuclear and extreme "environmental" lobbies, as well as the popular press, often avidly feed. This paradox could be avoided if there existed common agreement on a level of collective dose commitment (or collective exposure) that could be ignored. While there is general agreement that there are levels of individual exposure to radiation that are so low as to be regarded as trivial (often referred to as de minimis doses), there is less agreement on whether a collective dose, comprising such low individual doses, arising from a source or practice is also trivial. There is another situation in which a component of the collective dose arises from a mixture of individual dose rates. Fortunately, it is often the case that this component of the collective dose is common to all the options being compared and does not unduly upset the calculations.

Cost-benefit analyses are not the only tools available for optimization. Multi-attribute analysis is a technique whereby a scoring system is devised for different choices. For each choice, several factors are identified and a common scale of values devised for each factor. Its main advantage is said to be that it

enables all the various factors that are involved in dealing with particular problems to be dealt with in an equitable fashion. Of the attributes that can be assessed, the following preferences might be made: minimization of the short-term detriment; lowest projected individual exposures; lowest collective exposure; most equitable share of benefit and detriment to a single population, etc. A wider variety of social and political aspects can then be assessed, such as which choice would be most acceptable from an international perspective, which choice offers the opportunity for shortest (or longest) institutional control, which choice minimizes the need for post-operational monitoring.

The implementation of optimization depends on sufficient scientific understanding of the environment, and the behaviour of hazardous substances within it, to permit an equitable comparison of the exposure commitments from various practices and options. While it is possible to use worst-case assumptions to demonstrate that individual dose limits cannot be exceeded, or that the probability of this or that occurring is very low, this does not help in deciding between alternative options. Such evaluations must be made on as equitable and realistic a basis as possible. This requires use of the best understanding of the environmental behaviour of hazardous substances available. This should represent the scientific contribution to the optimization process. At best, it is an aid to decision-making. Ultimately, the social and political considerations will carry the greatest weight. This has been well-exemplified in certain practices such as management of radioactive waste, where disposal options may be selected wholly on the basis of political considerations prevalent at the time. Consequently, the amounts spent on radioactive waste disposal, effluent reduction, and other forms of control are occasionally out of all proportion to those identified as necessary, or even desirable, from a radiation protection perspective.

Optimization in an Environmental Protection Context

All the above really deals with the application of optimization to the protection of human health. Nevertheless, we have already referred to the establishment of limits of exposure to protect other life forms and amenities. There is similarly no reason why optimization cannot be directed towards reducing other exposures. The extent to which reductions in exposures are warranted will be somewhat more complicated than in the case of human health protection simply because the nature of the dose-response relationships is likely to be less well known. Nevertheless, in a spirit of caution and conservatism, this would raise the value of optimization in reducing both the levels of contaminants in the environment and the impact of human activities. The so-called "precautionary principle", adopted by the Government of the Federal Republic of Germany (Anon., 1986) and being increasingly quoted in environmental protection circles in Europe, has the intent of applying the best available means of reducing contaminant releases to the marine environment, irrespective of the degree to which such extreme controls are justified and irrespective of the social consequences. Optimization, on the other hand, provides a rational and holistic mechanism for reducing the overall impacts on the environment and its inhabitants.

The most urgent need for the application of optimization is in respect to the management and control of practices that result in the release to the environment of substances having stochastic effects. Equally, for the protection of the environment, its resources and amenities from chemicals known, or likely, to have stochastic effects on organisms, it would be very prudent not just to rely on compliance with exposure limits but to apply optimization. For practices that result in the release of substances having non-stochastic effects that are already present in the environment at generally innocuous levels, there would be some virtue in applying optimization to ensure that the range of exposures (due to natural and artificially induced variance) remains within that achieved through control of the practice under normal operational conditions. It will also be necessary, both in the development of exposure limits and in the process of optimization, to include examination of accident scenarios to ensure that the probability of accidental events and associated exposures are taken into account and kept within acceptable limits.

Concluding Remarks

The foregoing discussion of optimization procedures clearly indicates that this element of the framework demands a high level of managerial input. Optimization requires detailed analysis of frequently conflicting social, economic, and technical factors to determine the extent to which optimization measures should be applied to each practice, and the means of achieving them. However, the underlying rationale of the framework is that the formal introduction of procedures for the justification of a practice and for the derivation of contaminant exposure limits, both of which involve preliminary assessment of opportunities for optimization, will facilitate optimization of a practice that has reached the operational stage.

This serves to illustrate the essential integrity of the framework and, thus, the need to apply all three of its elements in order to fulfill the requirements of an environmental protection strategy.

There are probably many examples of the application of control procedures that incorporate elements of this system of environmental protection. It might be constructive to give one example that embodies aspects of the justification and optimization principles and, by implication, compliance with exposure limits. The example chosen is that used to implement the Canadian Pest Control Products Act, 1969. The evaluation procedure for screening applications for the registration of new pest control compounds is illustrated in Figure 12. It is inherently based upon an assessment of the balance between the benefits of the substance and the potential risks to human health and the environment associated with its use. It is implicit in this process that there must be a net benefit for a substance to receive approval. Furthermore, the risks must lie in a range of acceptable values. Thus, each new compound is subjected to a separate analysis of its potential hazards and the potential benefits associated with its use for pest control in agriculture. The balancing of benefits and risks is conducted on a "weight of evidence" basis that

has been commended in a recent review of the administration of the Act following an appeal against a decision made using this mechanism.

The ACMP acknowledges that environmental management systems in most countries have often evolved in a rather ad hoc manner, in response to changing circumstances and priorities. There is considerable variation between countries in the legislative and associated institutional arrangements for the control of different practices, in particular those which place demands on the terrestrial, atmospheric, and water environments.

The introduction of uniform management approaches, applicable to all sectors of the environment, would not be easy, nor would it be likely to occur rapidly. Nevertheless, the ACMP believes there are persuasive arguments for a gradual move towards the type of management framework described in this article. The key elements of the framework are not entirely new and most countries will already possess the administrative and technical expertise to implement them. The ACMP would welcome discussion of this important issue.

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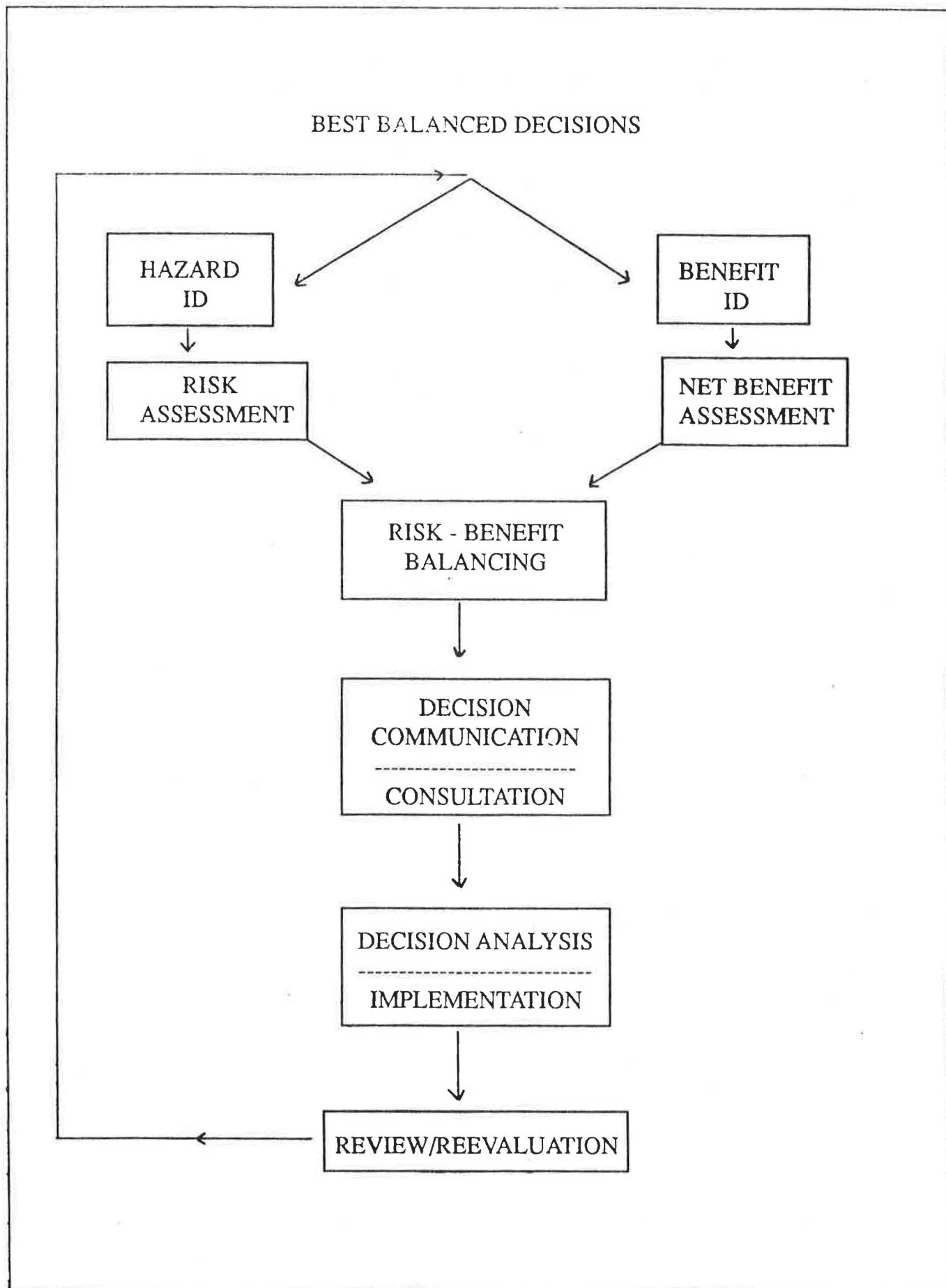


Figure 12 Evaluation scheme for pest control products, as applied under the Canadian Pest Control Products Act, that embodies elements of the proposed environmental protection strategy.

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The ACMP would like to emphasize that these studies would not have been undertaken without the pioneering work of the late Alan Preston, former Director of the MAFF Fisheries Laboratory, Lowestoft, UK, member of ACMP, and UK Delegate to ICES. Alan made a major contribution to improving the scientific basis of environmental management approaches in the face of considerable resistance. He embodied many of the concepts expounded here into the strategy for the IOC Comprehensive Plan for the Global Investigation of Pollution in the Marine Environment (GIPME) and a statement on environmental management principles in the 1981 ACMP report. For these reasons, the ACMP dedicates this presentation on management principles to the memory of Alan Preston, a distinguished scientist and a sadly missed friend and colleague.

22 ISSUES RELATED TO STANDARDS AND CRITERIA

22.1 Progress on the Review of Standards/Criteria

The ACMP reviewed the report of the preliminary discussion on standards and criteria at the meeting of the Working Group on Environmental Assessments and Monitoring Strategies. The Working Group had recognized that standards and criteria can be used as a tool in the assessment of measurements of contaminant levels.

Criteria for contaminant levels in the environment can be divided into two broad groups, depending on their applications. The first consists of those that are intended to protect the human consumer and, therefore, consideration is given to foodstuffs. The second group of criteria is intended to protect the environment, either the whole ecosystem or individual species within it.

Much attention has already been paid to the definition of criteria of the first group, mainly by WHO. These criteria are based on toxicological research, but they also contain a conservative safety factor. In transforming the WHO criteria into national standards for contents in food, the mean and extreme consumption, e.g., by critical groups, of the considered foodstuff plays an important role. As these will differ both within and between countries, national standards based on the WHO values may show some differences.

Fewer criteria of the second group have been developed. They are mainly for freshwater situations. However, the definition of these criteria poses some serious difficulties, and it was recognized that, where a group of experts could reach agreement on them, the criteria would play a useful interim role in the preparation of environmental assessments.

The ACMP agreed to keep under review the question of standards/criteria, particularly in connection with the management principles discussed in Section 21 of this report, and especially the establishment of exposure limits.

22.2 Quality Standards for Sediments

The ACMP took note of the discussions within the Working Group on Marine Sediments in Relation to Pollution of a paper prepared by the Dutch Ministry of Housing, Physical Planning and Environment outlining the underlying philosophy for the selection of soil and sediment quality standards. The approach is based on an environmental policy intended to preserve a physical and chemical environment that is "ecologically healthy", meaning that it provides a safe and healthy milieu for people, animals and flora. It is applied by sampling and analyzing conditions at a large number of assumed "ecologically healthy" locations. The values obtained from these analyses are then used as quality standards for determining, for example, the suitability of dredged materials for land and sea disposal. In certain circumstances, this may be an acceptable approach in the context referred to, although it is a conservative one. However, it takes no account of the uses and amenities of the environment which has to be protected and into which the disposal is proposed. This approach incorporates an a

priori assumption that the standards appropriate to a material are based wholly on the natural occurrence of substances. This ignores the indisputable fact of ubiquitous contamination and takes no account of meaningful levels required for maintaining legitimate uses of the environment and its amenities.

The ACMP considered that quality criteria of sediments should ideally be based on an understanding of the physical, chemical and biological processes involving sediments and the effects of these processes on the marine environment. Quality standards should also take into account differences in local natural conditions and priority aims for the use of the marine environment that may have been identified locally. Quality standards for sediments may, therefore, be different from those required for soils and vary according to the requirements of the potential users of the marine environment. The ACMP recognized, however, that the establishment of these criteria sometimes poses serious difficulties and that the environmental quality objectives must be formulated carefully on the basis of the latest results of research and monitoring efforts, and particularly in the context of the uses of the marine environment.

A pragmatic approach, such as that used by the Dutch authorities, may be justified as a preliminary step in regulation, but an approach that takes greater account of the preservation of resources and amenities in the receiving environment would be an improvement.

23 AUTOMATIC DATA PROCESSING ISSUES

The ACMP reviewed the status of the ICES automatic data processing (ADP) activities in relation to data on contaminants in marine media. The report considered three aspects of current concern, as follows:

- 1) the increasing demands on ICES in connection with the handling of the contaminants data sets, largely due to the expansion in the monitoring programmes for which ICES acts as data centre. Also noted was the expectation of further demands associated with North Sea Task Force (NSTF) ADP requirements;
- 2) the issue of increasing requests for development of facilities for direct or real-time access to ICES environmental data banks; and
- 3) the more general aspects of data quality, in particular data quality in relation to assessment procedures.

With regard to the second issue, the ACMP noted that, frequently, a disproportionate amount of consideration is given to the technical aspects of such requests (networks, data security aspects, etc.), without any evaluation of whether a real need for such a system exists. The perceived advantages of direct-access systems include 'interactive access to remote data-bases/banks' and 'rapid data-exchange via networks'. The ACMP considered, however, that in general, at the present time, it is difficult to identify any applications where a real demand for on-line access to the ICES environmental data sets might be justified. Similarly, on the issue of rapid exchange of data, no projects have yet revealed a need for data-exchange facilities that can not be satisfied using, for larger data volumes, magnetic media (tapes, discs), if necessary in conjunction with express delivery services, or, for smaller data sets, electronic transmission over the telephone lines using modems and standard protocols, etc.

The correct use of data held at data centres often requires an underlying appreciation/interpretation of the way in which data are stored, and the resources required to set up a completely open direct-access system can be considerable.

The ACMP considered therefore that, for the present, the development and distribution of data inventory facilities, to improve awareness of the data availability and improve specification of requests, might be more relevant than direct-access systems.

In terms of the third issue, the ACMP noted that much attention has been devoted to improving data quality by means of improving the analytical methodologies and their application (intercalibrations, reference materials, quality assurance practices, etc.). These aspects represent, however, only a part of the consideration of data quality in general, and there has been a tendency in the past to equate analytical data quality with the overall quality of data required for assessment purposes.

In this context, the assessment process can become the weak link in the monitoring effort. Increasingly, experience is showing that during short ad hoc meetings, experts are called together to assess data sets with which they have had little previous association. In the course of these meetings, so much of the available time is being devoted to the necessary process of familiarization with the data and addressing the data quality questions that the process of actual data analysis and interpretation is being adversely affected. In other circumstances, attention is immediately focussed on data assessment and little time is available to address the compatibility and quality of the data. For these reasons, alternative mechanisms for data assessment may need to be considered.

ANNEX 1

EXAMPLES OF THE APPLICATION OF ICES GUIDELINES FOR THE MONITORING OF BENTHIC COMMUNITIES AROUND POINT-SOURCE DISCHARGES

1 INTRODUCTION

This annex provides examples to illustrate the application of the guidelines for monitoring benthic communities around point-source discharges, that are contained in Section 7 of the 1988 ACMP report. Figure 1 summarizes the use of these guidelines for an idealized point-source discharge to a uniform area of sea bed. The steps range from an initial desk study, to exploratory and quantitative baseline surveys, and then to regular monitoring, in accordance with the guidelines in the 1988 ACMP report.

For brevity, attention is confined to sediment quality and the benthic infauna, but this is not to underrate the potential value of widening the scope of impact assessments to include other biota (e.g., epifauna and demersal fish communities).

The frequency at which restricted scale regular and more intensive baseline-type surveys are conducted will mainly depend on:

- i) the nature and prior history (if any) of the waste discharge: a new input may require more frequent sampling until an acceptable steady state has been reached regarding intensity and spatial extent of impact;
- ii) alterations to the nature and rate of an existing discharge: clearly, unanticipated changes occurring at regular or baseline stations as a result of alterations in a discharge may necessitate modification to the survey design or frequency;
- iii) the perceived sensitivity of the receiving environment, e.g., in relation to commercial fisheries resources or conservation value; such an evaluation may also involve other than purely scientific considerations.

As a rule, the minimum sampling frequency will be annual for regular surveys on a restricted scale, and every 2-3 years for the more detailed baseline-type surveys. In both cases, these should be conducted at the same time of year so as to minimize variability in the data.

The progression of Figure 1 is towards concentration of effort at a limited number of strategically placed sites, at which replicate samples are taken. In this hypothetical example, the regular survey design may take one of two forms, both of which retain a facility for spatial comparisons:

DESK STUDY

Review existing information: hydrography, benthic studies, waste discharge(s) etc

EXPLORATORY SURVEY

On-board assessment of sediments and biota; range of sampling gear

BASELINE SURVEY

Quantitative sampling of infauna; sediment physics and chemistry

REGULAR SURVEY

I

Spatial; temporal comparison of gradients in response

II

Temporal; spatial comparison of trends

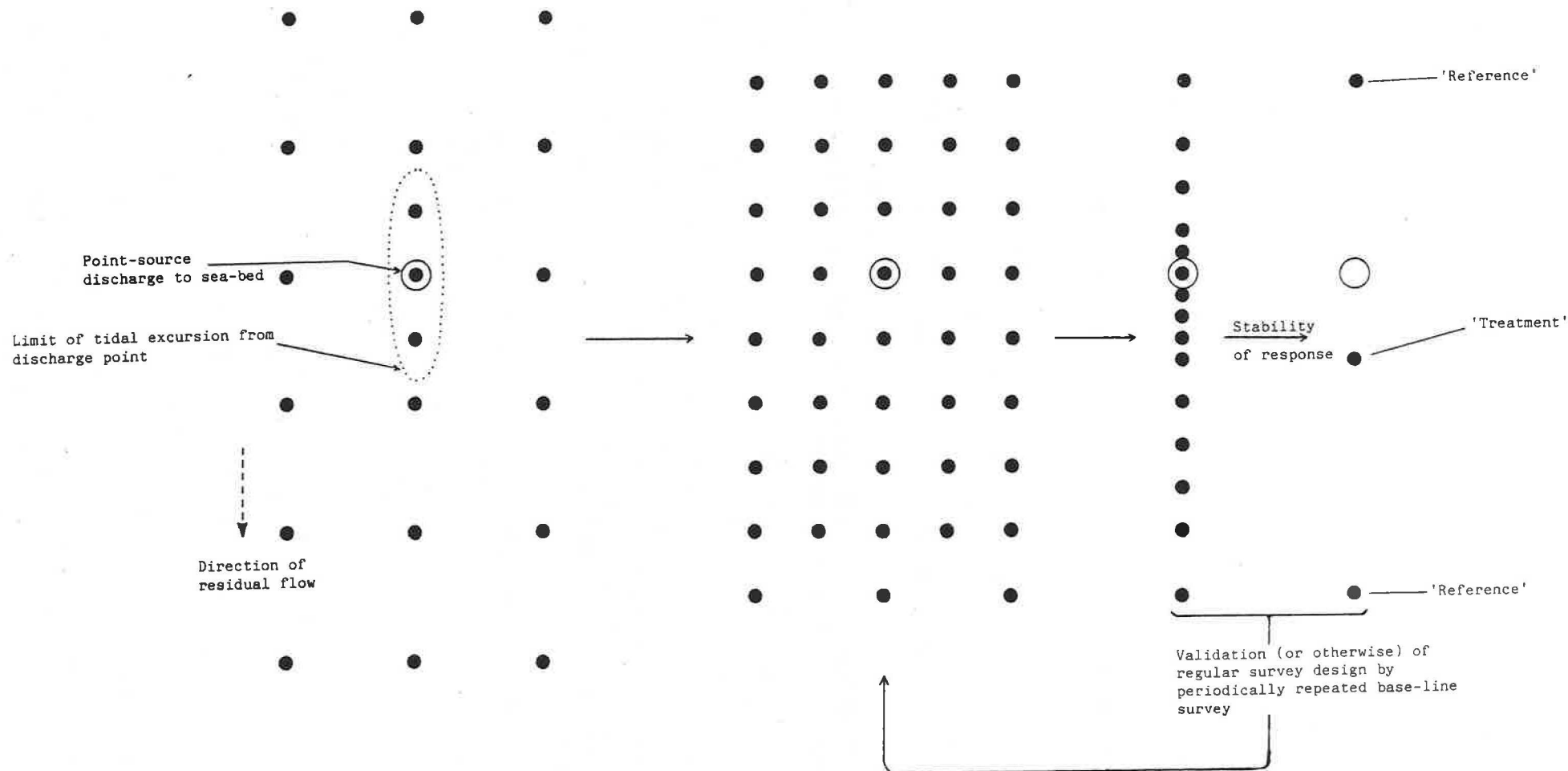


Figure 1 Idealized sampling strategy for benthic monitoring at a point-source discharge.

- i) the first assumes a good knowledge of the waste transport pathway, but some uncertainty as to the precise nature and lateral extent of benthic changes in relation to the waste plume.
- ii) the second assumes a good knowledge of both these factors, following stabilization of the benthic response to a discharge of constant rate and composition; in such a case, repeated sampling should provide reassurance as to the nature and extent of discharge impacts, and could, therefore, justify a much reduced sampling effort.

Coupled with periodically repeated baseline surveys, the overall strategy should be to detect both predictable and otherwise unforeseen changes (e.g., episodic pollution events), which may warrant an expansion of sampling effort, further controls on the discharge, or both.

The aim is to simplify the interpretation of trends for management purposes. However, it should be emphasized that it is not possible to provide a blueprint for the conduct of surveys of the sediments and benthos at all locations, because of the wide array of environmental conditions, as well as discharge types.

2 A CONCEPTUAL MODEL FOR INTERPRETING BENTHIC CHANGES IN RESPONSE TO POINT-SOURCE DISCHARGES

A framework for the interpretation of any changes which occur in response to a waste discharge is clearly fundamental to the successful outcome of any monitoring programme. A conceptual model developed by Pearson and Rosenberg (1978) for changes in the benthos in response to organic enrichment - probably the most commonly encountered manifestation of discharge effects - has proved to be particularly useful in this respect. As it has a bearing on the examples given below, a brief description of the model is appropriate.

A summary of the changes predicted to occur along an enrichment gradient is shown in Figure 2. A general enhancement in species numbers and biomass at low input levels is followed by proliferation of small-sized and short-lived "opportunists" at the expense of larger, less tolerant species as organic matter builds up, and sediments will tend to become increasingly anoxic with depth. At this stage, total abundance markedly increases, but species numbers and biomass decline. Further accumulation leading to conditions of anoxia, even at the sediment surface, results in the elimination of all macrofauna species.

The model has the advantage of being equally applicable to spatial and temporal trends; this can be illustrated by reference to changes in an effluent plume with distance from the source. The response in space along a series of stations away from the outfall, sampled on successive occasions, will be a compression of the sequence of changes of Figure 2 towards the left, i.e., there will be a reduction in the spatial extent over which changes will occur. The response in time at a single location near to a discharge will precisely mirror the sequence from left to right as shown in Figure 2. Actual examples of its application in both dimensions are given below.

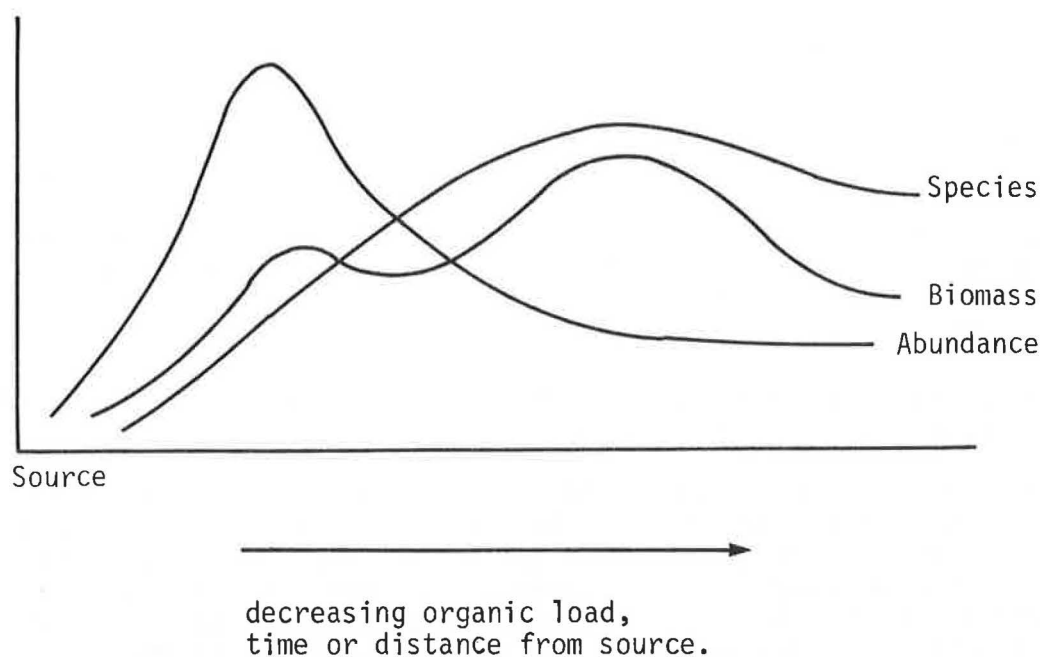


Figure 2 Empirical model for changes in the macrobenthos in response to organic load (adapted from Pearson and Rosenberg, 1978).

3 EXAMPLE 1

The following example is selected from numerous literature concerned with the monitoring of sewage discharges along the Californian coast, much of which was carried out under the auspices of the "Southern California Coastal Research Project" (e.g., Bascom, 1979; Mearns, 1981; Mearns and Word, 1982), and more recently by the U.S. Environmental Protection Agency (Swartz *et al.*, 1985, 1986). This work has employed a variety of sampling designs to meet different objectives, and follows a progression from wide-scale spatial grids extending well beyond any zones of impact, to line transects targetted at the examination of localized effects. The latter involved repetitive sampling at a few stations, to facilitate a statistical comparison of trends.

The main pipeline sewage discharges are located at depths of at least 60 m, and the predominant near-field dispersal pathway for particulates at the sea bed is parallel to the coastline. Figures 3a and 3b show spatial trends in a variety of sediment contaminants and faunal indices at stations sampled along the 60 m contour. Two 0.1 m² Van Veen grab samples were taken at each station, one for sediment quality and the other for benthos using a 1 mm mesh sieve. The effect of these outfalls, especially off Palos Verdes, can be clearly discerned.

The information from this and other sources was used to define "normal" conditions for a range of chemical and biological variables in the depth range 20-200 m (a locally derived "infaunal index" was used (see Word, 1979)). The findings were used to interpret the data from a survey employing 300 stations (also sampled singly for the benthos) spanning this depth range; the region off the Palos Verdes is shown in Figure 3c as an example.

Contours identify a "degraded" area in the immediate vicinity of the outfalls, along with a "changed" fauna with a notable north-westward extension. These contours agree with observations on a range of trace metal contaminants, e.g., zinc (Figure 4, from Hershelman *et al.*, 1981).

Rationalized sampling design for determining effects along a main gradient of contamination

Knowledge of the main dispersal pathway, contaminant distributions and impacts on the benthic fauna off Palos Verdes (cf., i.a., Swartz *et al.*, 1985) allowed sampling to be restricted to a limited number of stations westward of the discharges at 60 m depth, including one station representative of "normal" conditions as defined by the above baseline study. In this survey, ten Van Veen grab samples were taken at each station: five for the benthic infauna, using a 1 mm mesh sieve, and five for physical, chemical and toxicological analyses. Sampling was conducted in 1980 and 1983 (Swartz *et al.*, 1986), thus allowing statistical comparisons between stations and between years, during which time the contaminant loading from the discharges was estimated to have decreased by about 20%.

One of the main objectives of this work was to compare changes along the contamination gradient with the model of Pearson and Rosenberg (1978), which predicts a sequence of successional events in the benthos in response to organic enrichment.

Trends in numbers of individuals, species and biomass along the Palos Verdes station transect (see Figure 5) were broadly in agreement with the conceptual model. For example, in 1980, stations close to the outfall were strongly dominated by the polychaete *Capitella*, a common indicator of disturbed or enriched sediments. Dominance by this species was much reduced in 1983, and this was accompanied by significant increases in the number of species and in biomass. Other differences included a significant reduction in species number, densities and biomass at intermediate stations, and in a number of sediment contaminants. There were no significant differences in the various parameters at the distant control site.

Sediments sampled near the outfall in 1980 were acutely toxic to an amphipod crustacean in a bioassay experiment, but there was no evidence for toxic effects in 1983.

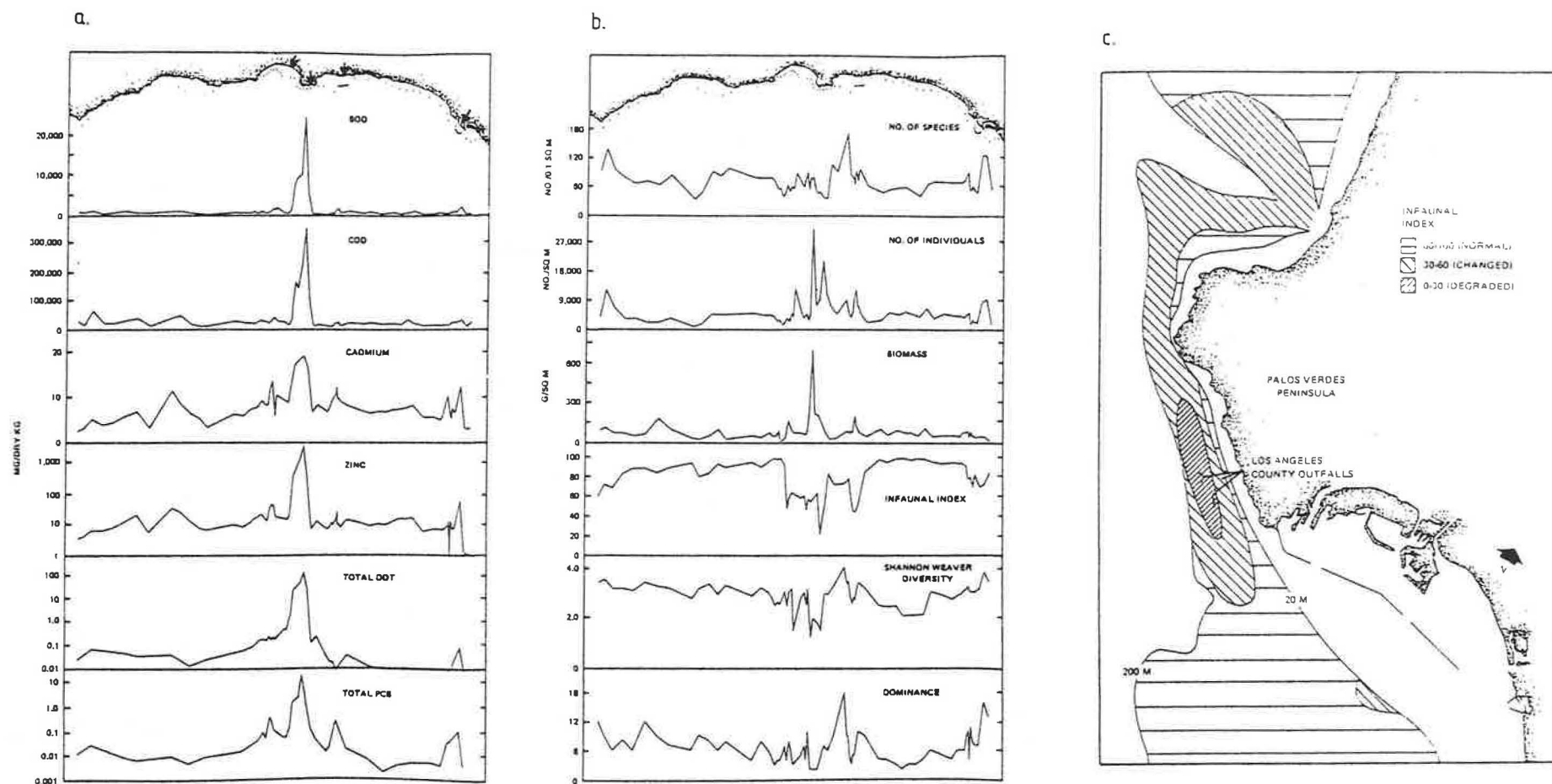
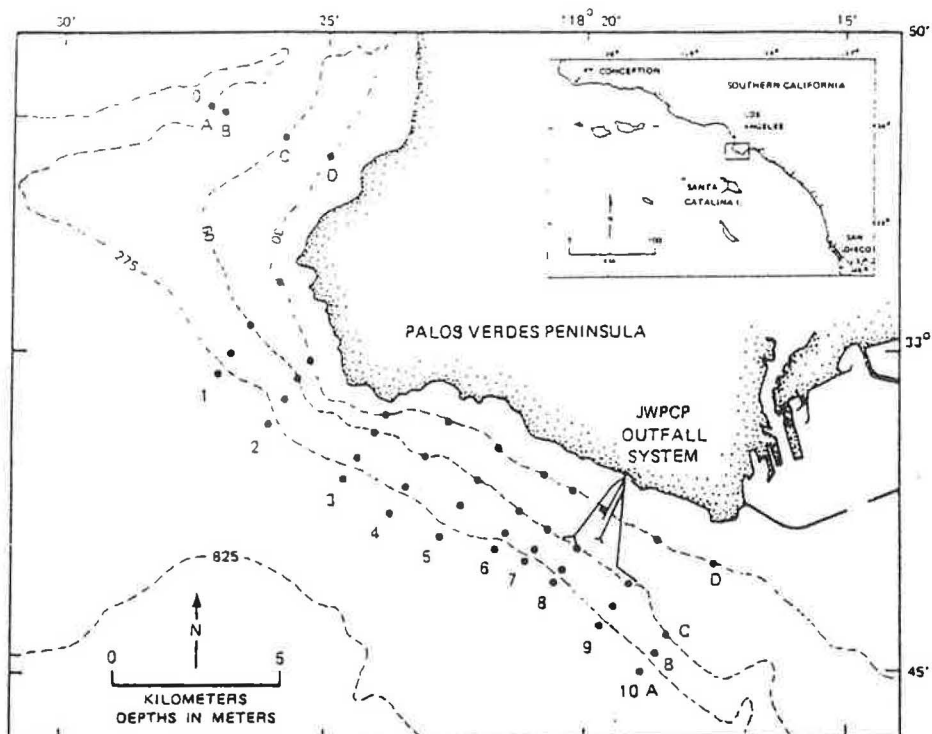


Figure 3 Trends in sediment contamination (a) and faunal indices (b) along the 60 m depth contour (arrows show the location of the major deep-water sewage discharges) (from Word and Mearns, 1979); zonation of the benthos determined from a grid of stations sampled off Palos Verdes (c) (from Bascom, Mearns and Word, 1979). Reproduced with permission from the Southern California Coastal Water Research Project Authority.

a.



b.

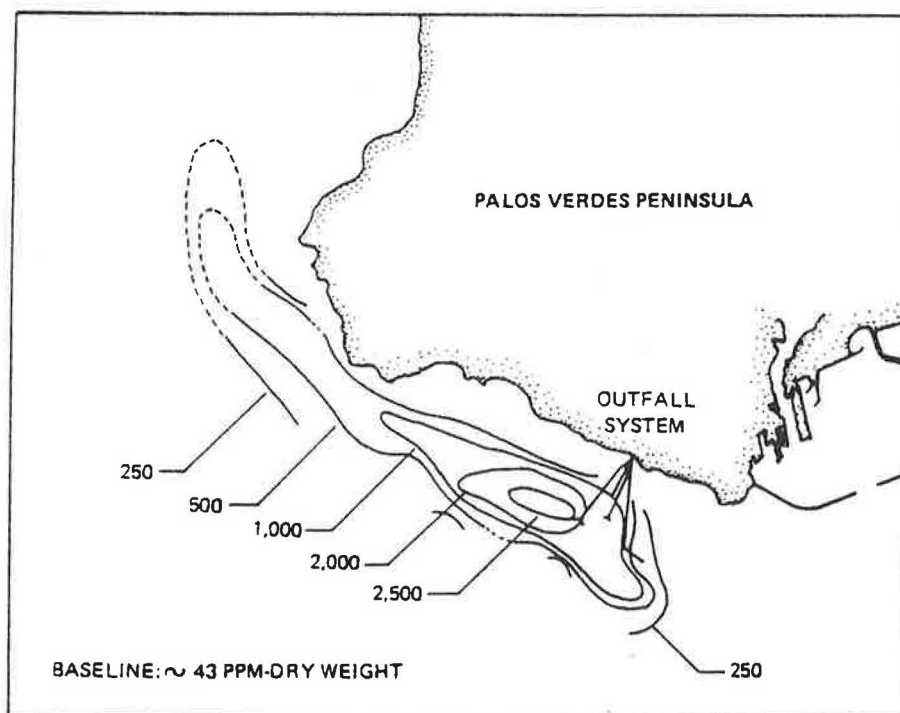


Figure 4 Location of sediment sampling stations (a) and contours for zinc concentrations (b). (Reprinted with permission from Marine Pollution Bulletin, Vol. 12, Hershelman, G.P., Shafer, H.A., Jan, T.-K., and Young, D.R., Metals in marine sediments near a large California municipal outfall. Copyright 1981. Pergamon Press PLC).

This decrease in the effects of enrichment, along with any which might be attributable to chemical contaminants, led the authors to conclude that there had been a significant improvement in conditions between 1980 and 1983. This was ascribed to a reduction in contaminant loading during this period, though the disturbing effect of severe storms may also have contributed to improved sediment quality. It may also be noted that Mearns and Word (1982) established a significant spatial relationship between the emission rates of suspended solids at five Southern California sewage discharges and the area of sea bed occupied by an altered benthic fauna.

4 EXAMPLE 2

The second example, selected from the large body of literature concerned with monitoring around oil platforms, is that of the Beatrice oilfield in the UK sector of the western North Sea. The Beatrice field was discovered in 1976; its development since then, along with an account of sea-bed monitoring, is described by Addy *et al.* (1984), Addy (1987), and Hartley and Bishop (1986), among others.

Baseline surveys

Pre-production surveys involved sampling on a grid of widely-spaced stations encompassing the oil platforms. The sampling in 1981 is shown in Figure 6a (from Levell *et al.*, 1989). Most of these stations were sampled singly for the benthic macrofauna, using a 0.1 m² Day grab, and a 1 mm mesh sieve to retain the animals. Additional sediment samples were taken for physico-chemical analyses, including particle size distribution and hydrocarbon content. These surveys allowed the faunal distributions to be related to natural environmental factors (Hartley and Bishop, 1986); there was no apparent influence due to industrial activity (Addy *et al.*, 1984).

Rationalized sampling design

Drawing on the knowledge gained from baseline surveys, and with an expectation that effects on the benthos would arise principally from the disposal of drilling discharges in the near-vicinity of platforms, subsequent investigations employed a limited number of stations located on inter-crossing transects (Figure 6b, from Addy *et al.*, 1984). Note that the innermost stations are much more closely spaced than on the baseline grid; also that the NNE-SSW transect is aligned with the predominant direction of tidal flow.

At each station, two Day grab samples were taken for the benthic macrofauna, also using a 1 mm mesh sieve. A further grab sample was taken to obtain sediment sub-samples for physico-chemical analyses.

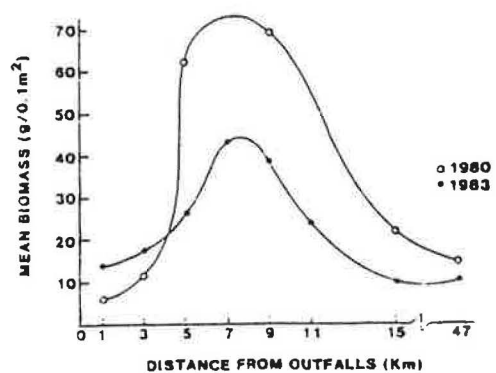
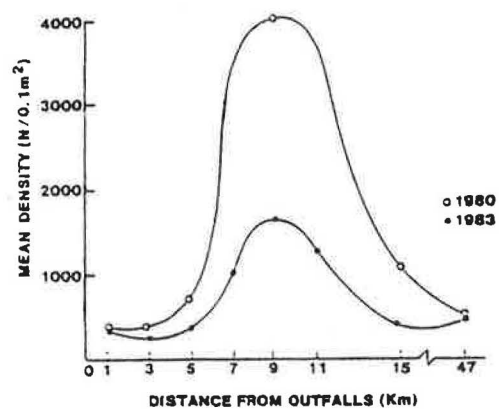
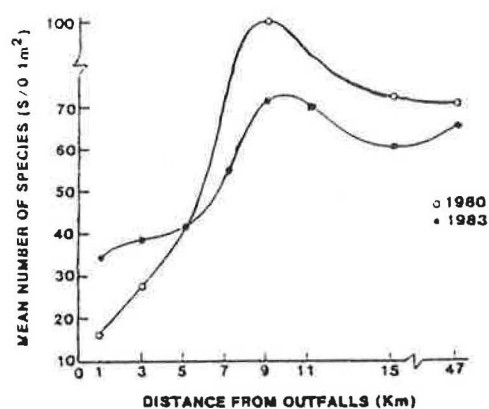
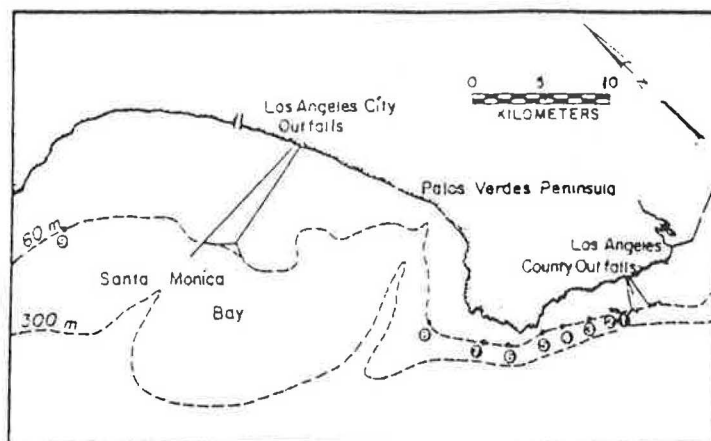


Figure 5 Station locations and trends in the main faunal indices (from Swartz et al., 1986).

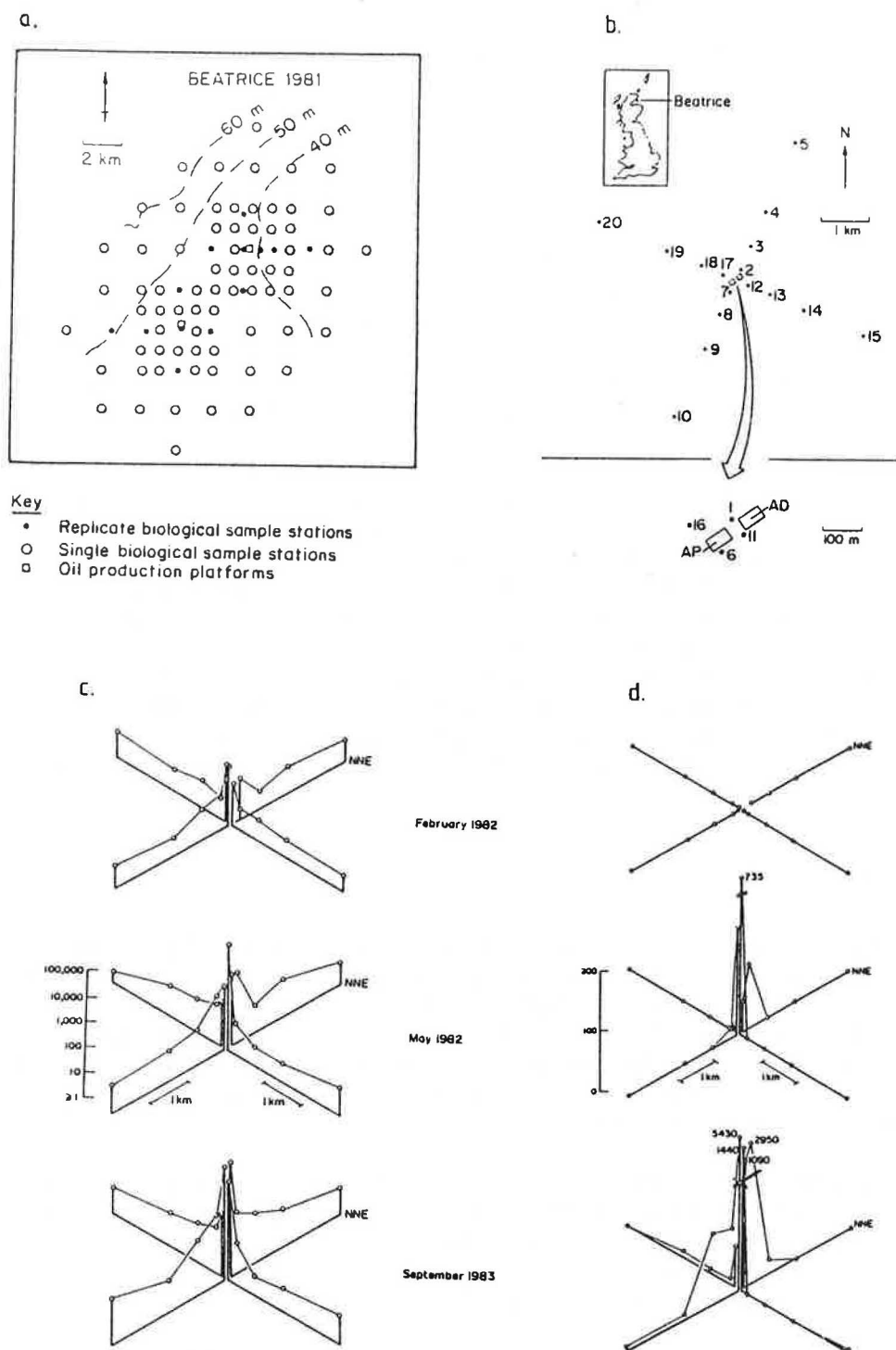


Figure 6. a. Grid of stations employed in a 1981 survey of the Beatrice oilfield (from Levell *et al.* 1989, reproduced with permission of J. Wiley and Sons and acknowledgement of the Institute of Petroleum); b. intersecting transects for studying 'near-field' effects (AD=drilling platform; AP=production platform); c. concentration of aliphatic hydrocarbons (ppm) in sediments; d. estimated numbers of *Capitella* per m².

(b, c and d reprinted with permission from Marine Pollution Bulletin, Vol. 15, Addy, J.M., Hartley, J.P. and Tibbetts, P.J.C., Ecological effects of low toxicity oil-based mud drilling in the Beatrice oilfield. Copyright 1984. Pergamon Press PLC.)

The concentrations of aliphatic hydrocarbons in sediments is shown in Figure 6c, on a logarithmic scale; as might be anticipated, the highest values occurred very close to the platform. Away from this, generally higher values were found along the NNE-SSW transect. Note also that higher overall concentrations after February 1982 could be accounted for by a switch from water-based to "low toxicity" oil-based drilling muds.

Counts of the opportunistic polychaete Capitella (Figure 6d) provide a useful illustration of local perturbation following the use of oil-based muds: highest densities occurred in the immediate vicinity of the platform, and elevated counts extended over a greater distance on the NNE-SSW transect. These changes were accompanied by a marked reduction in the numbers of taxa close to the platform.

In this example, an integrated study of the benthos, sediment physics and chemistry provided the basis for delimiting a localized zone of gross biological effect, which was attenuated along the axis of principal water flow. While it appears that sampling along this axis might profitably have been extended to a greater distance from the discharge point (and indeed subsequent work has taken this into account), the main effect could be attributed to a combination of physical disturbance in the immediate vicinity of the discharge, organic enrichment (including some changes analogous to the Pearson and Rosenberg model of Figure 2), and toxicity.

5 EXAMPLE 3

This example draws from survey work in a Swedish fjord, aimed at investigating the effects of an organically rich pulp mill waste (Rosenberg, 1976). The sampling area, and station locations, are shown in Figure 7a. At each station, five samples were taken with a 0.1 m² Smith-McIntyre grab, and the macrofauna were retained on a 1 mm mesh sieve. Sediment sub-samples were analysed for particle size and organic carbon.

Note that the extensive amount of previous work on the water, sediments and biota of this area (reviewed by Rosenberg, 1976), along with the narrowness of the fjord location, allowed the selection of representative stations for an examination of longitudinal trends away from the discharge.

Spatial gradients and the value of temporal continuity

Changes in space along a gradient of decreasing organic enrichment from left to right (Figure 7b) accord with those predicted by the model of Figure 2. Figure 7b is particularly useful in highlighting the value of continuity in sampling, allowing the progress of temporal changes to be evaluated. In this case, predictable changes occurred at a site in close proximity in response to a cessation of the discharge; the recovery time was about eight years.

6 CONCLUSIONS

It should be noted that the above examples were chosen from among the many available for two reasons: a) because of the amount of published information provided over many years, and b) the manner in which impacts and their spatial extent have been established through multidisciplinary study, employing appropriate sampling design.

These examples demonstrate the importance of:

- i) geographically extensive "baseline" surveys to establish zones of waste impact, and the broad boundaries of natural spatial variability;
- ii) integration of studies, especially on hydrography, sediment physics and chemistry, and biology;
- iii) rationalized sampling designs, where possible, in order to simplify interpretation of trends across main zones of impact identified from baseline surveys;
- iv) sample replication, facilitated by the reduction in effort implicit in (iii), allowing statistical analysis of station trends in space and time;
- v) continuity in sampling;
- vi) predictive models for the responses of the benthos to waste discharges, which are commonly non-linear along gradients of contamination, against which observed changes can be assessed.

Finally, while a survey strategy which succeeds in accurately detecting impacts on the benthos can provide a valuable management tool, it should be emphasized that, at present levels of understanding of ecosystem responses to waste discharges, this will rarely obviate the need for a judgement as to the wider significance of observed changes.

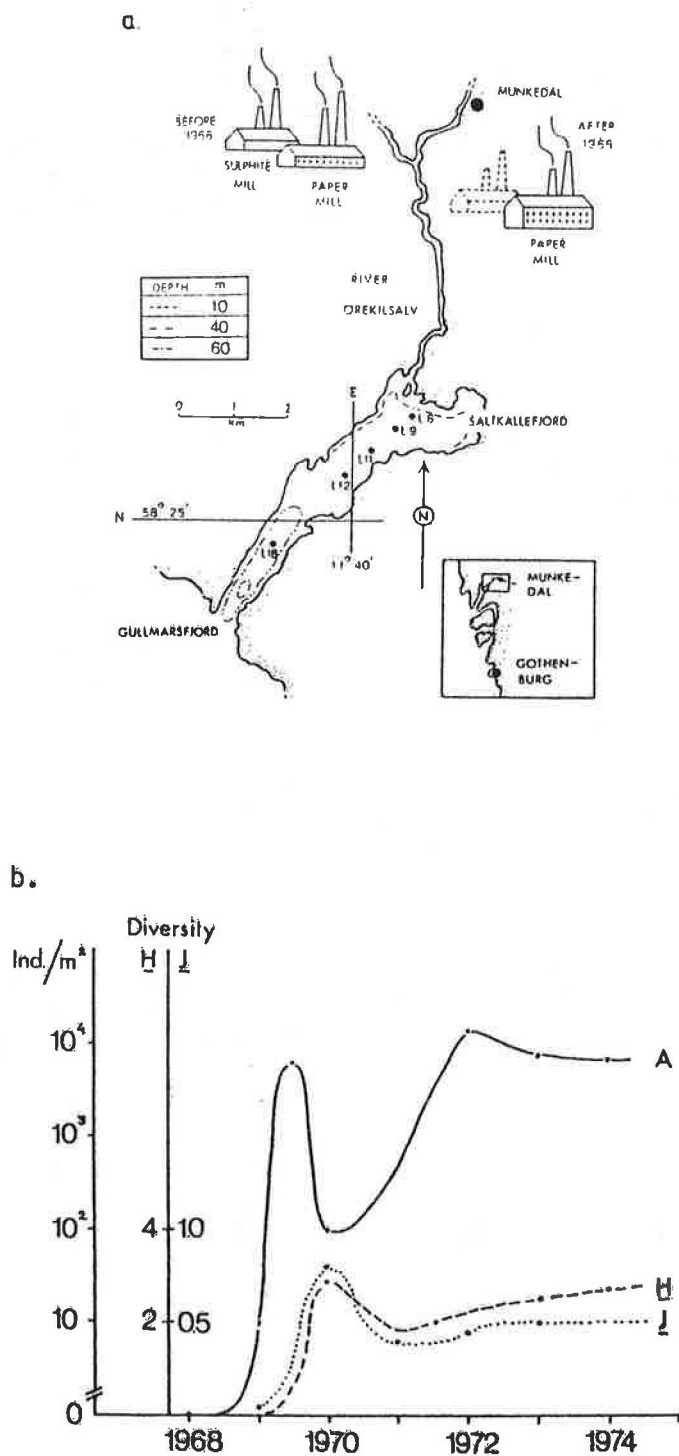


Figure 7. a. Station positions in the Saltskällefjord, W. Sweden (from Rosenberg, 1976, reproduced with permission of Oikos);

b. temporal changes in abundance (A), diversity (H) and evenness (J) (from Pearson and Rosenberg, 1978, reproduced with permission of the Oceanography and Marine Biology Annual Review, Aberdeen University Press).

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ANNEX 2

OVERVIEW OF INTERCALIBRATION/INTERCOMPARISON EXERCISES COORDINATED BY ICES

Trace Metals in Biota

First ICES Intercalibration Exercise on Trace Metals in Biological Tissue (1/TM/BT) 1972

Coordinator : G. Topping, United Kingdom.
 Sample : Fish flour prepared from commercial fish meal.
 Metals analysed: Hg, Cu, Zn, Cd and Pb.
 Participation : 8 laboratories from 7 countries around the North Sea.

Results published in Cooperative Research Report No. 80 (1978).

Second ICES Intercalibration Exercise on Trace Metals in Biological Tissue (2/TM/BT) 1973

Coordinator : G. Topping, United Kingdom.
 Samples : Fish flour prepared from unskinned muscle of inshore cod and acidified solution of metals.
 Metals analysed: Hg, Cu, Zn, Cd and Pb.
 Participation : 15 laboratories in 11 countries around the North Sea and the Baltic Sea.

Results published for North Sea laboratories in Cooperative Research Report No. 80 (1978) and for Baltic laboratories in Cooperative Research Report No. 63 (1977).

Third ICES Intercalibration Exercise on Trace Metals in Biological Tissue (3/TM/BT) 1975

Coordinator : G. Topping, United Kingdom.
 Samples : (a) Fish flour prepared from skinned muscle of distant water cod and (b) individual reference standard solutions for each metal.
 Metals analysed: Hg, Cu, Zn, Cd and Pb.
 Participation : 29 laboratories in 17 ICES member countries.

Results published for North Sea laboratories in Cooperative Research Report No. 80 (1978) and for Baltic laboratories in Cooperative Research Report No. 63 (1977).

Fourth ICES Intercalibration Exercise on Trace Metals in Biological Tissue (4/TM/BT) 1977

Coordinator : G. Topping, United Kingdom.
 Samples : Same fish flour as in 3/TM/BT.
 Metals analysed: Cd and Pb.
 Participation : 12 of the laboratories which had participated in 3/TM/BT.

Results published in Cooperative Research Report No. 108 (1981).

Fifth ICES Intercalibration Exercise on Trace Metals in Biological Tissue
(5/TM/BT) 1978.

Coordinator : G. Topping, United Kingdom.
 Samples : (a) Fish flour prepared from skinned muscle of distant water cod and (b) the same fish flour extracted to produce a lower Hg concentration.
 Metals analysed: Hg, Cu, Zn, Cd and Pb.
 Participation : 41 laboratories, including those associated with the Joint Monitoring Programme, from all 18 ICES member countries plus several laboratories in Australia.

Results published in Cooperative Research Report No. 108 (1981).

Sixth ICES Intercalibration Exercise on Trace Metals in Biological Tissue
(6/TM/BT) 1979

Coordinator : G. Topping, United Kingdom.
 Samples : (a) White meat of edible crab freeze-dried and ground into powder, (b) commercial fish meal freeze-dried and ground into powder, and (c) digestive gland of Canadian lobster treated and ground into powder.
 Metals analysed: Hg, Cu, Zn, Cd and Pb.
 Participation : 52 laboratories from 17 ICES member countries plus Australia.

Results published in Cooperative Research Report No. 110 (1981).

Seventh ICES Intercalibration Exercise on Trace Metals in Biological Tissue - Part 1
(7/TM/BT-1) 1983

Coordinators : S.S. Berman and V.J. Boyko, Canada.
 Samples : (a) Lobster hepatopancreas homogenized, spray-dried and acetone extracted, (b) scallop adductor muscle freeze-dried and ground, and (c) plaice muscle freeze-dried and ground.
 Metals analysed: Hg, Cu, Zn, Cd, As and Pb.
 Participation : 51 laboratories from 17 ICES member countries.

Results published in Cooperative Research Report No. 138 (1986).

Trace Metals in Sea Water

First ICES Intercalibration Exercise for Trace Metals in Sea Water
(1/TM/SW) 1976

Coordinator : P.G.W. Jones, United Kingdom.
 Samples : Two standard solutions of metals.
 Metals analysed: Hg, Pb, Ni, Co, Fe, Cr, Cu, Cd, Zn and Mn.
 Participation : 41 laboratories from 14 ICES member countries.

Results published in Cooperative Research Report No. 125 (1983).

Second ICES Intercalibration Exercise for Trace Metals in Sea Water
(2/TM/SW) 1976

Coordinator : J. Olafsson, Iceland.
 Samples : Two natural sea water samples and a mercury-spiked sea water sample; all acidified.
 Metal analysed : Hg
 Participation : 14 laboratories from 10 ICES member countries.

Results published in Cooperative Research Report No. 125 (1983).

Third ICES Intercalibration Exercise for Trace Metals in Sea Water
(3/TM/SW) 1977

Coordinator : P.G.W. Jones, United Kingdom.
 Samples : Two frozen samples of filtered sea water, one from open North Sea waters and one from coastal waters.
 Metals analysed: Co, Fe, Ni, Pb, Cd, Cr, Cu, Mn, and Zn.
 Participation : 49 laboratories from 14 ICES member countries.

Results published in Cooperative Research Report No. 125 (1983).

Fourth ICES Intercalibration Exercise for Trace Metals in Sea Water
(4/TM/SW) 1978

Coordinators : J.M. Bowers, J. Dalziel, P.A. Yeats, and J.L. Barron, Canada.
 Samples : Sets of six sea water samples consisting of four replicate sea water samples, one sample spiked with relevant metals and one dummy. Samples were frozen and acidified.
 Metals analysed: Cd, Cu, Mn, Fe, Ni, Pb, and Zn.
 Participation : 43 laboratories from 13 ICES member countries plus Monaco.

Results published in Cooperative Research Report No. 105 (1981).

Fifth ICES Intercalibration Exercise for Trace Metals in Sea Water
(5/TM/SW) 1982

Coordinators : J.M. Bowers, P.A. Yeats, S.S. Berman, D. Cossa, Canada; C Alzieu, P. Courau, France.
 Samples : (a) sea water samples, filtered and acidified, for analysis of metals except Hg; (b) sea water samples, natural and spiked, for analysis of Hg. In addition, 6 laboratories participated in an intercomparison of filtration procedures for coastal sea water samples.
 Metals analysed: Cd, Cu, Pb, Zn, Ni, Fe, Mn.
 Participation : 59 laboratories from 15 ICES member countries plus Monaco.

Results published in Cooperative Research Report No. 136 (1986).

Exercises on trace metals in sea water coordinated by ICES for
the Joint Monitoring Group of the Oslo and Paris Commissions (1979)

Cadmium

Coordinator : Y. Thibaud, France.
Samples : (a) Natural sea water, (b) sea water with a low Cd spike, and (c) sea water with a high Cd spike.
Participation : 33 laboratories from all 13 member countries of the Oslo and Paris Commissions plus Canada and Monaco.

Mercury

Coordinator : J. Olafsson, Iceland.
Samples : (a) two samples of natural sea water, (b) sea water with a low Hg spike, and (c) sea water with a high Hg spike.
Participation : 36 laboratories from all 13 member countries of the Oslo and Paris Commissions plus Canada, Japan and the United States.

Results of both intercalibration exercises published in Cooperative Research Report No. 110 (1981).

Trace Metals in Marine Sediments

First ICES Intercalibration Exercise for Trace Metals in Marine Sediments
(1/TM/MS) 1984

Coordinator : D.H. Loring, Canada.
Samples : (a) Estuarine calcareous sandy mud sediment, (b) harbour sediment, and (c) Baltic mud sediment "MBSS" (from Baltic Sediment Intercalibration Exercise)
Metals analysed: Cd, Cr, Cu, Ni, Pb and Zn.
Optional metals: Ti, Fe, Mn and Al.
Participation : 40 laboratories from 11 ICES member countries.

Results published in Cooperative Research Report No. 143 (1987).

Baltic Sediment Intercalibration Exercise

Step 1: Intercomparison of Analyses of Reference Samples ABSS and MBSS, 1985.

Coordinators : L. Brüggmann, German Democratic Republic and L. Niemistö, Finland.
Samples : Two mud sediments ("ABSS" and "MBSS") from different locations, dried and homogenized.
Analytes : Cu, Pb, Zn, Cd, Mn, Fe, Cr, Ni, and organic C.
Optional : Hg, Co, Al, inorganic C, P and N.
Participation : 42 laboratories from 15 ICES member countries.

Additional Exercise on Hg and Cd, 1985.

Coordinator : A. Jensen, Denmark.
 Samples : Six samples, some of which were pre-treated.
 Metals analysed: Hg and Cd.
 Participation : 8 (Hg) and 10 (Cd) laboratories from 6 countries around the Baltic Sea.

Step 2: Intercomparison of Analyses of Sliced Wet Cores, 1984.

Coordinators : L. Brüggmann, German Democratic Republic, L. Niemistö, Finland, and P. Pheiffer Madsen, Denmark.
 Samples : 20 cm cores, sliced into 1-cm slices and deep frozen.
 Main analytes : Cu, Cr, Zn, Pb, Mn, Cd, Fe, Ni, Al, Co, Hg, dry matter content, dating by Pb-210 technique.
 Optional : Cs-137, organic C, N, P, clay minerals.
 Participation : 11 laboratories from 6 countries around the Baltic Sea.

Results for the entire exercise published in Cooperative Research Report No. 147 (1987).

Organochlorines in Biological Tissue

First ICES Intercalibration Exercise for Organochlorine Residues in Biological Tissue (1/OC/BT) 1972

Coordinator : A.V. Holden, United Kingdom.
 Samples : (a) Natural fish oil and (b) same fish oil spiked with selected organochlorines.
 Analytes : pp'-TDE, pp'-DDE, pp'-DDT, PCBs, dieldrin, γ -HCH
 Participation : 9 laboratories from 7 ICES member countries.

Results published in Cooperative Research Report No. 80 (1978).

Second ICES Intercalibration Exercise for Organochlorine Residues in Biological Tissue (2/OC/BT) 1974

Coordinator : A.V. Holden, United Kingdom.
 Samples : (a) unspiked maize oil and (b) same maize oil spiked with selected organochlorines.
 Analytes : pp'-TDE, pp'-DDE, pp'-DDT, PCBs, dieldrin, γ -HCH
 Participation : 30 laboratories from 13 ICES member countries.

Results published in Cooperative Research Report No. 80 (1978) and, for Baltic laboratories, in Cooperative Research Report No. 63 (1977).

Third ICES Intercalibration Exercise for
Organochlorine Residues in Biological Tissue
(3/OC/BT) 1978.

Coordinator : A.V. Holden, United Kingdom.
Sample : Fish oil (capelin).
Analytes : pp'-TDE, pp'-DDE, pp'-DDT, PCBs, dieldrin, α -HCH, γ -HCH.
Participation : 30 laboratories from 16 ICES member countries.

Results published in Cooperative Research Report No. 108 (1978).

Fourth ICES Intercalibration Exercise for
Organochlorine Residues in Biological Tissue
(4/OC/BT) 1979

Coordinators : J.F. Uthe and C.J. Musial, Canada.
Samples : (a) Fish oil prepared from herring muscle tissue and (b) same oil
spiked with PCBs.
Analytes : PCBs
Participation : 23 laboratories from 12 ICES member countries.

Results published in Cooperative Research Report No. 115 (1982).

Fifth ICES Intercalibration Exercise for
Organochlorine Residues in Biological Tissue
(5/OC/BT) 1982

Coordinators : J.F. Uthe and C.J. Musial, Canada.
Samples : (a) Herring oil and (b) same oil spiked with individual chlorobi-
phenyls (CBs).
Analytes : Individual CBs.
Participation : 30 laboratories.

Results published in Cooperative Research Report No. 136 (1986).

Sixth ICES Intercalibration Exercise for
Organochlorine Residues in Biological Tissue
(6/OC/BT) 1983

Coordinators : L. Reutergårdh and K. Litzén, Sweden.
Samples : (a) Standard solution of 12 pure CBs, (b) solution of an internal
standard, and (c) herring oil.
Analytes : Individual CBs.
Participation : 12 laboratories.

Results to be published in Cooperative Research Report series.

Hydrocarbons in Marine Samples

First ICES Intercomparison Exercise on Petroleum Hydrocarbons in Marine Samples (1/HC/BT and 1/HC/MS) 1980

Coordinators : R.J. Law and J.E. Portmann, United Kingdom.
 Samples : (a) Crude oil standard, (b) aliphatic fraction of crude oil standard, (c) marine sediment, and (d) mussel homogenate.
 Analytes : Total hydrocarbons, aliphatic hydrocarbons (nC_7 - nC_{33}), and several aromatic hydrocarbons.
 Participation : 36 laboratories from 12 ICES member countries and Bermuda.

Results published in Cooperative Research Report No. 117 (1982).

ICES/IOC Intercomparison Exercise on Petroleum Hydrocarbons in Biological Tissues (2/HC/BT) 1984

Coordinators : J.W. Farrington, A.C. Davis, J.B. Livramento, C.H. Clifford, N.M. Frew, A. Knap, United States.
 Samples : (a) Three samples of frozen, freeze-dried mussel homogenate, (b) reagent grade chrysene, (c) methylene chloride solution of n-alkanes, (d) methylene chloride solution of aromatic hydrocarbons, and (e) Arabian Light Crude Oil standard.
 Analytes : Aliphatic hydrocarbons (nC_{15} - nC_{32}) and selected aromatic hydrocarbons.
 Participation : 38 laboratories from 13 ICES member countries and 12 laboratories from 11 IOC member countries (most, if not all, ICES member countries are also members of IOC).

Results published in Cooperative Research Report No. 141 (1986).

Third ICES Intercomparison Exercise on Polycyclic Aromatic Hydrocarbons in Biological Tissue (3/HC/BT) 1984

Coordinators : J.F. Uthe, C.J. Musial, and G.R. Sirota, Canada.
 Samples : (a) Acetone powder of lobster digestive gland, and (b) the oil extracted during the preparation of this powder.
 Analytes : 21 selected polycyclic aromatic hydrocarbons.
 Participation : 11 laboratories from 7 ICES member countries.

Results published in Cooperative Research Report No. 141 (1986).

ANNEX 3

RECENTLY PUBLISHED RELEVANT COOPERATIVE RESEARCH REPORTS

No.	Title
150	Report of the ICES Advisory Committee on Marine Pollution, 1987
151	Results of 1985 Baseline Study of Contaminants in Fish and Shellfish
152	ICES Sixth Round Intercalibration for Trace Metals in Estuarine Water (JMG 6/TM/SW)
154	Report of the <u>ad hoc</u> Study Group on "Environmental Impact of Mariculture"
155	The Status of Current Knowledge on Anthropogenic Influences in the Irish Sea
156	Marine Environmental and Water Quality Models
160	Report of the ICES Advisory Committee on Marine Pollution, 1988
162	Statistical Analysis of the ICES Cooperative Monitoring Programme. Data on Contaminants in Fish Muscle Tissue (1978-1985) for Determination of Temporal Trends
163	Baltic Sea Patchiness Experiment -- PEX '86 -- Volumes 1 and 2
165	Current Meter Data Quality
166	Methodology of Fish Disease Surveys

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ACRONYMS

ADP	- Automatic Data Processing
BCR	- Community Bureau of References of the Commission of the European Communities
BMP	- Baltic Monitoring Programme (under the Helsinki Commission)
CBs	- Chlorobiphenyls
CMP	- Coordinated ICES Monitoring Studies Programme
GEEP	- IOC/UNEP Group of Experts on the Effects of Pollutants
GESAMP	- Group of Experts on the Scientific Aspects of Marine Pollution (sponsored by a number of UN agencies)
IOC	- Intergovernmental Oceanographic Commission
JMP	- Joint Monitoring Programme of the Oslo and Paris Commissions
PAH	- Polycyclic aromatic hydrocarbons
PEX	- Joint Multi-Ship Investigation on Patchiness in the Baltic Sea

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Indication of spine colours

Reports of the Advisory Committee on Fishery Management	Red
Reports of the Advisory Committee on Marine Pollution	Yellow
Fish Assessment Reports	Grey
Pollution Studies	Green
Others	Black

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