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ICES ADVISORY COMMITTEE ON THE MARINE ENVIRONMENT

LIST OF MEMBERS

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R. Law		Chair, MCWG
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Secretariat members participating in the meeting or portions thereof:

D. Griffith	ICES General Secretary
M. Sørensen	Data Manager

EXECUTIVE SUMMARY

The ICES Advisory Committee on the Marine Environment (ACME) met from 3 to 7 June 2002. As part of its work during this period, the ACME prepared responses to the requests made to ICES by the OSPAR Commission and the Helsinki Commission. This report contains these responses. In addition to responses to direct requests, this report summarizes the deliberations of ACME on topics for which advice was not directly requested but for which the ACME felt that there was information that would be of interest to the Commissions, ICES Member Countries, and other readers of this report.

As a result of the creation of the Advisory Committee on Ecosystems (ACE), several topics previously handled by ACME have been moved to the remit of ACE and scientific information and advice on these topics can be found in the ACE report for 2002. The topics covered include ecosystem effects of fishing, ecological quality objectives, ecosystem modelling and assessment, marine mammals issues, biodiversity issues, and marine habitat classification and mapping.

Advice or information in direct response to requests from, or which is relevant to, the work of both the OSPAR Commission and the Helsinki Commission

Monitoring

In 2002, the ACME continued work on the development of biological effects monitoring programmes. The ACME reviewed the activities of the Sea-going Workshop on Pelagic Biological Effects Methods that was conducted during 2001 (Section 4.1.1) and considered biological effects measures to complement EU Water Framework Directive monitoring (Section 4.1.3). The ACME also reviewed new effects techniques in molecular biology (Section 4.1.2) and progress with the project on Biological Effects of Environmental Pollution in Marine Coastal Ecosystems (BEEP) (Section 4.1.4).

In continuation of guidelines for monitoring contaminants in marine sediments, the ACME reviewed a technical annex on metal analyses in sediments, but did not accept it for use in ICES as it provided for the use of a method that has not been tested on a broad geographical scale (Section 4.2.1). The ACME also gave initial consideration to procedures for monitoring temporal trends of contaminants in sediments (Section 4.2.3) and continued its review of national sediment quality criteria (Section 4.2.2).

The ACME reviewed new information on statistical considerations relative to monitoring programmes (Section 4.3). Further advice for OSPAR on smoothers for use in the trend analysis of monthly monitoring data on inputs of nutrients and contaminants to the marine environment is provided in Section 4.3.1, with details in Annexes 1 and 2. In continuation of advice from 2001, advice on appropriate sampling schemes for the detection of hotspots of contamination in the marine environment is also provided (Section 4.3.3 and Annex 3).

Quality Assurance and Intercomparison Exercises

In relation to the quality assurance of biological measurements in the Baltic Sea, the ACME reviewed the results of the work on this topic during the past year and provided advice for the Helsinki Commission (Section 5.1). This advice includes the recommendation that QA measures for biological monitoring procedures be implemented and harmonized in the institutes and countries around the Baltic Sea.

For the OSPAR area, the ACME adopted the Guidelines for Quality Assurance of Biological Measurements for use in ICES and transmitted them to OSPAR for use within the OSPAR Area (Section 5.2). These guidelines describe the QA system in relation to survey objectives and design, and contain more detailed QA guidance for every step in sample treatment from sampling to data handling. They cover the monitoring of chlorophyll *a*, phytoplankton, macrozoobenthos, and macrophytobenthos. Consideration is also given to accreditation schemes for the quality assurance of biological studies and the applicability of analytical quality control criteria for evaluating the acceptability of biological monitoring data.

In Section 5.3, the outcome of the EU-funded project Biological Effects Quality Assurance in Marine Monitoring (BEQUALM) is reviewed in relation to the quality assurance requirements of the biological effects monitoring techniques that have been selected for ultimate inclusion in the OSPAR Coordinated Environmental Monitoring Programme (CEMP). Advice is provided identifying the methods for which limits of variability have been attained that are acceptable for adoption of the method in the CEMP.

With regard to chemical measurements, further progress has been made in the development of additional technical annexes for the "Guidelines on Quality Assurance of Chemical Measurements in the Baltic Sea", that were initially prepared in 1997 for the monitoring programmes carried out under the Helsinki Commission (Section 5.4). One additional Technical Note, on Measurement Uncertainty of Analytical Methods, was completed and adopted, while several others are in preparation. Work has also continued, based on work started in 2001 in response to requests from OSPAR and HELCOM, on the development of quality criteria to be employed in reviewing monitoring data prior to their use in the preparation of data products for environmental assessments (Section 5.5 and Annexes 4 and 5).

Contaminants in the Marine Environment

The ACME reviewed the OSPAR List of Chemicals for Priority Action and provided initial advice on the state of the analytical methodology for analysing each chemical, or group of chemicals, in marine environmental samples (Section 7.1). A brief review is also provided of other priority lists from international or regional organizations.

New information is provided on the following contaminants: 1) dioxins, furans, and dioxin-like CBs (Section 7.2.1); 2) *tris*(4-chlorophenyl)methanol (TCPM) and *tris*(4-chlorophenyl)methane (TCPMe) (Section 7.2.2); 3) polybrominated diphenylethers (PBDEs) (Section 7.2.3); and 4) toxaphene (Section 7.2.4). There is a need to obtain additional data on the occurrence of these contaminants in the marine environment and, in furtherance of this, ICES recommends to OSPAR to consider the inclusion of PBDEs in the JAMP programme, as validated methods for their determination are now available.

Ecological Quality Objectives with regard to Nutrients and Eutrophication Effects in the North Sea

An overview of the progress in relation to the establishment of ecological quality objectives on nutrients and eutrophication effects in the North Sea is provided, along with advice concerning further work that will be needed in relation to the development of operational ecological quality elements and objectives on these issues (Section 6.5).

Environmental State Indicators

In response to a request from OSPAR, the ACME considered the issue of data products for trace metals, organic contaminants, and eutrophication in relation to environmental state indicators. While there is clearly a need for the development of indicators of environmental status to present complex data in a more understandable way for the public and politicians, the ACME advises that the aims of such indicators first need to be clearly stated. As this request was not accompanied with a clear statement of the exact use and purpose of the data products, it had not been possible for the relevant ICES Working Groups to prepare a draft response to this request for consideration by ACME (Section 6.6).

Several draft indicator fact sheets prepared by the European Environment Agency were reviewed (Section 6.7), and a number of comments were provided on the further elaboration of these fact sheets.

Effects of Extraction of Marine Sand and Gravel on Marine Ecosystems

The ACME reviewed marine extraction activities in ICES Member Countries during 2001 and the results of assessments of the environmental effects of marine extraction activities, as summarized in Section 12.2. Progress on the development of methods to assess localized impacts from aggregate extraction on fisheries was reviewed in Section 12.3.

New ICES Guidelines for the Management of Marine Sediment Extraction are adopted (Section 12.1 and Annex 7), which replace the previous ICES Code of Practice on Commercial Extraction of Marine Sediments and the ICES Guidelines for Environmental Impact Assessment of Marine Aggregate Dredging.

Report sections responding to requests specific to the OSPAR Commission

Pilot Assessment Integrating Input Data and Environmental Concentrations

Preliminary advice covering the initial work done on a pilot assessment integrating input data and environmental concentrations is given in Section 6.2. To further develop this work, it is advised that OSPAR organize a meeting of policy-makers and relevant experts (chemists, statisticians, and modellers) to discuss the objectives of such joint assessments and develop a statistical framework for these assessments.

Eutrophication Status of the Marine Area

Advice in relation to data products for developing the OSPAR Common Procedure for Identification of the Eutrophication Status of the Maritime Area is presented in Section 14.3. This includes a proposal that consideration be given to the usefulness of calculating nutrient budgets based on the approach being developed within LOICZ (Land-Ocean Interactions in the Coastal Zone).

Data Handling

The annual review of data handling activities by the ICES Marine Data Centre on contaminants data relevant to the requirements of OSPAR, HELCOM, and AMAP is contained in Section 14.1 of this report. This section also includes a brief overview of the structure of the new environmental database in ICES. Section 14.2 summarizes the work of the ICES Marine Data Centre in handling nutrients data relevant to the OSPAR programmes. A brief review of the implementation of the biological community databases for phytoplankton, zooplankton, phytobenthos, and zoobenthos is given in Section 14.5. Progress in the further development of reporting formats for data obtained using the biological effects techniques adopted by OSPAR is noted in Section 14.6.

Report sections responding to requests specific to the Helsinki Commission

Statistical Considerations in relation to the Calculation of Background Concentrations of Contaminants

Two approaches, a parametric and a non-parametric, were considered in relation to the estimation of a concentration level for a defined percentile point of a population, as a means of determining background concentrations of contaminants in the marine environment. As both of these approaches have drawbacks, ICES advises further investigation of a hybrid approach, including the use of appropriate data and clearly stated goals for statistical assessments (Section 6.4).

Data products on nutrients in the Baltic Sea

ICES has prepared a website that provides an inventory of data on nutrients in the Baltic Sea, including tables with the numbers of measurements of each parameter at Baltic Monitoring Programme stations, and a facility to plot temporal trends of mean concentrations. This is reviewed in Section 14.4.

Report section responding to work requested by the Arctic Monitoring and Assessment Programme (AMAP)

An overview of the outcome of a temporal trend assessment of AMAP data on heavy metals in Arctic biota is contained in Section 6.1. This assessment evaluated possible temporal trends in the concentrations of mercury, cadmium, and lead in a number of species of Arctic biota, including terrestrial mammals, freshwater fish, and marine fish, birds, and invertebrates.

Advice and information on topics of general interest

Fish Diseases

An overview of new trends in the occurrence of diseases in wild and farmed fish and shellfish stocks is contained in Section 8.1. Viral Haemorrhagic Septicaemia virus has been isolated from a large number of marine fish species in the North Sea, the Skagerrak, the Kattegat and the Baltic Sea, as well as along the Pacific coast of the USA and Canada. Outbreaks of this virus in sea-reared rainbow trout in Finland and the Åland Islands occurred in 2001, but apparently the sources of the two outbreaks are different.

The M74 syndrome in Baltic salmon continues to occur at high levels, with the average prevalence in Swedish and Finnish rivers during 2001 at nearly 31 % (Section 8.2). Nodavirus infection has caused serious problems in many fish species that are of importance for aquaculture; much work needs to be done before effective control measures such as vaccines are developed (Section 8.3). Infectious Pancreatic Necrosis, a viral infection affecting the pancreatic tissue of fish, is having a significant impact on salmon aquaculture in Scotland and Norway; research is required on preventive measures and improved management strategies (Section 8.4).

The ACME considered the results of studies on the relationship between environmental contaminants and shellfish pathology (Section 8.5 and Annex 6). With the exception of data on imposesx/intersex conditions in marine gastropod species following exposure to tributyltin compounds, information on the relationship between environmental contaminants and pathological disorders in marine shellfish is limited.

Introductions and Transfers of Marine Organisms

The ACME reviewed information on the imports of live aquatic species in ICES Member Countries for aquaculture, restocking, and live food sales (Section 9.1). The most commonly moved species in 2001 were Atlantic salmon (*Salmo salar*) and Pacific oysters (*Crassostrea gigas*). Selected examples of current invasions of non-indigenous species, such as the red king crab in northern Norway and the toxic alga *Pfiesteria piscicida* on the east coast of the U.S.A., were also assessed (Section 9.3).

A revised Code of Practice on the Introductions and Transfers of Marine Organisms, to update the 1994 Code of Practice, was considered but not adopted (Section 9.2). It is anticipated that this will be completed in 2003.

Issues relevant to the transfer of organisms via ships' ballast water and hulls are reviewed in Section 9.4. This material includes an assessment of the types of ship vectors in relation to the introduction of non-native species, and a review of ballast water control and management technologies.

Marine Biological Communities, Processes, and Responses

Summaries of progress in the North Sea Benthos Project and progress in studies of phytoplankton responses to enhanced nutrient inputs, zooplankton responses to climate change, and harmful algal bloom dynamics are reported in Sections 10.1, 10.2, 10.5,and 10.4, respectively. The ACME considered the scientific and operational merits of including primary production measurements and zooplankton studies in eutrophication monitoring programmes and advised against including such measurements in monitoring programmes in relation to regulatory requirements at the present time (Section 10.6).

The outcome of the Workshop on Contrasting Approaches to Understanding Eutrophication Effects on Phytoplankton (The Hague, March 2002) was reviewed and ACME endorsed the consensus conclusions of this workshop (Section 10.3).

Environmental Assessments

Contributions to the ICES Environmental Status Report for 2002 have been made concerning oceanographic conditions (Section 6.8.1 and http://www.ices.dk/status/clim0001), zooplankton (Section 6.8.2), harmful algal blooms (Section 6.8.3 and http://www.ices.dk/status/decadal/), and fish and shellfish disease prevalence (Section 6.8.4 and http://www.ices.dk/status/fish_and_shellfish_diseases/index.htm).

Issues Related to Mariculture

With regard to the potential environmental interactions of mariculture, the ACME prepared information and advice concerning the need for proper regulatory management and monitoring of mariculture operations (Section 11.1). Specifically with regard to large-scale shellfish farm developments, the ACME recommends the adoption of interim guidelines for the preparation of Environmental Impact Statements and Environmental Reports, as provided in Section 11.2.1, with regard to the development of marine shellfish farms. Advice is also provided for the development of guidelines for monitoring large-scale shellfish cultures (Section 11.2.2).

In Section 11.3, information and advice is provided concerning issues in relation to the sustainability of mariculture, including interactions between mariculture and other users of resources in the coastal zone. It is recommended that ICES Member Countries (who have not yet done so) adopt Codes of Conduct for responsible aquaculture.

An overview of chemicals used in mariculture is provided in Section 11.4, with a review of the trends in use of these chemicals in several ICES Member Countries.

Global Programmes

The ACME reviewed recent activities by ICES for the North Atlantic in relation to the Global Ocean Observing System (GOOS), particularly the plans for an ICES-EuroGOOS North Sea Ecosystem Pilot Project (NORSEPP) (Section 13). This pilot project will initially concentrate on physical oceanography in relation to fish stocks.

Sources of Information Considered by the ACME at its 2002 Meeting

At its 2002 meeting, the ACME considered, *inter alia*, information included in the most recent reports of the following ICES groups:

BEWG	Benthos Ecology Working Group
MCWG	Marine Chemistry Working Group
PGNSP	ICES-EuroGOOS Planning Group on the North Sea Pilot Project
SGBOSV*	ICES/IOC/IMO Study Group on Ballast and Other Ship Vectors
SGGOOS	ICES/IOC Steering Group on GOOS
SGQAB*	ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea
SGQAC*	ICES/HELCOM Steering Group on Quality Assurance of Chemical Measurements in the Baltic Sea
SGQAE*	ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements related to Eutrophication Effects
SGPOP*	ICES/AMAP Study Group for the Assessment of AMAP POPs and Heavy Metals Data
WGBEC	Working Group on Biological Effects of Contaminants
WGECO	Working Group on Ecosystem Effects of Fishing Activities
WGEXT	Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem
WGHABD	ICES/IOC Working Group on Harmful Algal Bloom Dynamics
WGITMO*	Working Group on Introductions and Transfers of Marine Organisms
WGMS	Working Group on Marine Sediments in Relation to Pollution
WGPDMO	Working Group on Pathology and Diseases of Marine Organisms
WGPE	Working Group on Phytoplankton Ecology
WGSAEM	Working Group on Statistical Aspects of Environmental Monitoring
WGZE	Working Group on Zooplankton Ecology

*These groups report directly to ACME.

1 INTRODUCTION

The Advisory Committee on the Marine Environment (ACME) is the Council's official body for the provision of scientific advice and information on the status and outlook for the marine environment, including contaminants, as well as a range of other environmental issues, as may be requested by ICES Member Countries, other bodies within ICES, relevant regulatory Commissions, and other organizations.

In handling the requests, the ACME draws on the expertise of its own members and on the work of various expert ICES Working Groups and Study Groups. The ACME considers the reports of these groups and requests them to carry out specific activities or to provide information on specific topics.

The ACME report is structured in terms of the topics covered at the ACME meeting on which it has prepared scientific information and advice.

The topics include both those for which information or advice has been requested by the Commissions or other bodies and those identified by the ACME to enhance the understanding of the marine environment.

Information relevant to the Commissions' requests and specific issues highlighted by the ACME for their attention are summarized in Section 2 for the OSPAR Commission and in Section 3 for the Helsinki Commission, where the individual work items from each Commission are listed and related to relevant sections of the main text.

In 2000, the Council created a new Advisory Committee on Ecosystems (ACE), with the primary responsibility to provide scientific information and advice on the status and outlook for marine ecosystems, and on exploitation of living marine resources in an ecosystem context. Accordingly, some of the issues that ACME has previously considered have been transferred to ACE. Thus, the ACME report will no longer contain sections on issues regarding seabirds or marine mammals, unless the material pertains to contaminants and their effects, nor on marine habitat classification and mapping or ecosystem assessment.

A summary of the progress on the 2002 programme of work requested by the OSPAR Commission is given below, along with reference to the relevant sections and annexes of this report where more detailed information can be found. This summary is provided according to the format of the Work Programme, with the questions on the Work Programme shown in italics and a summary of the ICES advice below in normal print.

SCIENTIFIC ADVICE

1 QUALITY ASSURANCE (QA)

1.1 To operate a joint ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements in the Northeast Atlantic in order to coordinate the development of QA procedures and the implementation of QA activities.

A summary of progress in the work of the ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements in the Northeast Atlantic (SGQAE) is provided in Section 5.2 of this report. SGQAE has completed the Guidelines for Quality Assurance of Biological Measurements in the OSPAR Area. These guidelines describe the various steps in the QA procedure, including critical QA factors and priority QA actions for monitoring chlorophyll *a*, phytoplankton, macrozoobenthos, and phytobenthos. Relevant OSPAR subsidiary bodies reviewed the final draft of these guidelines during 2002, so they have now been adopted for use in both OSPAR and ICES. The guidelines will be published in the *ICES Techniques in Marine Environmental Sciences* series.

Fruitful cooperation has been established between SGQAE and the ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea (SGQAB), as well as with other bodies dealing with quality assurance and standardization of methodology related to biological monitoring.

2 ASSESSMENT TOOLS

2.1 Participate in the joint assessment of concentration and input data to apply the trend assessment procedure.

The precise requirements of OSPAR in relation to this request were not made clear to ICES, however, a partial response has been presented in Section 6.2 of this report, in which reviews of several of the documents presented at meetings of OSPAR subsidiary bodies have been compiled. In addition, this section presents a simple, general model that could be used to begin to establish a more explicit link between inputs and concentrations in the marine environment, for example, in sediments.

A clearer statement of the objectives of joint assessments is required to take this issue forward. Furthermore, this is a substantial task, which will require considerably more time and data to be able to develop relationships between input data and environmental levels of contaminants.

3 FURTHER DEVELOPMENT OF THE COMPREHENSIVE PROCEDURE OF THE COMMON PROCEDURE

3.1 Provide assistance in the preparation of data products based on the relevant data series available in ICES databanks, for inclusion in an assessment report of the eutrophication status of the OSPAR maritime area.

The work on this request is mainly conducted by the ICES Secretariat and the ICES Marine Data Centre. A brief review of this issue by ACME is presented in Section 14.3 of this report.

DATA HANDLING

4 DATA HANDLING ACTIVITIES

To carry out data handling activities relating to:

4.1 contaminant concentrations in biota and sediments;

4.2 measurements of biological effects;

4.3 the implementation of the Nutrient Monitoring Programme;

4.4 data on phytobenthos, zoobenthos and phytoplankton species.

The ICES Marine Data Centre has handled all data submitted in 2001, covering monitoring activities in 2000. However, although the Biological Data Reporting Format has been available for use since May 2001, no biological data have yet been submitted for OSPAR purposes. For data on nutrients, there have been few data submissions for the past few years. Further information is contained in Section 14 of this report.

5 Provide advice on data products in relation to the preparation of indicators

5.1 advise on what data products might be produced as a basis for indicators to be decided upon in the light of the conclusions of the IRF workshop;

5.2 undertake the preparation of such data products based on data submitted under 4.1 *and 4.3 above relevant for use in the development of indicators.*

Unfortunately, the conclusions of the Inter-Regional Forum Workshop on Indicators did not provide an adequate basis for determining data products that should be suitable for use as a basis for relevant indicators. The ACME discussion of this topic is contained in Section 6.6, with some considerations regarding statistical aspects relevant to the development of environmental indicators contained in Section 6.7.

In order to progress this issue further, the ACME proposes that a workshop be held on this topic, bringing together persons with the relevant expertise from OSPAR, ICES, and possibly also HELCOM, to agree on the objectives and use of such indicators and decide on their precise nature.

In addition, given the close relationship between environmental indicators and Ecological Quality Objectives, the discussion in Section 10 of the 2002 report of the ICES Advisory Committee on Ecosystems (ACE) is relevant.

6 Continue with the development of a relational database for data on contaminants in biota, sediments and water to cover the following issues:

6.1 Conversion to relational database;

6.2 Conversion of screening program;

6.3 User-friendly data and information import/export facilities;

6.4 Development of programs for data products, including web inventories.

Considerable work on the development of the relational database for data on contaminants in marine media and biological effects of contaminants has been conducted during the past year. This has particularly focused on the development of the requirements for the addition of data on biological effects of contaminants (see Section 14.6) and the conversion of the screening program to the new system.

Additional requests

In addition to the requests in the 2002 work programme from OSPAR, ICES received two special requests from OSPAR during 2002.

The first of these extra requests was received in January 2002 and concerned an assessment by ICES of the data on which the justification of the OSPAR Priority List of Threatened and Declining Species and Habitats will be based. The relevant material, as supplied by OSPAR, was reviewed by a number of ICES Working Groups and ultimately by ACE. The response to OSPAR is contained in Section 6 and Annex 1 of the 2002 ACE report.

The second extra request was received in April 2002, requesting ICES to review and comment on the revised Joint Assessment and Monitoring Programme (JAMP) and advise where ICES work might contribute to the preparation of specific JAMP products, develop synergy between ICES and OSPAR programmes, and identify gaps in the context of provision of an overall assessment of the quality of the marine environment. Given that the request was received after all relevant ICES Working Groups had met for 2002, the JAMP was reviewed by ACME directly. The full review has been sent to the OSPAR Secretariat.

3 PROGRESS ON TASKS FOR THE HELSINKI COMMISSION

The present status of work on the 2002 requests by the Baltic Marine Environment Protection Commission (Helsinki Commission) is given below, along with reference to the relevant sections and annexes of this report where more detailed information can be found. The requests are shown in italics and a summary of the ICES advice is then given in normal print.

CONTINUING RESPONSIBILITIES

1) *To coordinate quality assurance activities on biological and chemical measurements in the Baltic marine area and report routinely on planned and ongoing ICES intercomparison exercises, and to provide a full report on the results.*

Progress in the development of quality assurance procedures for biological measurements in the Baltic Sea is summarized in Section 5.1 of this report. In particular, the ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea (SGQAB) reviewed QA issues in relation to phytoplankton monitoring. A checklist on phytoplankton species in the Baltic Sea has now been completed, and this checklist has been included in the ICES biological community database to support the submission of HELCOM phytoplankton data.

Based on the work of SGQAB, ICES recommends that HELCOM consider the possibility of upgrading the category of phytobenthos monitoring from main parameter to core parameter in the COMBINE programme.

As summarized in Section 5.4 of this report, the ICES/HELCOM Steering Group on Quality Assurance of Chemical Measurements in the Baltic Sea (SGQAC) has finalized the Technical Notes on Measurement Uncertainty of Analytical Methods for inclusion in the COMBINE Manual. Several additional Technical Notes are in preparation, particularly for QA in relation to the measurement of organic contaminants in sediments and biota, and several current Technical Notes are being considered for revision in the light of further developments in methodology.

The current Guidelines for Quality Assurance of Chemical Measurements in the Baltic Sea will be published in the *ICES Techniques in Marine Environmental Sciences* by the end of 2002.

2) *To evaluate every third year the populations of seals and harbour porpoise in the Baltic marine area, including the size of the populations, distribution, migration, reproductive capacity, effects of contaminants and health status, and additional mortality owing to interactions with commercial fisheries (by-catch, intentional killing).*

   Being aware of that the next report will be reported 2004, and that the evaluation is based on annual submission of data to ICES from ICES member states and other data submitted to ICES.

   This is a triennial evaluation, which is next scheduled to take place in 2003.

3) *Based on the outcome of the HELCOM WORKSHOP on New reporting requirements and working practices of HELCOM MONAS, 30–31 October 2000 in Göteborg, Sweden, the second meeting of HELCOM MONAS recognized nutrients as essential eutrophication indicators.*

   As ICES will receive all the 2000 HELCOM hydrographic and hydrochemical data from the contracting parties in May 2001, the Meeting proposed that ICES in cooperation with Denmark should consider the possibilities to meet the requirements to:

   - *download the DAS program from Stockholm University and make maps of the geographical distribution of winter inorganic nutrient concentrations and summer TN and TP concentrations 2000 in the whole Baltic Sea area;*
   - *make plots from representative stations (at least one station per basin, also coastal and/or hot spot stations) of the measurements in relation to average seasonal variation;*
   - *analyse the trends in winter nutrient concentrations at the representative stations; and*
   - *report the outcome of the work at the MONAS 3 meeting.*

In response to this request, a web-based product has been prepared, as described in Section 14.4 of this report. This product will be further refined based on comments from HELCOM subsidiary bodies and Baltic scientists that make use of this product. This product is accessible on the ICES website at: http://www.ices.dk/ocean/asp/helcom/helcom.asp.

5) *From HELCOM's point of view biotope mapping is a useful instrument for collecting information on biotopes and habitats of the Baltic Sea. There is, however, a need to coordinate and, as appropriate, to harmonize the methods used for marine biotope mapping in the different Baltic Sea countries.*

The response to this request is contained in Section 5 of the 2002 report of the ICES Advisory Committee on Ecosystems (ACE). To pursue this issue further, ICES recommends that funding be found to support the conduct of a workshop, which should be attended by representatives of all countries around the Baltic Sea, to discuss and agree on a classification system for the Baltic marine environment. This can consider the European Nature Information System (EUNIS) in terms of its potential usefulness for the Baltic Sea.

4 MONITORING TECHNIQUES AND GUIDELINES

4.1 Biological Effects Monitoring

4.1.1 Sea-Going Workshop on Pelagic Biological Effects Methods

Request

This is part of continuing ICES work to review progress regarding studies investigating biological effects of contaminants in the marine environment and to develop tools to be applied in marine environmental monitoring programmes. This issue is of particular relevance for national and international regulatory Commissions assessing environmental impacts of offshore oil and gas industries.

Source of the information presented

The 2002 report of the Working Group on Biological Effects of Contaminants (WGBEC) and ACME deliberations.

Status/background information

The ICES Workshop on Biological Effects of Contaminants in Pelagic Ecosystems (BECPELAG) was initiated by the ICES Working Group on Biological Effects of Contaminants (WGBEC) and organized by the ICES Steering Group for a Sea-going Workshop on Pelagic Biological Effects Methods (SGSEA). The planning and management of the Workshop was carried out by a Scientific Steering Committee, chaired by K. Hylland (Norway), and consisting of experts from ICES Member Countries, including a representative from the Norwegian oil industry. The major aims of the Workshop are to study biological effects of contaminants in pelagic ecosystems and to assess the usefulness of various biological effects techniques along contaminant gradients in two geographical regions, the Statfjord area in the northern North Sea and the German Bight.

A detailed overview of the BECPELAG objectives and its components (sampling of pelagic organisms in the field, cage exposure experiments with cod, three-spined stickleback, and blue mussels, bioassays, chemical analyses) was provided in the 2001 SGSEA report (ICES, 2001a). A progress report, including an overview of the accepted biological effects methods, was included in the 2001 ACME report (ICES, 2001b).

At its 2002 meeting, WGBEC reviewed the progress made since its 2001 meeting. The practical BECPELAG field work was finalized in autumn 2001 and all samples have been distributed to the institutes participating in the Workshop for further analyses (for more details, see Table 4.1.1.1).

Table 4.1.1.1. Present status of the work carried out in the BECPELAG Workshop.

Activity	Species/sample	Locations
Field work finalized	Herring collected	German Bight, Statfjord reference site
	Saithe collected	Statfjord sites
	Mackerel collected	All sites (autumn cruise)
	Zooplankton, fish larvae, fish embryos	All sites (not all same species of fish larvae)
Cages retrieved	Cod	11–30 at each site
	Blue mussels	Norwegian, Irish all sites
	SPMDs	All sites except Statfjord 2
	DGTs	All sites, but one lost
Samples distributed	All biological samples	
	All extracts	SPMD and produced water
	All chemistry samples	Under analysis at NIVA and IMR

Note: SPMDs: Semi-permeable membrane devices;
DGTs: Diffusive Gradient in Thin film.

Most of the activities proceeded according to plan, but there had been some problems. Caged stickleback did not survive at any site. Semi-permeable membrane devices (SPMDs) were not deployed at one of the sites in the Statfjord transect due to logistic problems and one Diffusive Gradient in Thin film (DGT) was lost.

A central database has been established at the University of Bremen, Germany, where all data generated by institutes participating in the Workshop are maintained and are statistically analysed in a comprehensive overall assessment. The objectives of this assessment are: 1) to identify common characteristics in the biological responses measured utilizing various techniques, 2) to quantify the role of contaminants and other factors (including hydrography and hydrodynamics) and, ultimately, 3) to identify a suite of sensitive biological effects techniques that can be recommended for future programmes for monitoring biological effects of contaminants in pelagic ecosystems.

It is intended that the BECPELAG results will be published in a special issue of a common peer-reviewed publication series and serve as a document for use as background to establish future monitoring programmes. More information about SGSEA/BECPELAG can be found at http://www.niva.no/pelagic/web.

Recommendations

ICES recommends that Member Countries and relevant regulatory Commissions take note of the progress made with regard to the ICES Workshop on Biological Effects of Contaminants in Pelagic Ecosystems (BECPELAG). The results are considered to be of particular relevance for the activities associated with the OSPAR Strategy on Environmental Goals and Management Mechanisms for Offshore Activities.

Additional comments

The ACME appreciated the progress made regarding the BECPELAG Workshop and emphasized that it constitutes a major ICES activity related to the study of biological effects of contaminants in marine ecosystems. The ACME is convinced that the results of the Workshop will be of great interest to ICES Member Countries, national and international regulatory Commissions, and the offshore industry.

References

ICES. 2001a. Report of the Steering Group for a Sea-going Workshop on Pelagic Biological Effects Methods (SGSEA). ICES CM 2001/E:01, 38 pp.

ICES. 2001b. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report, 248: 5–7.

4.1.2 Applicability for marine monitoring of new biological effects techniques in molecular biology

Request

This is part of continuing ICES work to improve the tools available for monitoring contaminants and their effects in the marine environment.

Source of the information presented

The 2002 report of the Working Group on Biological Effects of Contaminants (WGBEC) and ACME deliberations.

Status/background information

WGBEC reviewed a presentation on the potential application of high throughput gene expression profiling technologies in marine ecotoxicology. The presentation described the types of molecular techniques required to develop fish gene arrays (also known as DNA microarrays) specifically for determining toxicant-related gene expression changes (toxicogenomics). The paper also provided information on how gene array programmes can be initiated in species that are not model genetic organisms and therefore lack extensive genome sequence information. This was followed by a presentation on how such an approach has been adopted by the UK to develop a toxicology-focused gene array for the European flounder (*Platichthys flesus*).

WGBEC discussed the potential application of gene array technologies to environmental monitoring. Consideration was also given to integrating population genetics studies with current biomonitoring programmes.

The *Platichthys flesus* DNA microarray project

The development of a DNA array for flounder (*Platichthys flesus*) provides a relatively new technology for measuring gene expression levels by DNA microarrays. DNA microarrays allow the expression of hundreds to many thousands of genes to be monitored simultaneously. They thereby provide a broad integrated picture of the way an organism responds to changes in an environment (e.g., following toxicant exposure). The actual technology behind DNA microarrays is not new; it is based on the same hybridization principle as is used in traditional Northern blotting procedures. However, recent advances have facilitated the miniaturization of the hybridization arrays and, thus, the development of gene arrays capable of containing many thousands of gene probes on a substrate approximately the size of a microscope slide.

Generation of flounder-specific gene sequences

To date, microarray analyses have been applied almost exclusively to model species for which gene sequence data are abundant. At the onset of the *P. flesus* DNA microarray project, there was a paucity of suitable gene sequences available for inclusion in a toxicology-focused array. Therefore, the majority of *P. flesus* toxicant-related genes had to be first isolated, cloned, and sequenced by the UK research group. All ESTs (expressed sequence tags) identified were submitted to web-based DNA databases.

Methods used to isolated partial gene sequences included:

1) degenerate PCR (polymerase chain reaction) using conserved regions of published gene sequences from related species;

2) selective subtractive hybridization (SSH). This technique compares mRNA populations between two tissue samples (control versus exposed fish) and allows the isolation of cryptic genes which are expressed in one population but not the other. These

genes are then cloned and sequenced for identification.

Detecting gene expression profiles

DNA microarrays quantify target mRNA sequences (specific mRNA targets for each gene of interest) and, thus, gene expression profiles for a particular target tissue. The current experimental design of the *P. flesus* DNA microarray allows gene expression profiles to be measured between two cell populations (e.g., contaminant-exposed flounder versus unexposed control fish). The mRNA extracted from each sample is reverse transcribed to cDNA and the two cDNA populations are labelled with a different fluorochrome. In the majority of experiments, cye3-dUTP (green) and cye5-dUTP (red) fluorochromes are used. Following this, the cDNA from both cell populations are mixed and allowed to hybridize with the gene-specific probes on the DNA microarray. After the hybridization, the array will be scanned with a laser beam of the correct excitation wavelength. The red and green fluorochromes will absorb the light and emit fluorescent light, which will be measured and processed with an image analysis program. Usually the ratio of the emission levels from the two fluorescence dyes is calculated, representing the gene expression level. When the light emitted by a particular spot on the array is red, it means that more cye5-labelled cDNA has hybridized at this spot. This means that the respective gene is over-expressed in the cells from cye5-labelled cDNA. When the spot lights up green, it is the cye3-labelled cDNA that is over-expressed. If a gene is equally expressed in both cell populations, the cye3-labelled and the cye5-labelled cDNA molecules will both hybridize with the particular spot on the microarray, causing the spot to emit a yellow colour.

Current status of *P. flesus* DNA microarray

Currently, the *P. flesus* DNA microarray has >100 toxicant response-related genes incorporated. Additional genes are being isolated and characterized using SSH and flounder EST libraries. The array is currently being validated using both laboratory and environmentally exposed flounder.

Need for further research or additional data

The ACME concluded that there is considerable promise in the development of genomic approaches in biological effects monitoring, but expertise was limited to a very few individuals within WGBEC. Presently it is difficult to determine the cost/benefit of adoption of genomic/proteomics because the field is moving very rapidly. This issue will be considered again in 2003 to draw in additional expertise for more detailed discussion.

4.1.3 Biological effects measures to complement Water Framework Directive monitoring

Request

This is part of continuing ICES work to improve the tools available for monitoring contaminants and their effects in the marine environment.

Source of the information presented

The 2002 report of the Working Group on Biological Effects of Contaminants (WGBEC) and ACME deliberations.

Status/background information

For reasons outlined in the 2001 ACME report (ICES, 2001), there are many reasons why the proposed methodology in the EU Water Framework Directive (WFD) to assess the health of the environment is not satisfactory. These will not be elaborated on further here, but two major points are:

- The proposed methods for ecological status (community structure and production) are retrospective, show effects late in a deleterious process, and are not sensitive to contaminants. It is unlikely that such methods can be used to distinguish among any of the three highest quality classes (high, good, moderate) due to particular types of anthropogenic impact.
- The use of chemical ecological quality standards to assess biological quality has earlier been shown to be very problematic (e.g., the development of OSPAR Ecotoxicological Assessment Criteria (EAC)).

WGBEC suggested two approaches to include diagnostic, health-related methods to assess ecological status in the WFD:

- integrated methods to assess individual or population health aligned with the proposed community endpoints in classification schemes;
- establishment of environmental quality standards (EQS) for direct assessment of environmental health (in addition to the currently proposed standards for chemical endpoints).

For the first approach, tools already exist that can be used to quantify ecologically relevant endpoints in marine organisms (e.g., scope for growth, intersex, imposex). Such methods should be further developed with additional methods to assess the health of individuals (e.g., acetylcholinesterase (AChE) inhibition, DNA damage) to provide an integrated holistic tool for ecosystem health assessment.

For the second approach, it is important that each method is not used alone and that a strategy using integrated chemical and biological effects measurements is developed.

The Water Framework Directive already imposes a considerable burden on organizations responsible for monitoring. Thus, it is suggested that these methods may be used to complement national monitoring programmes developed to support the WFD. They are not intended to become mandatory additions.

Nonetheless, the ACME concluded that the proposed methodology in the EU Water Framework Directive to assess the health of the environment is not satisfactory for that purpose.

Need for further research or additional data

The ACME encourages the development of a framework for both of the above approaches.

Reference

ICES. 2001. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report, 248: 10–16.

4.1.4 Progress with the EU-funded project on Biological Effects of Environmental Pollution in Marine Coastal Ecosystems (BEEP)

Request

This is part of continuing ICES work to improve the tools available for monitoring contaminants and their effects in the marine environment.

Source of the information presented

The 2002 report of the Working Group on Biological Effects of Contaminants (WGBEC) and ACME deliberations.

Status/background information

At its 2002 meeting, WGBEC reviewed progress made with regard to the EU-funded Biological Effects of Environmental Pollution in Marine Coastal Ecosystems (BEEP) project. To measure the biological effects of contaminants on marine biota, there is currently a need for:

- geographical/regional integration (e.g., developing a standard approach in different areas of Europe);
- integration of chemical and biological effects monitoring;
- integration of approaches employed to measure biological effects (as an “integrated response”).

In order to address these tasks, the idea to create a large, pan-European biomarker project was introduced during a joint workshop co-sponsored by ICES, EEA, and AMAP on combined effects of contaminants, held in November 1998 in Copenhagen, Denmark.

The three-year EU-funded BEEP project was launched in February 2001. Coordinated by the University of Bordeaux, France, thirty partner institutes from twelve European countries are currently participating in the project. The main objectives of the BEEP project are to:

1) validate the use of a suite of biomarkers in the monitoring of biological effects of contaminants in the marine environment using selected target species;
2) standardize biomarker methods in current use;
3) develop new biomarkers ranging over different levels of biological organization;
4) prepare information and advice for user groups, policy-makers, and fishery institutions about the biological effects of chemical contamination on coastal marine resources;
5) validate a methodology for biomarker exploration in ecological risk assessment;
6) establish a network of biomarker researchers throughout European countries with the emphasis on developing the monitoring of biological effects.

In 2001, field sampling campaigns were carried out in three sub-regions of Europe (Baltic Sea, Mediterranean Sea, and North Atlantic) to collect selected target organisms (fish, bivalves, crustaceans) for biomarker analyses. The sampling campaigns are being repeated in 2002. In addition, selected supporting parameters and environmental factors are measured. Research on new biomarker methods was also started within a specific work package and networking activities (workshops, intercalibration exercises, exchange of researchers, etc.) have also been initiated.

The outcome of the project is expected to be useful for the development and harmonization of marine monitoring programmes and is therefore considered to be of vital importance to regulatory Commissions such as OSPAR and HELCOM. To make the biomarker approach known and available for potential end-users, preliminary contacts have been made to relevant organizations on a national and international level.

More detailed information about the project can be found at http://beep.lptc.u-bordeaux.fr.

4.2 Techniques for Sediment Monitoring

4.2.1 Technical annex on metal analyses in sediments

Request

This is part of ongoing ICES work on techniques for the monitoring of contaminants in the marine environment and is of relevance to monitoring authorities.

Source of the information presented

The 2002 report of the Working Group on Marine Sediments in Relation to Pollution (WGMS) and ACME deliberations.

Status/background information

In 2001, the ACME endorsed guidelines on the normalization of contaminant concentrations in sediments (ICES, 2001), which were subsequently adopted by OSPAR for monitoring purposes. The development of these guidelines was the result of tremendous efforts for several years and was urged by the ongoing implementation of the OSPAR Coordinated Environmental Monitoring Programme (CEMP) on temporal trend monitoring and spatial surveys of contaminants in sediments on a continuous and periodic basis.

The ACME encouraged the use of this normalization document as a basis for the further development of specific guidelines on the monitoring of particular contaminants in sediments. In this respect, the ACME reviewed a new technical annex on metal analyses in sediments that had been evaluated at the 2002 meeting of WGMS. It was noted that this annex had been agreed by the OSPAR Working Group on Monitoring (MON) in 2001 to be forwarded to the OSPAR Environmental Assessment and Monitoring Committee (ASMO) in 2002 for adoption in the OSPAR Joint Assessment and Monitoring Programme (JAMP) guidelines; the annex was discussed by the ICES Working Group on Marine Sediments in Relation to Pollution (WGMS) with a view to evaluation and completion.

The ACME reviewed the document and welcomed the progress on new insights on digestion techniques for trace metal analysis, namely, on the current developments in methodologies and the applicability of partial digestion, and felt that the results at present are promising.

The ACME noted that, despite the reservations of some WGMS members, WGMS had accepted the technical annex on metal analyses after revision of the reference section and adjustment of the detection limits contained therein to more realistic levels. The ACME also expressed reservations about the technical annex and remarked that its use in monitoring programmes is premature, given that comparisons between total and partial digestions were restricted to a very limited number of sediment samples. In fact, all knowledge was obtained from experiments on samples originating from the QUASH programme. Therefore, the ACME highlighted again its earlier concerns on the use of partial digestion (ICES, 2000), namely, that 1) the use of partial digestion on a broad geographical scale was not recommended—a view that was shared with WGMS; 2) the growing complexity of the tools might endanger their applicability in monitoring programmes; and 3) appropriate Certified Reference Materials (CRMs) for partial digestion and QA measures were not, and still are not, available, as was otherwise stated in the annex. Furthermore, the annex also contains uncertainties on the adequacy of the performance of partial digestion.

The ACME stressed that the adoption of research protocols as monitoring guidelines requires thorough testing and evaluation. Since this is not yet the case for partial digestion, the ACME concluded that the inclusion of partial digestion in monitoring guidelines, as an alternative to total digestion, for total metal analyses in sediment, may, in the current state of knowledge, critically affect the effectiveness of the monitoring programme. Thus, the ACME again expressed its previously stated view that partial digestion methods should not be used under the current state of knowledge.

Need for further research or additional data

Additional research concerning the applicability of strong partial digestion of sediments on a broad geographical scale and the development of appropriate CRMs are needed before the use of partial digestion techniques can be recommended for total metal analyses in sediments. In addition, the further development of appropriate extraction techniques for risk assessments based on the measurement of the bioavailable fractions of metals in sediments should be encouraged.

Recommendations

Taking note of the information above, ICES recommends that OSPAR await further proof of the applicability of strong partial digestion of sediments for total metal analyses prior to the implementation of this technique in its monitoring programmes.

References

ICES. 2000. Report of the ICES Advisory Committee on the Marine Environment, 2000. ICES Cooperative Research Report, 241: 38, 163–169.

ICES, 2001. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report, 248: 20–21, 116–120.

4.2.2 National sediment quality criteria

Request

This is part of ongoing ICES work on marine environmental quality objectives and is of relevance to all authorities that are developing standards for use in regulatory processes.

Source of the information presented

The 2002 report of the Working Group on Marine Sediments in Relation to Pollution (WGMS) and ACME deliberations.

Status/background information

Sediment Quality Criteria are becoming an increasingly important tool to quantify, and ultimately regulate, the quality of the marine environment. They are used throughout the world, although in some areas they are not well defined. Over many years already, ICES has developed expertise in this field to inform regulators and to generally contribute to this area. Results from this topic can be of use to all authorities that are developing standards for use in regulatory processes.

In 2001, the ACME reviewed the existing methodologies to define sediment quality criteria and identified the weaknesses of the different approaches, especially regarding the lack of more sensitive biological endpoints than immobilization or death in sediment bioassays (ICES, 2001). As a result, the ACME fully supported the views of the Working Group on Biological Effects of Contaminants (WGBEC) to encourage studies on biomarker-type endpoints for organisms that are used in the tests and advised the use of less robust organisms than the species now used.

In 2002, the issue was again addressed at the WGMS meeting, which initiated the preparation of an inventory of national sediment quality criteria values, including information on advantages and disadvantages of the approaches used in the different countries to define these values. A draft version of the paper was reviewed and the ACME noted that WGMS intends to complete a final document at its meeting in 2003. The draft inventory identifies existing sediment quality criteria in ICES Member Countries for two applications: environmental quality standards and dredged material disposal; contaminant limits have been included when available.

A preliminary summary of the outcome of the evaluation is given below:

1) Most countries do not currently have environmental quality standards for sediments set in legislation. In these cases, responsible authorities frequently use guideline values, which may be based on the OSPAR background/reference concentrations for substances, or on locally derived background concentrations. However, the development of environmental quality standards is under review in many countries owing to the requirements of the EU Water Framework Directive.
2) In contrast, most countries do have legislative standards governing the disposal of dredged material at sea.
3) A great variety in the meaning of the criteria was identified and sometimes the criteria are only valid for special purposes. The definitions used should be harmonized.
4) For most substances considered, there is some consistency among the concentrations set for target concentration values.
5) Ranges in limit values are much higher and it seems likely that the large differences between limit values in different countries reflect local conditions.
6) Different countries use different approaches for setting sediment quality guidelines. Some approaches are based on chemical concentrations; others are based on effects on biota. Only one approach, the sediment quality triad, is based on integrative chemistry and effects.
7) Most toxicological approaches still use acute endpoints and do not allow the prediction of chronic effects.
8) No currently used single approach is free of problems.

The ACME noted that a final document would be available at the ACME meeting in 2003. The ACME recognized that the paper would be a useful contribution to the developments in this field and could be a basis for improvement and harmonization of the approaches and value ranges. Since little progress on biomarker-type endpoints has been reported, the ACME again stressed the need to include sensitive biological endpoints in the approaches.

The ACME also brings to the attention of monitoring authorities that research to derive sediment quality standards based on bioavailable concentrations of contaminants in sediments is being continued within the ICES community. Up to now, measurements of total concentrations of contaminants in sediments have been used in monitoring organizations and regulatory bodies to estimate the potential risk. In the past years, the ACME reported on the application of new tools to study sediment-water exchanges in relation to contaminant exposure, especially using Semi-Permeable Membrane Devices (SPMD) and, based on scientific results, looked forward to receiving further information as the studies progress (ICES, 1995, 1999, 2001).

At its 2002 meeting, WGMS revisited the topic and prepared an overview of currently available methodologies on risk assessments for both metals and organic contaminants in sediments. After deliberation, WGMS concluded that:

1) As far as metals are concerned, no single method seems sufficiently developed to reach any firm conclusions or to try approaches at this stage.
2) Looking at the different techniques for organic compounds, the SPMD (Semi-Permeable Membrane Device) method does not seem very practical, as it requires a rather extensive set-up. In addition, controlling the kinetics in order to assure a stable rate constant seems unachievable. Matrix SPME (Solid Phase Micro-Extraction) is an excellent technique as such, but unfortunately does not allow clean-up. It is very useful in dedicated studies, but the applicability for routine monitoring programmes has some limitations. For instance, only one group of contaminants can be analysed at a given time and the desorption of the fibre requires more specialized equipment that will not generally be available in routine monitoring laboratories. POM-SPE (solid material, like polyacetal plastic) and silicone rubber sheets, on the other hand, seem to have a far better potential. Both can easily be analysed using routine procedures such as Soxhlet extraction and there is no limit to the number of contaminants that can be analysed at the same time. Thus far, they have not been applied in situations where a non-depletive extraction is warranted. Nevertheless, the latter seems possible when a much larger sediment/reference phase ratio is applied than what has been reported so far.
3) To conclude, POM-SPE and silicone rubber appear to be the most appropriate techniques for the initial test, with the former being the more promising. It has lower partition coefficients, which will facilitate the creation of non-depletive situations, and much shorter equilibrium times can be reached. Further work should focus initially on these materials.

The ACME noted that WGMS will perform extensive experiments intersessionally using POM-SPE and silicone rubber and that the outcome should be evaluated at the next WGMS meeting and reported to ICES.

Based on this preliminary evaluation, the ACME decided that the development of sediment quality criteria based on more realistic risk assessments, such as bioavailability of contaminants, is still in a research phase and should be further examined.

Need for further research or additional data

The ACME encourages further progress and development of integrative approaches that combine chemical/toxicological measurements to set sediment quality guidelines.

References

ICES. 1995. Report of the ICES Advisory Committee on the Marine Environment, 1995. ICES Cooperative Research Report, 212: 81.
ICES. 1999. Report of the ICES Advisory Committee on the Marine Environment, 1998. ICES Cooperative Research Report, 233: 90–91.
ICES. 2001. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report 248: 50–51.

4.2.3 National procedures for temporal trend monitoring of contaminants in sediments

Request

This is part of continuing ICES work to provide a basis for scientific advice on current needs in relation to the monitoring and assessment of temporal changes in sediment quality within the ICES area (e.g., in monitoring programmes of ICES Member Countries and Regulatory Commissions, particularly the next OSPAR JAMP assessment of concentrations and temporal trends of contaminants in sediments).

Source of the information presented

The 2002 report of the Working Group on Marine Sediments in Relation to Pollution (WGMS) and ACME deliberations.

Status/background information

At its 2002 meeting, WGMS continued the work initiated in 2001 on temporal trend monitoring of contaminants in sediments. This included the production of an inventory of national procedures for the implementation of temporal trend monitoring of contaminants in sediments, and continuation of work on sediment dynamics of importance to this monitoring.

The material contained in the 2002 WGMS report presented here comprises two parts: a) an inventory of national procedures; and b) information on sediment dynamics in relation to temporal trend monitoring.

The aim of WGMS in preparing the inventory of national procedures is to supply ICES and OSPAR with an overview of sampling strategies for monitoring currently carried out or planned within each country, the analytical procedures used, and the contaminants analysed in the sediments.

A draft document was prepared by WGMS containing available information. For each country represented at the WGMS meeting, information on the type of sampling, grain size used for analysis, sampling frequency, and starting year is summarized in one table, together with an indication of whether the data have been sent, or are planned to be sent, to the ICES Marine Data Centre. The metals and organic compounds analysed and the extraction methods used are summarized in a second table, together with comments on the availability of data for normalization.

Although WGMS pointed out that the document is not yet finished, and additional existing information has to be included, it shows that a number of countries have not yet begun national trend monitoring programmes on contaminants in sediments, or have only recently done so. All countries report that data have been sent, or are planned to be sent, to the ICES Data Centre. WGMS reported that verification and collection of further available information will be done intersessionally, with the aim of finalizing the inventory at the 2003 meeting.

The ACME noted the strong relevance that a comprehensive, accurate inventory of strategies and procedures used by ICES Member Countries, available alongside the sediment data, has for data assessment purposes. Therefore, the ACME looked forward to completion of the inventory by WGMS for all ICES Member Countries.

Regarding the analytical procedures used, differences between the size fractions analysed were noted. Most studies include the use of total HF digestion for trace metals, and all analyse more than one normalizer.

Temporal trend monitoring using a repeated surface-sediment sampling scheme has been undertaken, or is planned for the near future, by most of the countries represented at the 2002 WGMS meeting. Some of them also carry out research studies of contaminants using dated sediment cores.

With regard to sediment dynamics, experience from three different areas was presented and discussed by WGMS:

1. Work carried out in two different areas of the North Sea shows, according to WGMS, the importance of taking into account the differences in sediment dynamics between areas, in the planning of trend monitoring studies of sediment quality. In the shallow sandy part of the North Sea, the upper 15–40 cm layer is described as being reworked by storms, waves, and tides so frequently that the entire “active” layer would contain the most recent mud present in the water column and, therefore, would represent the recent quality status. In contrast, in the deeper Oyster Grounds, the quieter situation allows sedimentation of fine sand and mud, with an estimated sedimentation rate of 2–4 mm yr^{-1}. As a result, sampling a 10-cm layer every three years would be acceptable in the first case, but such a sample may comprise an average period of 20 years at the Oyster Grounds. And, since the latter area is also strongly bioturbated, a more sophisticated approach would be needed if temporal trends on a few years’ basis were to be detected.

2. On the basis of Swedish studies in the Baltic Sea, it was reported that, in general, sediments are laminated, but storms often disrupt the regular pattern; this effect is different in the open Baltic compared to some places in the Swedish archipelago. Many factors need to be taken into account when interpreting sediment core data.

3. The outcome was reviewed of recent work on a few dated sediment cores taken in a trough in the French part of the Bay of Biscay, which seems to be a good accumulation site. In general, the cores showed an excellent, smooth pattern, indicating little perturbation. Core dating was carried out with unsupported ^{210}Pb and ^{137}Cs. Provided that the core resolution is adequate (sedimentation rate sufficiently high compared to the sediment mixed layer), and no drastic diagenetic phenomena occur, it is considered that the profile gives a good historical record of contaminant deposition in the sediment. It was reported that: 1) sensitive trend detection was possible, 2) the concentrations did not show a steep gradient, and 3) for most elements, a slight decrease was observed. Also, concentrations close to or at background levels were reported at the sampling site near Gironde. In addition to the core studies, sampling of surface sediments along the French Atlantic coast at 120 locations will be carried out every tenth year, mainly in muddy areas. Coarser sediments may be taken if no mud is present, but sands will not be sampled.

Based on the discussion of this material, WGMS decided to prepare a Technical Annex to the ICES Guidelines on Monitoring Contaminants in Sediments, where in general all physical, chemical, and biological processes acting on or within the sediment, that may affect its content of contaminants, would be covered. It is intended that a finalized version will be presented at the 2003 WGMS meeting.

The ACME noted that, as seen from the WGMS examples, it is important to take sediment dynamics into account when trend studies are planned. The ICES area is very large, and a number of Member Countries have a long coastline, which includes areas with different sediment dynamics, from very dynamic areas to accumulation sites.

The ACME welcomed the presentation of results of temporal trend monitoring of contaminants in sediments, as well as research studies on contaminants using dated sediment cores, which includes discussion on approaches and strategies being used, and encouraged WGMS in this regard.

The ACME also encourages the plans by WGMS to develop a review of physical, chemical, and biological processes acting on or within the sediment, that may affect its content of contaminants, for inclusion in the ICES Guidelines on Monitoring Contaminants in Sediments.

4.3 Statistical Aspects of Monitoring

4.3.1 Smoothers for use in trend analysis of monthly data on inputs of nutrients and contaminants in the marine environment

Request

This is a continuation of work in relation to item 2 of the 2000 Work Programme from the OSPAR Commission:

2.3 The use of monthly data

2.3.1 Development of provisions for the use of monthly data in these trend detection methods (taking into account that any recommendations should be based on real need and best scientific judgements and should not be driven purely by statistical considerations).

Source of the information presented

The 2002 report of the Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM) and ACME deliberations.

Status/background information

Weighted smoothers offer a simple approach that may improve trend assessments by incorporating available information about sources of variance, and especially about sources for varying uncertainty in different years (inhomogeneity of variance). How this information is used will vary with the context, and with the assumed structure of different variance components. In the 2001 ACME report (ICES, 2001), an example was provided in which a weighted smoother was fitted to lead concentrations in river water where the annual mean was based on variable numbers of observations and fluctuating standard deviations.

The ACME reviewed additional examples of weights calculated from the within-year variance, as provided in the 2002 WGSAEM report. Annex 1 considers the weighted LOESS smoother with weights calculated from the within-year variance (see ICES, 2001). The within-year variance can be considered as an estimate which includes not only sampling variance and environmental variance, but—apart from bias constant or random between years—also the analytical variance, and it can be used to estimate the uncertainty of the annual index. It is assumed that this index is an annually aggregated mean value, e.g., the mean of measured concentrations or the annual load (which in many cases can be considered as a mean value of transport figures). If the uncertainty weights are based on the within-year variances, the comparison with the actual residual variance of the LOESS smoother allows an examination of whether or not the underlying model is consistent with the empirical result. It is shown that random fluctuations of the seasonal cycle may highly affect the actual residual variance, and it is further shown that an appropriate selection of the aggregation period may highly affect the performance of the trend detectability.

Annex 2 describes an extended weighted LOESS smoother which allows one to take into account discontinuities and varying dynamics of the trend. Again, it is assumed that the trend is an annually aggregated mean value based on monthly or biweekly data. It is demonstrated that discontinuities in the trend may highly affect the actual residual variance, and it is further demonstrated that the inclusion of a method to detect discontinuities may lead to a better model fit.

In the discussion, it was pointed out that these types of discontinuities could also be assessed by including an additional shift variable. However, it has then to be decided where and how many shifts there are. Comparison of within-year and between-year variance might be quite helpful in order to detect specific model deviations. At least in some cases, the so-called random component of inter-annual variability has a very simple and specific origin.

Both temporal fluctuations of the seasonal cycle and discontinuities in the trend may introduce considerable random or pseudo between-year variability, respectively, and it is therefore important to examine these characteristics and to adapt the models accordingly.

Recommendations

ICES recommends to OSPAR:

1) that, in further trend assessments of riverine contaminant concentrations based on monthly or biweekly data, the weighted LOESS approach should be considered;

2) that, for further trend assessments, not only annual indices such as the annual mean concentration or the annual (adjusted) load should be provided, but also the number of measurements and the corresponding empirical standard deviation;

3) to examine whether, for some parameters and some stations, other aggregation periods than the calendar year (e.g., July–June) would be more appropriate.

Reference

ICES. 2001. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report, 248: 22–27, 121–125.

4.3.2 Alternative fixed-cost sampling schemes using data from the VIC database

Request

This is part of the continuing ICES work to provide advice on the development of effective methods for designing monitoring strategies; it is of particular relevance to the OSPAR monitoring programme.

Source of the information presented

The 2002 report of the Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM) and ACME deliberations.

Status/background information

In 1996, the OSPAR Ad Hoc Group on Monitoring (MON) proposed a simple international programme entitled Voluntary International Contaminant (VIC) monitoring for temporal trends in contaminants in fish. It involved conducting supplemental analyses to the OSPAR Joint Assessment and Monitoring Programme (JAMP) to obtain quantitative information on the variability in time and space within the guidelines for the sampling strategy. Over three to four years, the countries participating in the VIC programme (Germany, the Netherlands, Norway, and Sweden) have conducted multiple sampling each year at selected stations, at more than one location and/or at different times within the sampling season. The general principle is that controlling sampling over a broader spatial/temporal frame may reduce the level of between-year variability in contaminant concentrations, although constraints on sampling and costs could limit the choice of sampling.

In 1999–2001, WGSAEM discussed several analyses of the information collated in the VIC database. Estimates of spatial and temporal variation in the extended space-time region in the vicinity of monitoring sites could only be derived using the VIC data for a restricted range of sites (Norway, Sweden, and the Netherlands). Hence, it is difficult to draw general conclusions about potential improvements that would arise from possible revisions to the current OSPAR monitoring guidelines, for example, to collect data in a controlled way over a wider area. Due to the small sample sizes of the VIC programme, there is large uncertainty in the variance components derived from the VIC database.

In 2001, the ACME noted (ICES, 2001) that it may be possible to extend the VIC database using any data in the ICES database that have been collected over a wider spatial/temporal window than strictly allowed by the OSPAR sampling guidelines. However, an intensive search in 2002 revealed no suitable new data. If more estimates of the relevant variance components are to be obtained, either further specific sample collection is required or national institutes must search for relevant data. Failing these options, there could be further analysis of the VIC data.

Recommendations

ICES recommends that institutes in Member Countries search for relevant data (variance component estimates for spatial and temporal variability, or data sets of appropriate measurement data) in order to extend the VIC database.

Reference

ICES. 2001. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report, 248: 30–32.

4.3.3 Appropriate sampling schemes for the detection of hotspots of contamination in the marine environment

Request

This is part of the continuing ICES work to provide advice on the development of effective methods for designing monitoring strategies. It continues the response to the tasks of 2001 concerning spatial design, methods for analysing sediment data, and the detection of hotspots.

Source of the information presented

The 2002 report of the Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM) and ACME deliberations.

Status/background information

Spatial surveys are usually aimed at mapping or estimating the mean of some quantity in a survey area. In some contexts, however, the purpose shifts to simply confirming whether or not a particular feature is present. For example, in contaminant monitoring, there may be more concern about the presence of a "hotspot"—a localized region with unduly high levels of some contaminant—rather than with estimating the average concentration of the contaminant over a wider area.

In the 2001 ACME report (ICES, 2001), a demonstration was given, based on the 2001 WGSAEM report and Nicholson (2001), of the theoretical functions for missing a circular target of varying size using a random, square lattice, or triangular lattice design, respectively, of sampling points. In 2002, WGSAEM investigated:

- the influence of target shape on the chance of detecting a hotspot;
- the performance of three additional sampling designs and whether a combination of regular and random components can provide a more efficient design (e.g., the unaligned square lattice design).

To achieve this, circular and fixed-orientated rectangular target shapes of various proportions were investigated using a "Monte Carlo" approach (for details, see Annex 3). For each sampling design and shape, a plot is produced by simply placing the target of a certain size randomly many times (e.g., 2000 times) in the sampling area and recording the number of events when a sample point actually hit the target. The proportion of hits is displayed in the plots as a +-sign for the current size. This procedure is repeated for various target sizes (see Figures 4.3.3.2 and 4.3.3.3). This randomization technique corresponds very well with the theoretical functions for circular targets, but is also applicable to various shapes and *ad hoc* sampling designs.

The results showed that the square lattice design, performing very well for circular targets (Figure 4.3.3.1), could be inefficient for rectangular targets (Figure 4.3.3.2). The triangular lattice design was considerably more robust for elongated objects, except for extremely elongated, string-like objects. The unaligned square lattice design (Figure 4.3.3.3) combines the merits of a random and a regular design, performing almost as well for circular targets as a regular design, and is as effective for string-like objects as the random design. The detailed results are provided in Table 4.3.3.1.

Figure 4.3.3.1. Theoretical functions for the risk of missing a target (y-axis) vs. standardized hotspot radius (x-axis) (defined in Annex 3), *R*, for a circular target for random sampling design, upper function; square lattice design, middle function; and triangular lattice design, lower function. As the size of the target increases, the risk of missing the target decreases and decreases more rapidly for square and triangular sampling designs, respectively, compared to the random design.

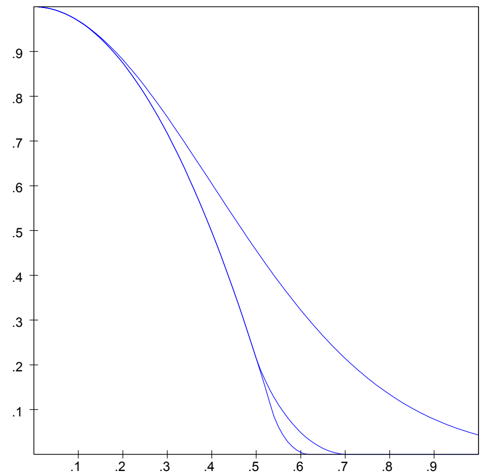


Figure 4.3.3.2. Square lattice sampling design. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). 2000 randomizations for each target size. Rectangular target, fixed orientation: a) rectangular target of moderate elongation (1:2); b) rectangular target of more extreme proportions (1:4). The square lattice sampling design, although very efficient for circular objects, can perform very poorly if the shape of the target is elongated.

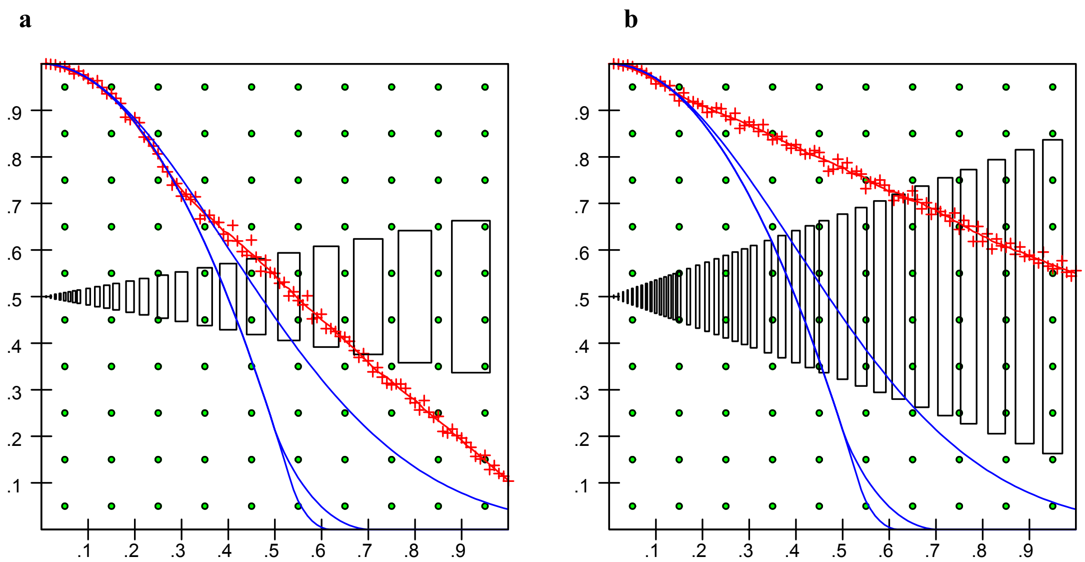
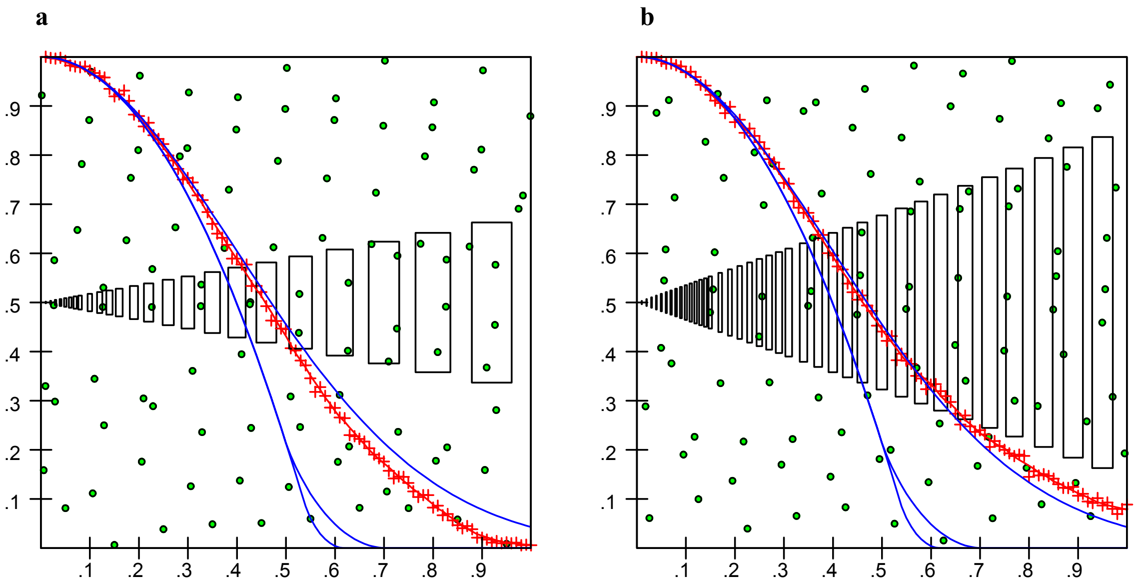


Figure 4.3.3.3. Unaligned sampling scheme. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). Rectangular target: a) rectangular target of moderate elongation (1:2); b) rectangular target of more extreme proportions (1:4). 2000 randomizations for each target size. The unaligned sampling strategy is more effective than the random design for rectangles of moderate proportions.



Summary

The random design is superior to the square lattice design in detecting regular patterns or rectangular targets. On the other hand, its generally low performance makes it less valuable compared to methods combining both a random and a regular component. The square lattice performs very well for circular targets, but is much less sensitive for elongated objects. This fact makes the triangular lattice far superior to the square lattice. For string-like targets, however, the triangular design may fail to be very effective.

The unaligned square lattice, the random with inhibition distance, and the Sobol sequence (all three described in Annex 3) seem to be fairly robust for various target shapes, with the Sobol sequence the best for extreme proportions.

The unaligned square lattice design is well described in the literature and might be a good choice if the target shape is unknown, string-like, or if a regular pattern in the distribution of the targets is suspected. On the other hand, the unaligned square lattice design might be difficult to apply in many practical situations (e.g., sampling from a ship), where, if possible, the triangular lattice design would be a better alternative compared to the square lattice design if rectangular targets can be expected.

Table 4.3.3.1. Proportion of the area above the estimated function in the figures of the total area and the percentage of success compared to the triangular lattice design for circular targets.

Design	Circular target shape, theoretical	Circular target shape	Square target	Rectangular 1:2	Rectangular 1:4
Random	0.506 (81 %)	0.508 (82 %)	0.500 (80 %)	0.507 (81 %)	0.508 (82 %)
Square lattice	0.617 (99 %)	0.616 (99 %)	0.627 (101 %)	0.441 (71 %)	0.225 (36 %)
Triangular lattice	0.623 (100 %)	0.621 (100 %)	0.625 (100 %)	0.613 (98 %)	0.435 (70 %)
Unaligned square lattice		0.586 (94 %)	0.592 (95 %)	0.562 (90 %)	0.504 (81 %)
Random inhibition, dist.= 30 m		0.589 (94 %)	0.591 (95 %)	0.548 (88 %)	0.511 (82 %)
Sobol sequence		0.566 (91 %)	0.566 (91 %)	0.562 (90 %)	0.552 (89 %)

Need for further research or additional data

Further investigations could be carried out to consider, e.g., randomly orientated elongated objects and the sensitivity of the results to missing sampling points in regular sampling schemes.

References

ICES. 2001. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report, 248: 29–31.

Nicholson, M.D. 2001. The detection of patches and trends. Ph.D. Thesis, University of East Anglia, UK.

5 QUALITY ASSURANCE PROCEDURES AND ACTIVITIES

5.1 Quality Assurance of Biological Measurements in the Baltic Sea

Request

Item 1 of the 2002 requests from the Helsinki Commission: to coordinate quality assurance activities on biological and chemical measurements in the Baltic marine area and report routinely on planned activities and ongoing ICES intercomparison exercises, and provide a full report on the results.

Source of the information presented

The 2002 report of the ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea (SGQAB) and ACME deliberations.

Status/background information

Development of quality assurance guidelines and procedures for the biological measurements in the HELCOM Cooperative Monitoring in the Baltic Marine Environment (COMBINE) Programme has been carried out by the ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea (SGQAB) since its establishment in 1992. The following progress has been made since the 2001 meeting of ACME.

SGQAB reviewed the experience in the use of the ICES Biological Data Reporting Format by HELCOM laboratories. Most of the countries had not yet used the data format and had not submitted data. Only Sweden has submitted data using this new ICES format. The main problem is that entry programs fitting both national databases and the ICES format have not yet been developed.

The phytoplankton checklists for the Baltic Sea area have almost been completed and are available on the Alg@line website. The German national checklist on phytoplankton is under preparation. SGQAB was also informed about progress in developing QA-related issues in some OSPAR countries.

Three reports on the outcome of the phytoplankton ring tests were reviewed. The conclusions from these were that: 1) a unified species list, including all synonyms, is needed; 2) exact definitions should be used; and 3) regular training courses for all staff involved in routine monitoring should be organized. Several workshops and ring tests are planned for the future.

An important instrument in implementing QA in phytoplankton monitoring is the regular meeting of the Phytoplankton Expert Group (PEG). Reports of two meetings, in 2000 and 2001, were reviewed by SGQAB. These meetings covered several aspects of phytoplankton monitoring QA: training in identification, estimation of biomass, and creation of the checklist. The ACME acknowledges the efforts done by Guy Hällfors (Finland) in completing the phytoplankton checklist and the work by PEG in introducing the QA into phytoplankton monitoring.

SGQAB considered the comments given by the ICES/HELCOM Steering Group on Quality Assurance of Chemical Measurements in the Baltic Sea (SGQAC) on QA protocols for chlorophyll *a* and primary production measurements and noted that they continued the improvement of the protocols.

The development of QA for macrozoobenthos monitoring procedures is progressing. The German national checklist on macrozoobenthos is under preparation. Also, a one-week taxonomical workshop is planned for October 2002.

SGQAB reviewed the COMBINE Manual chapter on biological monitoring and made several suggestions for improvement. The ACME accepted these changes and agreed to transmit them to HELCOM.

In addition, SGQAB proposed that a recommendation be made to HELCOM to consider the possibility of upgrading the category of phytobenthos monitoring from main parameter to core parameter in the COMBINE Programme. This recommendation was made on the basis of the developments that are occurring under the EU Water Framework Directive and the need to monitor the Baltic Sea Protected Areas.

SGQAB has many links to other ICES Working Groups and Study Groups and it became obvious from the SGQAB report that discussions and communication are vital. Many contacts have been developed between SGQAB and the ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements in the Northeast Atlantic (SGQAE) (see also Section 5.2, below). Both the implementation of international monitoring programmes and the increasing interest in an ecosystem approach are likely to require more integration of data sets from different disciplines. Cooperation between SGQAB and SGQAE is a high priority in order to achieve harmonization on QA matters between OSPAR and HELCOM. SGQAB is also carefully following the development of QA procedures for biological effects monitoring programmes (BEQUALM).

Recommendations

ICES recommends that the implementation and harmonization of QA measures for biological monitoring procedures be pursued in the different countries and institutes within the HELCOM area.

ICES recommends that Member Countries make an effort to develop software that enables the transfer of national data to the ICES Biological Data Reporting Format and that these data be submitted to the ICES Marine Data Centre on a regular basis.

ICES wishes to emphasize to HELCOM the benefits (in scientific and cost terms) arising from synergistic interactions between SGQAB and SGQAE on matters of common interest.

ICES recommends that HELCOM consider the possibility of upgrading the category of phytobenthos monitoring from main parameter to core parameter in the COMBINE Programme.

5.2 Quality Assurance of Biological Measurements in the OSPAR Area

Request

Item 1.1 of the 2002 Work Programme from the OSPAR Commission: to operate a joint ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements in the Northeast Atlantic in order to coordinate the development of QA procedures and the implementation of QA activities.

Source of the information presented

The 2002 report of the ICES/OSPAR Steering Group on Quality Assurance of Biological Measurements in the Northeast Atlantic (SGQAE) and ACME deliberations.

Status/background information

Several points on the agenda of SGQAE were aimed at identifying relevant QA activities within Member Countries which are conducting biological studies, and compiling a list of workshops and ring tests planned by countries in the ICES, OSPAR, and HELCOM areas within the next two years. QA issues were also reviewed both in relation to other ICES Working Groups, and from other international QA groups, such as the CEN/TC 230/WG 02.

The OSPAR/ICES General Guidelines for Quality Assurance of Biological Monitoring have now been fully reviewed and a final text has been adopted by SGQAE. These guidelines cover the following biological measures: chlorophyll *a*, phytoplankton, macrozoobenthos, and macrophytobenthos. The QA guidelines are presented across the full range of monitoring activities, i.e., from the objective-setting and sampling design stages of field surveys to the generation, analysis, and archiving of data. Tables of critical QA factors and priority QA actions for these measures are presented. Where possible, illustrative examples of good practice in relation to QA of biological measures are included. The ACME noted that "every effort has been made to ensure compatibility with the recently revised ICES/HELCOM guidelines contained in the HELCOM COMBINE manual", as it is considered of primary importance when establishing guidelines in two different groups.

The ACME accepted these guidelines for use within ICES and agreed to transmit them to OSPAR. These guidelines will be published in the *ICES Techniques in Marine Environmental Sciences* series.

The ACME appreciated that many contacts have been developed between SGQAE and the ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea (SGQAB). Both the implementation of international monitoring programmes and the increasing interest in an ecosystem approach are likely to require more integration of data sets from different disciplines. Cooperation with SGQAB is a high priority in order to achieve harmonization on QA matters between OSPAR and HELCOM. Terms of reference for such interactions have been proposed in the report of SGQAE, and a common agenda for joint meetings was elaborated. Furthermore, contacts have been established with ISO 5QA (aspects of soft-sediment studies) and with the European CEN. SGQAE members are also closely involved in scientific work, including QA and analytical quality control (AQC) aspects, associated with the implementation of the EU Water Framework Directive. Opportunities for opening, or consolidating, lines of communication with other agencies will be pursued by SGQAE.

The joint SGQAE/SGQAB meeting discussed accreditation schemes for the quality assurance of biological studies. It is recognized that accreditation is often mandatory in chemistry, while it has been slow in becoming accepted for biological assessments. Accreditation covers Standard Operating Procedures (SOPs), equipment, and training, and guarantees consistency of data. SGQAE and SGQAB recognize that the lack of national and international standards on which to assess compliance may be addressed through increased involvement with ISO/CEN.

In joint session with SGQAB, SGQAE recognized the potential value of the determination of primary production, which, as a "rate" variable, was directly relevant to evaluations of ecosystem function, and a necessary component in the modelling of energy flow. Reference was made to the relatively demanding nature of the work (both in time and resources), which was necessary in order to generate credible results, and the difficulties associated with the lack of standardization in approaches to sampling and analysis. As a result, it was considered that measures of species composition, densities, and biomass provided more dependable alternative means to evaluate environmental status. The scope and limitations of estimating primary production from chlorophyll *a* determinations were also discussed, leading to the conclusion that it may be locally acceptable but could not be advocated for wider application. SGQAE further considered the advantages and limitations of measurements of primary production and of zooplankton communities in monitoring programmes, noting that they were not a requirement under the OSPAR Joint Assessment and Monitoring Programme (JAMP). SGQAE concluded that, for both primary production measurements and zooplankton studies, further critical evaluation of their advantages and limitations in environmental monitoring programmes was required. Such an evaluation should combine considerations of practicality (including QA/AQC aspects) with those of scientific merit (see also Section 10.6, below).

SGQAE reviewed the progress with the EC BEQUALM project (see Section 5.3, below) and its implications for ICES/OSPAR QA activities. The first phase of BEQUALM ended in April 2002 and will be followed by Phase II. It is envisaged that the EU may fund BEQUALM II for an initial start-up period, but after that it will have to be self-funding in the same way as the QUASIMEME programme for marine chemistry. Both SGQAB and SGQAE supported continuation of the BEQUALM project, and encouraged the participation of all laboratories involved in marine monitoring.

SGQAE and SGQAB reported on the application of AQC criteria for evaluating the acceptability of biological data in monitoring programmes. They discussed the topics on four levels, i.e., the site criteria, sample criteria, laboratory criteria, and data bank criteria. They insist on the fact that rejection is not the only way to deal with dubious data, and that another option is flagging and the use of different levels of precision.

In reviewing this material, the ACME appreciated the common efforts of SGQAE and SGQAB to cooperate on quality assurance issues with joint meetings, the establishment of terms of reference for such interactions, and an agenda for combined and separate plenary sessions.

Recommendations

ICES recommends to the OSPAR Commission that the activity of SGQAE be continued under its revised terms of reference, as several biological measurements are not yet covered by QA procedures, given that adequate procedures have not yet been established. The ACME stressed the benefits (in scientific and cost terms) arising from synergistic interactions between SGQAE and SGQAB on matters of common interest.

5.3 Quality Assurance Procedures for Biological Effects Techniques

Request

This is part of continuing ICES work to improve the tools available for monitoring contaminants and their effects in the marine environment. This issue is of particular relevance to the OSPAR Commission with regard to implementation of biological effects monitoring under the Coordinated Environmental Monitoring Programme.

Source of the information presented

The 2002 report of the Working Group on Biological Effects of Contaminants (WGBEC) and ACME deliberations.

Status/background information

Progress in the EU-funded BEQUALM (Biological Effects Quality Assurance in Marine Monitoring) project during 2001/2002 was reviewed. The ACME noted that the initial trigger for this work was a WGBEC requirement to develop a view on the robustness of biological effects techniques used in monitoring programmes such as the OSPAR Joint Assessment and Monitoring Programme (JAMP) Coordinated Environmental Monitoring Programme (CEMP). WGBEC considered the implications of the BEQUALM work in the context of the CEMP and concluded that a review of the quality of the final BEQUALM report should be made for consideration by ACME when available. The future of the scheme was discussed and suggestions were provided for additional techniques for inclusion in the scheme.

CEMP requirements

The OSPAR JAMP guidelines recommend different types of biological effects monitoring tools for different objectives. There are guidelines for General Quality Assessment, Local Impact Assessment, and Contaminant-specific Monitoring. These guidelines should be used within monitoring programmes to address specific JAMP issues, that currently include:

- JAMP issue 1.11: Do PAHs affect fish and shellfish?
- JAMP issue 1.17: Where do pollutants cause deleterious effects?
- JAMP issue 1.3: To what extent do biological effects occur in the vicinity of major shipping routes, offshore installations, marinas and shipyards?

The CEMP comprises those parameters of the OSPAR JAMP where guidelines and QA procedures have been developed to such an extent that monitoring can commence on a Convention-wide basis. Therefore, the OSPAR CEMP should be regarded as one of the main drivers for biological effects monitoring in the Northeast Atlantic. In 1998, OSPAR agreed that, in respect of the implementation of the CEMP, all components of the JAMP matrix should be considered mandatory. The CEMP-rated biological effects issues relate to PAHs, metals, and organotins. In this respect, monitoring organizations must give a high priority to the implementation of the following JAMP biological effects techniques:

- cytochrome P4501A;
- DNA adducts;
- PAH metabolites;
- liver pathology;
- metallothionein;
- δ-aminolevulinic acid dehydratase (ALA-D);
- oxidative stress;
- imposex and intersex.

These techniques are currently rated Category II by OSPAR. Category I guidelines are those for which quality assurance procedures are in place. Category I guidelines may be used for monitoring and the data are appropriate for Convention-wide use. Category II guidelines are those for which quality assurance procedures are not yet in place. Category II guidelines may be used for monitoring, although caution should be used when making comparisons of the data obtained among different Contracting Parties. It was originally envisaged that in 2001, when the necessary Quality Assurance (QA) procedures were in place (via BEQUALM), the above-mentioned techniques would become Category I methods and thereby mandatory under the CEMP.

Status of the scheme

BEQUALM is now in its third and final year of EU funding. Previous documents submitted to ACME detail the scope of the programme (see, e.g., ICES, 2001). In summary, Standard Operating Procedures (SOPs) and QA procedures have been developed for eight work packages:

1) Water and sediment bioassays;
2) DNA adducts;
3) Metallothionein and ALA-D;
4) P4501A and imposex/intersex;
5) Lysosomal stability;
6) External fish diseases and liver pathology;
7) Phytoplankton assemblages;
8) Benthic communities.

Draft final reports are under completion for all of the work packages and are expected to be available in mid-2002. An overview of the outcome of BEQUALM is provided in Table 5.3.1. SOPs and training CD-ROMs are also near completion. Results of intercalibration exercises are encouraging and it appears at this stage that many of the techniques are robust enough to be used more widely in monitoring programmes. However, full statistical evaluations are not yet available.

Future of the scheme

Following last year's progress meeting, the BEQUALM Steering Group developed a view of the management of a future self-funding scheme and a briefing document was provided to the OSPAR Working Group on Concentrations, Trends, and Effects of Substances in the Marine Environment (SIME) meeting in January 2002. Due to inherent difficulties in the management of different aspects of the full spectrum of potential biological effects techniques, it was proposed that BEQUALM provide an umbrella for three strands of work under the headings of biomarkers, cellular to organism (bioassay and fish disease) methods, and community (benthos and plankton) methods. A steering group will advertise the work programmes under these headings each year and uptake by sufficient numbers of laboratories will dictate the final shape of the annual programme. In order to prevent duplication of effort with other QA schemes, BEQUALM will flag any ongoing relevant intercalibrations under the auspices of other schemes, e.g., QUASIMEME. Since the BEQUALM concept was originally inspired by WGBEC, and WGBEC will require outputs of progress annually, the steering group meeting will convene in advance of the annual WGBEC meetings and provide a draft of the annual programme for WGBEC approval.

New techniques for the scheme in 2002

After considering the range of biological effects techniques currently in widespread use throughout marine monitoring organizations, WGBEC suggested that two additional techniques should be added to the scheme: plasma vitellogenin concentration (vtg) and acetylcholinesterase activity (AChE).

Table 5.3.1. Summary of the performance of the biological effects techniques covered in the BEQUALM project.

Assay	Limits of variability acceptable for adoption in the CEMP	Notes
Water and sediment bioassays	Yes	Good QA is in place for a number of methods; expert laboratories provided reliable results. Issues remain about assay precision in the light of biological variablity.
DNA adducts	Yes	Very small participation for the technique, but expert laboratories provided good intercomparability.
Metallothionein	Yes	Good comparability despite the use of a wide range of methods. Some tissue types and some methods appear more robust than others.
ALA-D	?	Small level of participation and high variability. Further work needed on method improvement, test and reference materials.
P4501A (EROD)	Yes?	Surprisingly, systematic errors are still evident in both the EROD assay and protein measurement. Although good methods are available and they function in the hands of expert laboratories, more training is required.
Imposex/intersex	Yes	Good intercomparisons; methods are robust.
Lysosomal stability	?	Small level of participation and determinations contain subjective elements. Training is required.
External fish disease, liver pathology	Yes?	Good standard protocols are available. Variability will reduce with training.
Phytoplankton assemblages	Yes?	Good results obtained using standard protocols for counting. Chlorophyll *a* methods indicate training need.
Benthic communities	Yes?	Variability is controllable with training.

Need for further research or additional data

WGBEC has concluded that there are few inherent problems with any of the techniques used when in the hands of expert laboratories. There are a number of training issues to be addressed, and it will be important to develop a data filter before accepting information into international data sets.

Recommendations

ICES recommends that, with the exceptions of ALA-D and lysosomal stability, where participation and the use of the techniques are too small for proper evaluation, the biological effects techniques tested under BEQUALM are robust enough to become part of the OSPAR CEMP and other regional monitoring programmes. However, future QA schemes should provide a strong training element and data filters for acceptance criteria should be developed before accepting information into international data sets.

ICES recommends that the BEQUALM project be continued in order to maintain and improve the QA standards already achieved in relation to biological effects techniques. ICES Member Countries conducting biological effects monitoring are strongly encouraged to participate in the continuation of this programme.

Reference

ICES 2001. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report, 248: 34–37.

5.4 Quality Assurance of Chemical Measurements in the Baltic Sea

Request

Item 1 of the 2002 requests from the Helsinki Commission: to coordinate quality assurance activities on biological and chemical measurements in the Baltic marine area and report routinely on planned and ongoing ICES intercomparison exercises, and to provide a full report on the results.

Source of the information presented

The 2002 reports of the ICES/HELCOM Steering Group on Quality Assurance of Chemical Measurements in the Baltic Sea (SGQAC) and the Marine Chemistry Working Group (MCWG), and ACME deliberations.

Status/background information

The ACME reviewed the work of the ICES/HELCOM Steering Group on Quality Assurance of Chemical Measurements in the Baltic Sea (SGQAC), noting further progress by SGQAC in the development of QA provisions in relation to the Guidelines for the Cooperative Monitoring in the Baltic Marine Environment (COMBINE) Programme.

One additional Technical Note was completed for addition to the COMBINE Guidelines. This is the Technical Notes on Measurement Uncertainty of Analytical Methods, which has been reviewed and commented on by the Marine Chemistry Working Group (MCWG) and the Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM). The ACME approved this Technical Note for transmission to HELCOM.

There are several other Technical Notes that are presently under preparation. These include the following:

1) Technical Notes on the Determination of Chlorobiphenyls in Sediments

   This is essentially complete as the text is to a large extent based on a previous publication by Smedes and de Boer (1998); it was reviewed in 2002 by MCWG, which had no major comments.

2) Technical Notes on the Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Sediments

   Some further work is required on this document, based on comments prepared by MCWG. It is anticipated that it will be completed in 2003.

3) Technical Notes on the Determination of Polycyclic Aromatic Hydrocarbons in Biota

   Some additions are required to the text to take account of new extraction techniques, for instance, microwave-assisted solvent extraction, which are now being applied to PAH analysis. After this, the text should be complete.

The future work programme of SGQAC will include consideration of the following topics:

- Evaluate the results of the QA questionnaire, and develop performance criteria for HELCOM laboratories;
- Update the technical note on the analysis of trace metals in fish;
- Update the technical note on method validation concerning the validation of an existing analytical method;
- Update the technical note on co-factors with respect to sediment analyses;
- Update the part of the Guidelines on validation of an analytical method with respect to the limit of determination and the detection limit;
- Update the part of the Guidelines on routine quality control with respect to precision control charts;
- Consider the Pollution Load Compilation (PLC) guidelines;
- Review the technical note on heavy metal determination in sediments;
- Finalize the technical notes on the determination of persistent organic compounds in biota.

Additional comments

The ACME expressed its appreciation for the up-to-date development of comprehensive QA Guidelines for the HELCOM COMBINE monitoring programme by SGQAC, with assistance from MCWG and WGSAEM. However, the ACME is of the opinion that some parts of the Guidelines (e.g., on determination of contaminants in the marine environment) are purely advisory and by no means constitute operational procedures. Therefore, users of the guidelines should be encouraged to make a thorough study and validation of the procedures they intend to use.

The ACME appreciates SGQAC efforts, together with MCWG, to cooperate on quality assurance issues in the Baltic Sea and supports a 2003 SGQAC and SGQAB back-to-back meeting to complete QA guidelines for chlorophyll *a* determination and QA guidelines for primary production determination.

The ACME noted that the Guidelines on Quality Assurance of Chemical Measurements in the Baltic Sea, including all Technical Notes prepared to date, will be published in the *ICES Techniques in Marine Environmental Sciences* (TIMES) series in early 2003.

Recommendations

ICES recommends that the Technical Notes on Measurement Uncertainty of Analytical Methods be transmitted to the Helsinki Commission for inclusion in the COMBINE Guidelines.

ICES also recommends that the Technical Notes on Units and Conversions and the Technical Notes on the Determination of Co-factors, which were completed and transmitted to HELCOM in 2001 and 2000, respectively, be included in the COMBINE Guidelines.

ICES recommends that quality criteria for laboratories participating in the COMBINE Programme (Annex 6, 2002 SGQAC report) should be implemented, to be used to give guidance on the level at which the laboratories are expected to perform.

Reference

Smedes, F., and de Boer, J. 1998. Chlorobiphenyls in marine sediments: Guidelines for determination. ICES Techniques in Marine Environmental Sciences, No. 21.

5.5 Guidelines and Criteria for Data Screening and Evaluation Prior to Assessment of Chemical Monitoring Data, including Potential for a "Data Filter"

Request

This is a continuation of work initiated in 2001 in response to requests from OSPAR and HELCOM in 2001 for methods to aid the assessment of monitoring data, particularly with regard to data with various degrees of quality assurance.

Source of the information presented

The 2002 reports of the ICES/HELCOM Steering Group on Quality Assurance of Chemical Measurements in the Baltic Sea (SGQAC), the Marine Chemistry Working Group (MCWG), and the Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM), and ACME deliberations.

Status/background information

Data screening and evaluation

A paper on this subject, by Mike Nicholson and Rob Fryer entitled "Weighting procedures for assessing trend data of variable analytical quality" (attached as Annex 4), was considered at the 2002 MCWG meeting. MCWG accepted the aim of the paper, which is to aid data assessment within organizations such as OSPAR by maximizing the utility of historical data. However, MCWG still felt that the approach was fraught with problems. In particular, for years for which QA data are absent, and which tend primarily to be the early years of the data sets, there are also likely to be methodological differences which can alter the comparability of the data (for instance, following the change from packed gas chromatography columns to capillary columns for the analysis of chlorobiphenyls). These cannot easily be accounted for, and their effect on the overall trend is not obvious. As the highest values occur in these early years, they are critical to the determination of any trend, and are still not well controlled following this statistical treatment.

This paper was also considered by WGSAEM at its 2002 meeting. The authors argued that appropriate down-weighting of trend data where analytical variability was high offered a practical method of dealing with data of variable analytical quality. Further, this approach was likely to lead to more efficient trend detection than simply removing data deemed unsatisfactory on analytical grounds. Such an approach could then be incorporated into an effective strategy for data filtering and assessment, such that the maximum volume of submitted data could be assessed. In terms of the ability to detect a linear trend, four potential weighting strategies were ranked from best to worst as 1 *optimum*-; 2 *intuitive*-; 3 *equal*-; and 4 *zero-weighting* (i.e., deletion). Two weighting strategies (*optimal* and *intuitive*) were applied to trends of PCBs. The PCB example had been chosen to demonstrate the difficulty of applying the *optimal* weighting strategy. Analytical quality control data were only available for a small part of the trend series, requiring further modelling to estimate the components of between-year and within-year analytical variability. An alternative analysis using an intuitive weighting strategy was therefore also provided. Much of the discussion at the WGSAEM meeting concerned the problem of dealing with bias in analytical methods. Shifts in bias are not corrected by down-weighting and can lead to spurious trends. However, their influence with regard to the test of the linear trend component could be reduced, although not completely eliminated. This was discussed also in Annex 5, which demonstrates the interaction between analytical bias, down-weighting, and trend detection by simulation.

This problem with potential analytical bias might argue for the deletion of historical data of uncertain quality. However, this should be a policy decision, and not a statistical one. WGSAEM commented that there are several statistical approaches that could be adopted if there is additional information about changes in analytical method (see, e.g., Beliaeff *et al.,* 1997). However, this information would need to be consistently available to be of benefit within large trend assessment meetings. A query addressed to the ICES Marine Data Centre revealed that information on analytical methods has been included for data submitted to the ICES database since 1991, but perhaps not prior to this.

WGSAEM also discussed the problem of local weighting, i.e., in some sections the trend estimated by weighted LOESS equals the unweighted LOESS, although the point-wise confidence bands would be different. Hence, it might be useful to emphasize the confidence bands graphically and to reduce the emphasis on the trend line. In the extreme, one might even consider removing the trend line.

Need for further research or additional data

Both temporal fluctuations of the seasonal cycle and discontinuities in the trend may introduce considerable random or pseudo between-year variability, respectively, and it is therefore important to further examine these characteristics and to develop the statistical methods accordingly.

With regard to the incorporation of QA information into trend assessments, the problems that remain are practical problems that particularly arise in large international assessments. These include:

- setting objective criteria for data selection;
- defining criteria with respect to the acceptability of historical data;
- establishing appropriate analytical targets for the quality of data submitted for different monitoring programmes;
- establishing appropriate targets for guideline compliance of submitted data, as well as evaluating and choosing between possible weighting strategies.

These issues should be resolved on the basis of interactions between policy-makers, chemists, and statisticians.

The consideration of the uncertainty of data is not only relevant with regard to temporal trend assessments, but also with regard to the establishment of data products, and especially with regard to environmental indicators.

Potential for a data filter

The ICES/HELCOM Steering Group on Quality Assurance of Chemical Measurements in the Baltic Sea (SGQAC) discussed the establishment of data quality criteria to be met for the acceptance of monitoring data for assessment purposes within the HELCOM area. This included requirements to associate uncertainty with monitoring data, limits of detection and determination, the use of control charts, and participation in proficiency testing schemes and intercomparison exercises. These were not, however, addressed in a quantitative manner. Subsequent to the 2002 meetings of MCWG and SGQAC, a paper was published outlining the implementation of a data filter within the National Marine Monitoring Programme (NMMP) in the UK (Gardner *et al.*, 2002). During the past twenty years, most laboratories have implemented a range of quality assurance and quality control (QA/QC) activities with the aim of achieving analytical fitness for purpose. These activities are now sufficiently widespread in environmental monitoring that it has become feasible to make an assessment of each individual laboratory's QA/QC work. Until recently, the results of interlaboratory or proficiency testing schemes were used as the principal source of information on data quality, and whilst this is an important aspect for consideration, it is difficult to make the assessment on this information alone. A major reason is that these exercises occur rather infrequently, and so decisions concerning the validity of a laboratory's data for a given monitoring year might have to be taken on the basis of as few as two sets of test results. Within the UK, a set of criteria have been developed which, if satisfied, demonstrate that the data are fit for purpose. These criteria constitute the "data filter". Each laboratory is scored on aspects of its QA/QC procedures under four headings: 1) QA/accreditation; 2) testing of analytical systems; 3) routine quality control; and 4) proficiency tests. Scores of 55 % or above were deemed to represent satisfactory performance such that a laboratory's data were acceptable and fit for the purposes of the NMMP.

Recommendations

As a result of the above work, theoretical techniques for incorporating QA information into trend assessments are currently available.

There is now a need for OSPAR and HELCOM to help resolve the remaining practical problems with regard to the incorporation of QA information in trend assessments. General decisions are needed on acceptable risks arising particularly in large international assessments. These issues should be resolved on the basis of interactions between policy-makers, chemists, and statisticians, who need to discuss:

- setting objective criteria for data selection;
- defining criteria with respect to the acceptability of historical data;
- establishing appropriate analytical targets for the quality of data submitted for different monitoring programmes;
- establishing appropriate targets for guideline compliance of submitted data, as well as evaluating and choosing between possible weighting strategies.

ICES recommends that the above-mentioned issues regarding the development and implementation of criteria for reviewing the quality of data to be used for temporal trend assessments by OSPAR and HELCOM should be discussed and resolved on the basis of interactions between policy-makers, chemists, and statisticians. Thus, ICES recommends that OSPAR and HELCOM be approached with a view to organizing a joint workshop of relevant experts to discuss the above-mentioned issues with policy-makers.

References

Beliaeff, B., O'Connor, T.P., Daskalakis, K., and Smith, P.J. 1997. U.S. Mussel Watch from 1986 to 1994: temporal trend detection at large spatial scales. Environmental Science and Technology, 31: 1411–1415.

Gardner, M., Dobson, J., Miller, B., Allchin, C., McMullan, D., Oliver, T., Wells, D., Hudson, R., Toft, R., and Jessep, M. 2002. Implementation of a "data filter" for the UK National Marine Monitoring Programme. Accreditation and Quality Assurance, 7: 60–65.

5.6 Standardized Presentation of the Long-term Performance of a Laboratory

Request

This is part of continuing ICES work to improve the tools for assessing environmental monitoring data, and is particularly relevant to temporal trend assessments.

Source of the information presented

The 2002 report of the Marine Chemistry Working Group (MCWG) and ACME deliberations.

Status/background information

At an earlier meeting, the MCWG considered a method for treating data from laboratory proficiency tests devised within QUASIMEME, which involved the calculation of a parameter entitled the rescaled sum of Z-scores. MCWG members were asked to bring other methods to the attention of the group, and in 2002 an alternative approach was discussed. In this case, the relative deviations from the assigned values are assumed to be Normally distributed and to be composed of two components, a constant error Ec (independent of the concentration in the sample) and a proportional error Ep. An Excel spreadsheet is used to calculate the values for Ec and Ep which result in the best fit to three criteria: 95 % of the data should have an error smaller than two standard deviations, 68 % of the data should have an error less than one standard deviation, and 50 % of the data should have an error less than 0.67 standard deviations. The advantage of this method is that the proficiency data from a number of rounds within a proficiency scheme can be condensed to only two numbers in an objective manner. It is, however, realized that this cannot be done for all laboratories and for all determinands, as in some cases data are not distributed according to the assumption of a constant and a proportional error. Intersessionally, this method will be tested further using data deriving from the QUASIMEME scheme.

Need for further research or additional data

The ACME noted that MCWG will consider further developments in this field at its meeting in 2003, including the outcome of intersessional work.

5.7 Developments within QUASIMEME

Request

This item is an ACME initiative to follow the developments in this QA project owing to the long-standing ICES involvement in quality assurance matters.

Source of the information presented

Reports from QUASIMEME and ACME deliberations.

Status/background information

Information on QUASIMEME can be found on its website: http://www.quasimeme.marlab.ac.uk/. This site provides details on Laboratory Performance Studies (LPS), previous newsletters, and information on the project and the test materials used in the LPS. The intercomparison exercise reports are also available on the website.

The QUASIMEME 2000/2001 year has been one of consolidation of the programme in view of the changes that were taking place within the FRS Marine Laboratory in Aberdeen and the major changes to data assessment using Cofino Statistics. During the year, the main achievements have been:

1) Transfer of the data assessment from Robust Statistics to Cofino Statistics. Cofino Statistics is a new model statistics using the uncertainties in the data (Cofino *et al.*, 2000). Use of this method was initiated during August/September 2000 and the subsequent data assessments showed that the Cofino Statistics would provide a number of benefits, including a better estimate of the assigned value, especially with a small number of laboratories.
2) Reducing the reporting time scale from three months to six weeks with the improvement in the automation of the quarterly reports.

The issue of resubmission of data that were originally based on wrong calculations has been raised by a laboratory. This was discussed in the QUASIMEME Scientific Assessment Group in August 2001. They concluded that data in the QUASIMEME database should not be changed to correct errors discovered by the participants in the light of the reports on the results of the exercise. Therefore, QUASIMEME cannot provide corrected Z-scores to participants in this type of situation. It is the responsibility of the individual laboratory to submit their data to ICES in a form that is acceptable to both parties. The QUASIMEME Advisory Board meeting in October 2001 agreed that data in the QUASIMEME database should not be changed in this type of situation. The Advisory Board recommended that the data submitted to ICES should be the same as that in the QUASIMEME database. The Advisory Board stated that participants should be advised to send their QUASIMEME data and Z-scores to ICES, along with a comment that the Z-scores were based on incorrect calculations, and note the Z-score that would have been obtained using the correct calculations.

In discussion of this issue, the ACME accepted the decision of the QUASIMEME Advisory Board that the Z-scores sent in data submissions to the ICES Marine Data Centre should be the same as those in the QUASIMEME database. This should be accompanied by a comment that the Z-scores were based on an incorrect calculation.

Recommendations

ICES recommends that Member Countries encourage their national laboratories to submit the QA information together with their monitoring data to ICES under the reporting obligations for monitoring in HELCOM and OSPAR, and ensure that the QA information submitted is correct. This QA information is important for the future use of the data during assessments.

Reference

Cofino, W.P., van Stokkum, I.H.M., Wells, D.E., Ariese, F., Wegener, J.-W.M., and Peerbom, R.A.L. 2000. A new model for the inference of population characteristics from experimental data using uncertainties in data. Application to interlaboratory studies. Chemometrics and Intelligent Laboratory Systems, 53: 37–55.

6 ENVIRONMENTAL ASSESSMENT

6.1 Outcome of the Assessment of AMAP Heavy Metals Data

Request

This is work in cooperation with the Arctic Monitoring and Assessment Programme (AMAP) in relation to the ICES Marine Data Centre serving as the Thematic Data Centre for marine data submitted for AMAP programmes.

Source of the information presented

The 2001 report of the ICES/AMAP Study Group for the Assessment of AMAP POPs and Heavy Metals Data (SGPOP) and ACME deliberations.

Status/background information

The work of the ICES/AMAP Study Group for the Assessment of AMAP POPs and Heavy Metals Data (SGPOP) was concentrated on time series of heavy metals in biota. The data sets on Persistent Organic Pollutants (POPs) were being considered by AMAP, but the most relevant of these had already been analysed by the time of the SGPOP meeting. Data on contaminants in sediments were not included. Time series shorter than five years were not treated by SGPOP. In total, 164 time series were available and were tested for temporal trends (see Table 6.1.1). The time series covered variable year spans during the past two to three decades. Most time series available were from sub-Arctic sites (in Canada, Iceland, Sweden, Norway, and the USA (Alaska)) and only a few time series were from the high Arctic (Greenland, Canadian Arctic Archipelago).

Unlike earlier ICES temporal trend assessments (e.g., those conducted for OSPAR and ICES (1991)), the AMAP time series included data from both the terrestrial/freshwater and marine environments, and included several species and tissues not previously considered by ICES. From the terrestrial/freshwater ecosystems, time series were available for reindeer/caribou and moose from Sweden and Canada, and Arctic char and pike from Sweden. From the marine ecosystem, time series were available for cod from Norway and Iceland, and dab from Iceland; data were also available for *Mytilus* spp. (blue mussels) from Iceland and Norway (and Alaska). Furthermore, data on metals in eggs from three species of seabirds from Canada, and data (for muscle, liver, kidney, and hair samples) from polar bears from Greenland were available. The most time series data were available for Hg (43), Cd (41), and Zn (39). Fewer data series were available for Cu (29), Pb (20), Cr (6), and Se (5).

Presentation and discussion of statistical methods of trend detection

SGPOP decided to use the geometric mean as the measure of the annual contaminant level for all data sets analysed; this choice was considered appropriate (and preferred over the median) given the skewed distribution of individual data values in a number of the data sets concerned. In some data sets, values were reported as "below detection limit". If the number of such values in any given data set was low, and it was considered that their inclusion would not unduly affect the analysis, the data were included and the value of the detection limit was used in the calculations. Otherwise, the data set concerned was excluded from the time series assessment.

Size and age are known to influence contaminant concentrations in some species/tissues, especially for Hg in fish muscle. In the case of Hg in the muscle of cod and dab in the Icelandic time series and cod in the Norwegian time series, an analysis of covariance was performed with year as a factor and fish length as a covariate. In all of the time series where length adjustment was performed, the effect on the results of the temporal trend analysis was marginal. In several of the other time series (e.g., terrestrial mammals), potential confounding factors such as age/size/sex, etc., had been taken into account by sampling, for example, only males or only females, sampling of selected age classes, etc.

The time series were subjected to a log-linear regression analysis. Outliers were detected by the procedure described by Hoaglin and Welsch (1978) and, when necessary, removed from the data sets. The power of the log-linear regression was calculated as described in Cohen (1977). The power of the test is defined as the probability of rejecting the H_0 hypothesis (and accepting the H_a hypothesis) when the H_0 hypothesis is false. The power to detect a linear trend depends on: the magnitude of the trend, the number of years in the time series, the number of samples per year, the residual variance, and the significance level.

A linear trend is only one possible pattern out of many temporal trend patterns. As an alternative to the regression analysis, the development of a trend over time can be described using a smoother. The trend as described by the smoother was then tested against that described by the regression line using the method of Nicholson *et al.* (1998). The choice of smoother is a trade-off between the bias and variance of the estimators (Nicholson *et al.*, 1998). The group adopted a three-year running average smoother fitted to the annual log-mean values, which has previously been recommended and used as an appropriate smoother for, e.g., OSPAR Joint Monitoring Programme (JMP) contaminant data with a time span of ten years (Nicholson *et al*., 1998).

Table 6.1.1. Summary table of the results of temporal trend analyses conducted in the assessment of AMAP data on trace metals in Arctic biota.

Country	Number of data sets	Hg trends	Cd trends	Pb trends	No. of years spanned	No. of yrs required to detect 5 % annual change with a power of 80 % and a significance level of 5 %	Adequacy of data, Median (Range)
Canada	Terrestrial mammals 6 (1 sp. @ 5 sites 1 sp. @ 1 site)	6 ---	6 ---	6 ---	4–9	9–38	0.24 (0.10–0.73)
	Marine birds 3 (3 spp. @ 1 site)	2 incr., 1 ---	NA	NA	24 (5–7 yr data)	9–16	0.64 (0.31–0.67)
Greenland	Marine mammals 4 (1 sp. @ 1 site, 4 tissues)	4 ---	3 ---	NA	16 (5–6 yr data)	12–38	0.22 (0.13–0.60)
Iceland	Marine invertebrates 8 (1 sp. @ 8 sites)	8 ---	1 incr., 1 decr., 6---	NA	5–10	9–30	0.43 (0.20–1.00)
	Marine fish 6 (2 spp. @ 3 sites)	2 decr., 4 ---	6 ---	NA	10	11–38	0.50 (0.13–0.69)
Norway	Marine invertebrates 8 (1 sp. @ 8 sites)	2 decr., 6 ---	8 ---	8 ---	4–13	6–27	0.40 (0.17–1.00)
	Marine fish 2 (1 sp. @ 2 sites)	2 ---	2 ---	NA	7–9	14–32	0.47 (0.28–0.53)
Sweden	Freshwater fish 2 (1 sp. @ 1 site)	2 ---	2 ---	2 ---	19–29	10–20	1.70 (0.90–2.64)
	Terrestrial mammals 4 (1 sp. @ 2 sites, liver + kidney/muscle)	2 ---	1 incr., 3 ---	1 decr., 1 ---	5–16	11–31	0.61 (0.19–1.55)
Alaska	Marine invertebrates 6 (1 sp. @ 2 sites)	1 incr, 1 ---	2 ---	2 ---	9–10	8–18	0.80 (0.56–1.25)

Trends: NA=data not available; --- = no significant change; incr. = significant increasing trend; decr. = significant decreasing trend.
Adequacy: (Ratio of No. of yrs spanned/No. of yrs required) 1.0 = adequate statistical power; <1.0 = inadequate power; >1.0 = more than adequate power.

The statistical approach adopted by the group to analyse the AMAP data sets was very similar to the method described by Nicholson *et al.* (1998). However, some differences between the approaches were noted. Firstly, it was decided to work with mean log-concentrations instead of log-median concentrations. Furthermore, the common procedure to test the significance of the regression line was used, whereas Nicholson *et al.* (1998) calculate the statistic (F-value) of the linear component as the reduction of the residual sum of squares of the regression line relative to the residual sum of squares from the smoother. In discussing the pros and cons associated with these two alternatives, it was noted that the approach of Nicholson *et al.* (1998) also has an implication when calculating the power of detecting a trend. During the meeting, a few attempts were made to compare the results obtained using the approach adopted by SGPOP with those obtained using the method described by Nicholson and co-workers. In general, the two methods gave very similar results, however, more comparisons have to be made in the future before any firm conclusions can be drawn as to which approach should be generally recommended.

Finally, the non-parametric Mann-Kendall trend test (Helsel and Hirsch, 1995) was applied to the time series. This test has a lower power than the regression analyses, provided that no outliers are present. However, it is not sensitive to leverage effects of data at the ends of the line/time series, which are well known in regression analyses. The Mann-Kendall test was therefore employed as an alternative (or supplement) to the analyses for linear and non-linear trends. Examples of the plots obtained are shown in Figure 6.1.1.

Presentation of the results of the statistical analyses

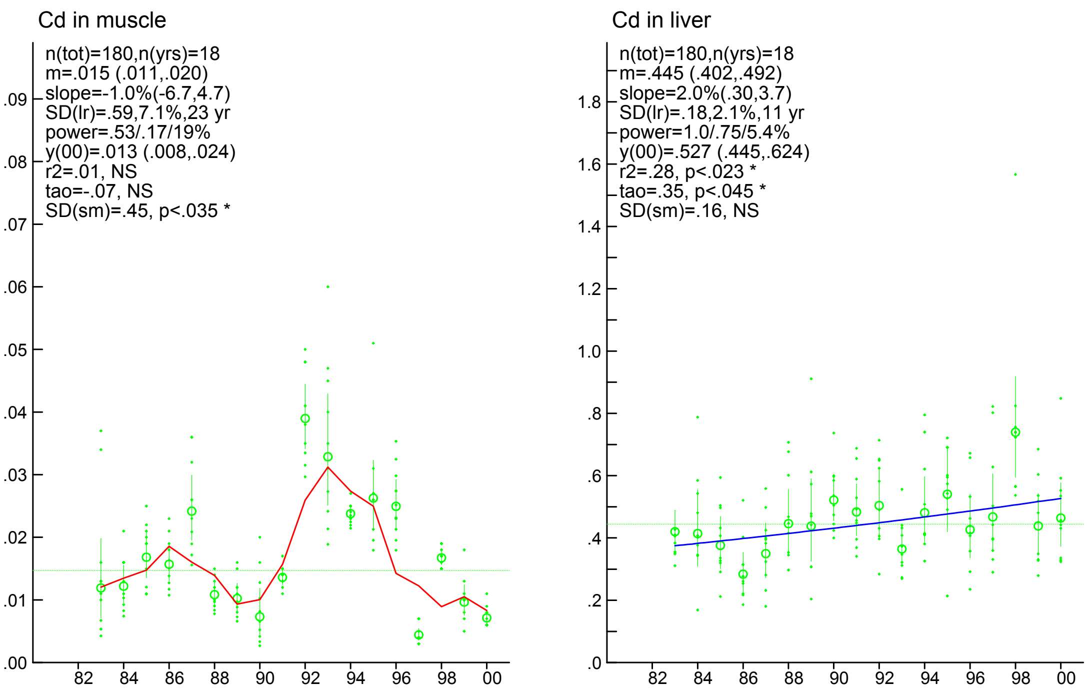
An overview of all results is presented in Table 6.1.1. Tables summarizing the results of the statistical analyses of the available time series for individual metals are provided in the full SGPOP report.

A preliminary draft of the AMAP assessment of temporal trends of heavy metals in the Arctic was presented, which will be part of the AMAP II assessment that is due to be published in October 2002. A summary of the results from the SGPOP statistical analysis of temporal trend data is as follows:

1) Long-term increases (2–17 times) in mercury concentrations have occurred in Arctic marine biota and humans since the Industrial Revolution, according to analyses of shells, hair, and teeth from Canada and Norway, suggesting a significant anthropogenic effect on mercury levels.

2) A number of species of marine biota (seals, beluga, narwhal, seabirds) in various regions of the Canadian and Greenland Arctic exhibit significant, increasing mercury trends, on the order of about 50–100 % over the past few decades. In contrast, biota in the European Arctic do not exhibit such trends. Possible explanations for this dichotomy will be reviewed.

Figure 6.1.1. Examples of plots and statistics reported in the plots. The plot on the left shows significant non-linear trend components, whereas the plot on the right shows a significant log linear upward trend.



3) Cadmium concentrations in biota and humans have remained generally unchanged since before the Industrial Revolution throughout the Arctic, suggesting the absence of an industrial effect.

4) Power analysis of existing short-term trend data sets from various terrestrial, marine, and freshwater biota showed that most data sets are generally inadequate in their period of coverage to detect even minimal (5 % annual) changes in metal concentrations, owing to large between-year variations and the small number of samples collected. In most cases, at least ten years, and up to thirty years, of monitoring at annual or perhaps longer intervals would be necessary to provide data of sufficient reliability. Time series monitoring programmes presently under way should continue so that, by the AMAP III Assessment, current trends can be assessed with more confidence.

Need for further research or additional data

The ACME noted that there is a need to consider the implications on the power to detect temporal trends using the methods recommended by WGSAEM, of sampling at greater than annual intervals, including irregular intervals. Of particular interest are temporal trends based on non-directly related monitoring activities conducted in different years over an extended period of time (e.g., thirty years).

References

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Cohen, J. 1977. Statistical power analysis for the behavioural sciences. Academic Press, New York.

ICES. 1991 Statistical analysis of the ICES Cooperative Monitoring Programme data on contaminants in fish liver tissue and *Mytilus edulis* (1978–1988) for determination of temporal trends. ICES Cooperative Research Report, 176. 189 pp.

Helsel, D.R., and Hirsch, R.M. 1995. Statistical Methods in Water Resources. Studies in Environmental Sciences 49. Elsevier, Amsterdam.

Hoaglin, D.C., and Welsch, R.E. 1978. The hat matrix in regression and ANOVA. American Statistician, 32: 17–22.

Nicholson, M.D., Fryer, R.J., and Larsen, J.R. 1998. Temporal trend monitoring: Robust method for analysing contaminant trend monitoring data. ICES Techniques in Marine Environmental Sciences, 20. 22 pp.

6.2 OSPAR Pilot Assessment Integrating Input Data and Environmental Concentrations

Request

Item 2.1 of the 2002 Work Programme from the OSPAR Commission: to participate in the joint assessment of concentration and input data to apply the trend assessment procedure.

Source of the information presented

The 2002 reports of the Marine Chemistry Working Group (MCWG), the Working Group on Marine Sediments in Relation to Pollution (WGMS), and the Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM), and ACME deliberations.

Status/background information

The aim of this request is to link input data to environmental concentrations of contaminants, such as CBs, organochlorine pesticides, PAHs, and trace metals, in sediments and biota. This is the so-called “joint” or “integrated” assessment requested by OSPAR.

It is known that transport models for contaminants are currently being developed for regional areas. Data about, for example, topography, hydrogeology (river flows, ocean water flows), contaminant levels in the different environmental compartments: water (dissolved and particle-associated fractions), sediments, biota, and air should be known or should be estimated, together with the respective contaminant transfer rates between the different ecological compartments or systems, the volumes of the compartments, and the breakdown rates of each contaminant in each compartment of a given system. The relationship between contaminant levels in biota and sediment at one side, and the various inputs at the other, is not straightforward. Also, there is doubt about the quality of the input data that have been collected so far. At specific locations, there may be a shortage of data on contaminant concentrations in the environment. Also, temporal trend data may be insufficient in some cases.

MCWG discussed a number of documents in relation to this agenda item that were made available from the December 2001 meeting of the OSPAR Working Group on Monitoring (MON). Concerning MON 01/4/1-E “Danish sediment data: availability and normalization”, the paper provides an introduction to the comprehensive sediment monitoring programme begun in 2000. The results of the first year’s monitoring data for heavy metals and organic contaminants are presented. As normalization parameters, the fraction <63 µm, the lithium and aluminium concentrations, the total organic carbon (TOC) content, and the loss on ignition were determined. The main conclusion was that further work is needed to decide on the most appropriate normalization procedure for sediments in this region.

Regarding the paper MON 01/4/2-E "Evolution of trace metal concentrations in sediments (fraction <20 µm) at selected sites in the German North Sea EEZ over a period of 15 to 25 years", the paper presents available data for temporal trend monitoring of heavy metals in sediments. Data were compiled according to general outlines presented at the MON meeting (MON 01/4/4-E) and discussed also by the Marine Chemistry Working Group. The paper contains all information necessary for an overall assessment of the temporal trends. To evaluate the comparability of the data with those from other monitoring stations or national reports, data on quality assurance and statements regarding the uncertainty of the data would be valuable. Additionally, a map could be provided for an easy overview of the locations of the sampling stations investigated, and a discussion of the temporal variation of heavy metal concentrations determined in sediments would be a useful addition to the text presented.

In general, MCWG agreed with proposals for a mechanism for assessing temporal trends in contaminant concentrations in sediments, but felt that the reports should include the following information as an aid to interpretation:

1) information on total organic carbon content and other normalizing parameters;
2) additional information on the grain size distribution, particularly the proportion of the fraction <2 microns;
3) concentration levels from pre-industrial time, as reference values;
4) sedimentation rates at the different sites and the age of the sediment layers (where undisturbed sediments were available).

Finally, MCWG discussed the report MON 01/3/7-E "Long-term trends in mercury, cadmium and lead in the Forth". This paper illustrates the response of concentrations in biota (mussels and fish) and sediment to the reduction in the inputs of Hg, Cd, and Pb to the Forth estuary. The biota show a clear response to the reduction in inputs that occurred primarily between 1981 and 1991. Hg and Cd concentrations in mussels and fish show a clear downward trend in the period 1983–2000. There is no clear trend for Pb. MCWG would also recommend the inclusion of information on the uncertainties associated with the data and on quality assurance.

In the discussion of the statistical aspects of the pilot assessment, WGSAEM commented on the relatively simple analysis that had been made of national data. Essentially this consisted of simple parallel plots of the trends in different time series with either a verbal description of common trends or a more formal characterization of common trends using a correlation coefficient. WGSAEM also agreed with the OSPAR conclusions that a clearer statement of the objectives of joint assessments is required. It was felt that a more formal approach to describing the relationship between inputs of contaminants and their concentrations in sediments would be useful, especially if this is linked to these objectives.

Here is one very simplistic example to demonstrate how one might begin to establish a more explicit link between, e.g., inputs and concentrations in sediment. Let

$L(t)$ be the unadjusted input into an estuary at time t,
$X(t)$ be the concentration in the estuary at time t,
$B(t)$ is the concentration in the sea at time t,
$S(t)$ is the concentration in the sediment at time t.

Assuming that within the time period t to t+1, a fraction w of water in the estuary is exchanged with water in the open sea, and V is the volume of the estuary

$$X(t+1) = (1-w)\,X(t) + w\,B(t) + L(t+1)\,/\,V.$$

Further, assume that the concentration in the sediment is governed by the relationship

$$S\,(t+1) = b\,S(t) + g\,X(t)$$

where b parameterizes the natural rate of decay in the sediment, and g parameterizes the uptake from the estuary.

To turn these mathematical models into statistical models, it is necessary to introduce an appropriate error structure (i.e., a stochastic term). For these types of mathematical models, this might typically lead to a vector autoregressive statistical model.

The parameters of the coupled equations above will generate correlations and cross-correlations between input loads and concentrations in sediment. The advantage of working with models of this type is that it is possible to estimate the relevant parameters, and thus to provide a quantitative assessment of the effect of the input load to the sediment concentration. Furthermore, it is possible to test these parameters, i.e., it could be examined whether input reduction has a significant impact on the sediment concentration or not.

These coupled equations might provide a starting point for developing both monitoring strategies and statistical models for relating sediment concentrations to inputs. Clearly, the model would need to be refined in the light of empirical data, mathematical modelling, common wisdom, etc. Similar approaches might be applied for the inclusion of contaminants in biota.

Finally, WGSAEM noted that there are already several mathematical models (process models) for describing marine systems, which might be integrated with statistical concepts for use in joint assessments.

Need for further research or additional data

A clearer statement of the objectives of joint assessments is required. This request involves a substantial task which could not be carried out simply within the framework of Working Group meetings.

A concerted international action would be necessary to develop relationships between input data and environmental levels, and collaboration between ICES and OSPAR on a broad scale is required.

Recommendations

ICES recommends that OSPAR organize a joint meeting with policy-makers and relevant experts (chemists, statisticians, and developers of mathematical models for describing marine systems) to address the following issues:

- discuss the objectives of joint assessments of data on inputs of contaminants and their concentrations in marine environmental compartments;
- develop a statistical framework for joint assessments;
- discuss approaches for joint assessments based on mathematical and statistical models describing marine systems.

OSPAR may consider organizing this meeting within a workshop for joint assessments, environmental indicators, and data filtering.

6.3 GESAMP/ICES Working Group on Environmental Exposure Models

Request

In 2001, the UN Food and Agriculture Organization (FAO) enquired whether ICES was willing to co-sponsor a Working Group on the development of risk assessment models with regard to contaminants in seafood.

Source of the information presented

The 2002 reports of the Marine Chemistry Working Group (MCWG), and the Working Group on Biological Effects of Contaminants (WGBEC), and ACME deliberations.

Status/background information

On the basis of the request of the Food and Agriculture Organization in 2001, ICES agreed to co-sponsor a working group under the IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) entitled the Working Group on Environmental Exposure Models for Application in Seafood Risk Analysis (Working Group 33). This Working Group held its first meeting in December 2001, at which it reviewed the objectives of the work and decided that the group should develop an approach to ensure that seafood is not harvested in a location or produced in a manner in which its quality would be suspect, rather than having seafood safety depend on controls applied to the post-harvest end product. The group felt that recognizing the relationship between global production and the use of chemical substances and seafood contaminant levels would be a crucial tool in the future to prevent seafood quality impairment. For example, the global production and use levels of certain substances, such as Persistent Organic Pollutants (POPs), has resulted in seafood safety concerns in certain parts of the world. Thus, the group felt that the first step in developing tools to assess the impact of global chemical use on the safety of seafood products is to develop tools that can relate ambient contaminant levels to concentrations in seafood products.

The first report of this Working Group was reviewed by the Marine Chemistry Working Group (MCWG) and the Working Group on Biological Effects of Contaminants (WGBEC). In the MCWG review, it was noted that the original intention of this work was to address hazard/risk assessment, but the aim of the current work appears to be towards exposure only. MCWG was somewhat sceptical that some of the claims made in the draft document could be realized in practice, and also of the indication that modelling would entail much less work than determining seafood contaminant concentrations directly. Regarding the choice of contaminants, MCWG felt that polybrominated diphenylethers (PBDEs) were to be preferred over polybrominated biphenyls (PBBs), as considerably more data are available for these compounds. Polycyclic aromatic hydrocarbons (PAHs) are also important contaminants in seafood, and are of concern for the potential health effects on human consumers.

The underlying assumption in this project is that it is difficult to determine seafood contaminants, and that modelling and prediction of them is a more cost-effective approach. However, in order to effectively model uptake and bioaccumulation, there is need for good knowledge on topics such as the ecology of the species studied, migration patterns, and concentration data for the contaminants in water, sediments, and the local food webs (the primary uptake source).

Overall, the intention of modelling bioaccumulation as a tool to predict and assess seafood contamination is a good one, but a very large amount of data will be needed to successfully develop and validate the models, and it may not be a straightforward matter to transfer a model validated at one location and for one species, to other species and areas.

The WGBEC review concurred with that of MCWG, finding that it was somewhat too ambitious to believe that models could be used to accurately predict concentrations in all marine organisms. The extent and availability of the data sets needed to produce such predictions for the range of proposed contaminants were also not clear to the group. WGBEC agreed with the approach chosen, i.e., to select one species (blue mussel) for initial testing of the approach. The extent to which such an approach is viable will depend on the availability of data to establish the model.

In considering these reviews, the ACME agreed with the assessments of MCWG and WGBEC, but noted that this work is still in its initial stages. It will require comprehensive data sets in several areas to be able to test the hypotheses developed by the GESAMP Working Group, and this will still not ensure the broader applicability of the models developed.

In sum, the ACME agreed with the comments of MCWG that this group was not taking adequate account of all possible factors that influence the contamination of seafood, and that post-harvest inspection would be the better approach as this integrates all sources of contamination. To achieve what this group hopes will take very detailed models, which we are quite far from having. It was doubted whether this approach would be usable to inspection agencies.

6.4 Statistical Considerations in relation to the Calculation of Background Concentrations of Contaminants

Request

This was an initial request by the Helsinki Commission on the ICES work programme for 2002 seeking advice concerning how many samples are needed for calculation of the fifth percentile and associated uncertainties of appropriate time series with regard to determining background concentrations of certain elements in biota; this request was subsequently withdrawn. However, the ACME considered that this might be an issue that could be of interest to ICES Member Countries.

Source of the information presented

The 2002 report of the Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM) and ACME deliberations.

Status/background information

In considering this issue, WGSAEM noted that the request was open to interpretation. The group assumed that it relates to the use of 95 % percentiles for estimating upper limits to what can be considered uncontaminated concentration levels, and how the precision of such estimates depend on the number of samples.

The assumed goal is to estimate a concentration level for a defined percentile point of a population, given a random sample from the population. As an example: Estimate a concentration level C_0 such that 95 % of individual fish from a population has concentration $<C_0$.

A $100 \cdot q$ % percentile point is the value x_q such that the probability $P(X<x_q) = q$ for a random X from the population distribution.

Non-parametric approach: Some methodology

Given a sample of n values x_i, (i=1,…,n) sorted by increasing values, the percentile point x_q can be estimated as

$$\hat{x}_q = (1-f)x_j + fx_{j+1}$$

where j and f are, respectively, the integer and decimal part of $(n+1)q$ as long as $1 \leq j < n$, otherwise the smallest or largest value is used directly. This estimate will be uncertain, because the sample proportion of values below a percentile point will vary randomly. Let k be the number of values below the percentile point in a random sample of size n. This number is a stochastic value defined by the binomial distribution with probability of success[1] q:

probability distribution: $$p(k) = \binom{n}{k} q^k (1-q)^{n-k}$$

cumulative distribution: $$P(k) = \sum_{i=0}^{k} p(i)$$

The cumulative distribution function means that a proportion $P(k_1)$ of random samples will have $\leq k_1$ values within the q-level percentile point in the population. A confidence interval for the percentile point with confidence level $1 - \alpha$ can then be estimated by looking at cdf points $\alpha/2$ and $1 - \alpha/2$. For a random sample, there is a probability $\geq(1 - \alpha)$ that the population percentile point will be between limits x_l, x_h defined by:

$$P(l) \leq \frac{\alpha}{2} \quad ; \; P(h) \geq 1 - \frac{\alpha}{2}$$

where l is the last index in the series of sorted observation values that satisfies the first inequality, and h is the first index satisfying the last inequality. The limits may also be interpolated between indices just below and above the probability limits:

$$\hat{x}_l = (1-f_l)x_l + f_l x_{l+1} \quad \text{with}$$
$$f_l = \left(\frac{\alpha}{2} - P(l)\right) \Big/ \left(P(l+1) - P(l)\right)$$

[1] Success being that an observation (a trial) gives a value less that the 100p % percentile point.

$$\hat{x}_h = (1 - f_h)x_h + f_h x_{h-1} \quad \text{with}$$

$$f_h = \left(P(h) - \left(1 - \frac{\alpha}{2} \right) \right) \Big/ \left(P(h) - P(h-1) \right)$$

Confidence band for the 95 % percentile

Figure 6.4.1 shows 90 % confidence limits when using non-parametric statistics to estimate the upper 95 % percentile point as a function of the number of samples used for the estimate. With less than 100 observations, an upper confidence limit cannot be established. With 200 observations, the estimated 95 % percentile point based on a random sample will, with probability 90 %, be found between the actual 92.5 % and 97.5 % percentile points of the population distribution. Only as the number of observations approaches 1000 will the percentile point be estimated with reasonable precision using the non-parametric approach.

Parametric approach

The non-parametric exact approach described above will give confidence limits in terms of the lower and upper percentile limits for the nominal percentile level specified. That is, it will specify which percentiles from a sample should be used to establish lower and upper confidence limits to the specified percentile point of the population.

The non-parametric approach will require a large sample to estimate high percentiles with any accuracy. An alternative approach would be to assume some parametric form of the distribution, for instance a log-normal distribution[2], and then estimate percentile points based on that. With such a parametric approach, one can estimate confidence limits with fewer observations than with the non-parametric approach. However, a potential problem with this approach is that the choice of parametric distribution is usually based on the bulk of observations and thus might not provide a good characterization of the tail of the distribution. WGSAEM noted that a hybrid parametric/non-parametric approach is possible. This assumes that, for example, the lower tail of the distribution can be modelled as an exponential distribution. This is appropriate for many standard distributions such as the Normal and the log-Normal, as well as for mixtures of these distributions.

Need for further research or additional data

The ACME recommended that the suggested hybrid parametric/non-parametric approach be investigated and that more background information for this request should be provided, including some real data with clearly stated goals for statistical assessments.

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[2] Percentiles with confidence limits would be calculated on the log-transformed values, i.e., for Normal distribution, and back-transformed.

6.5 Critique and Suggestions for Further Development of OSPAR Ecological Quality Objectives for the North Sea with regard to Nutrients and Eutrophication Effects

Request

The Bergen Declaration from the Fifth International Conference on the Protection of the North Sea includes a number of specific Ecological Quality elements and Ecological Quality Objectives for nutrient inputs and eutrophication effects. ICES has been assigned a key scientific advisory role during the implementation stage, and this critique is a necessary first step in addressing that role.

Source of the information presented

The 2002 reports of the Marine Chemistry Working Group (MCWG), the Working Group on Phytoplankton Ecology (WGPE), the Benthos Ecology Working Group (BEWG), the 2001 and 2002 reports of the Working Group on Ecosystem Effects of Fishing Activities (WGECO), and ACME deliberations.

Status/background information

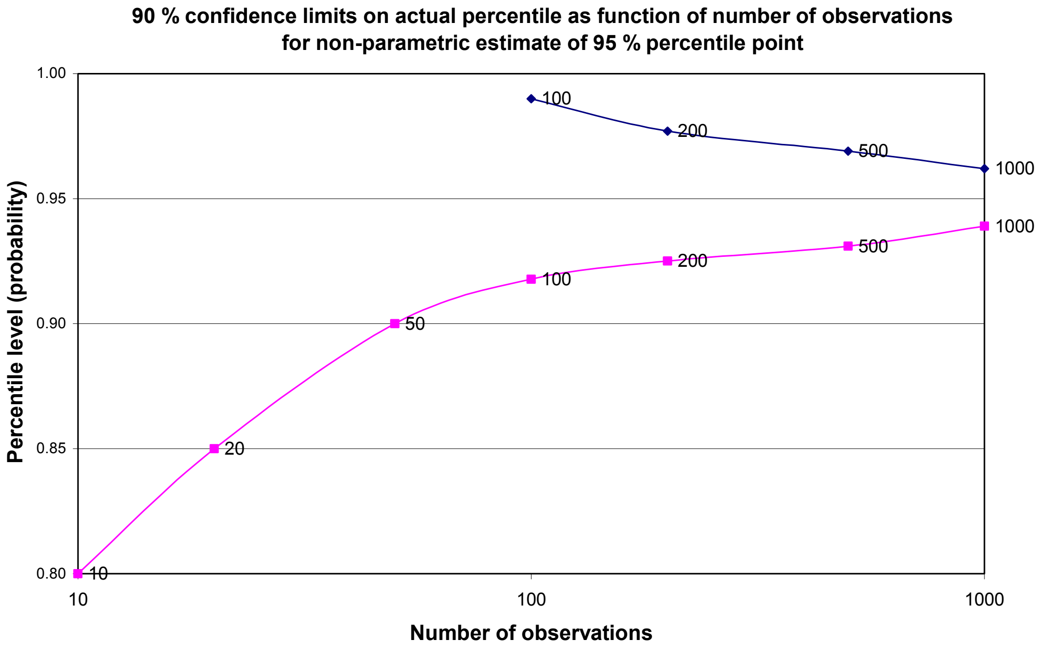
This issue must be considered in the context of the accepted OSPAR definitions of Ecological Quality (EcoQ) and Ecological Quality Objective (EcoQO). These definitions were agreed at the OSPAR workshop held in Scheveningen in 1999 (Anon., 1999; see also ICES, 2001).

Ecological Quality (EcoQ): An overall expression of the structure and function of the marine ecosystem taking into account the biological community and natural physiographic, geographic and climatic factors as well as physical and chemical conditions including those resulting from human activities.

Ecological Quality Objective (EcoQO): The desired level of ecological quality relative to a reference level.

Furthermore, EcoQOs must be selected in a manner that reference points can be readily defined and evaluated. In ICES advice regarding fisheries, **reference points** are specific values of measurable properties of systems (biological, social, or economic) used as benchmarks for management and scientific advice. They function in management systems as guides to decisions or actions that will either maintain the probability of violating a reference point below a pre-identified risk tolerance, or keep the probability of achieving a reference point above a pre-identified risk tolerance. There will be multiple reference points for any single property of a system, each serving a specific purpose.

Figure 6.4.1. 90 % confidence limits on the actual percentile as a function of the number of observations for a non-parametric estimate of the 95 % percentile point.



Annex 3 of the Bergen Declaration also uses the term **Ecological Quality Element**, which functions as a statement of intermediate specificity between EcoQs and EcoQOs, usually (but not always) suggesting the specific type of indicator that will be used in setting the EcoQO. It also lists **Issues** that seem to function as themes about which EcoQ statements are to be made. These definitions do not appear to be applied with complete consistency within the contents of Annex 3, and confusion about the terminology continues to impede rapid progress on implementation of the overall framework.

In the Bergen Declaration, paragraphs 57–59 address the prevention of eutrophication. It is noted that the goal of 50 % reduction in phosphorus inputs has been achieved by most countries around the North Sea. However, slow progress towards the objective of 50 % reduction in nitrogen inputs was noted with "considerable disappointment" by the North Sea Ministers. The commitment to these reduction targets is reaffirmed, supported by several specific commitments (paragraph 59). To facilitate monitoring and reporting on progress towards this goal, in Annex 3 specific Ecological Qualities (EcoQs) are identified for benthic communities (No. 6), plankton communities (No. 7), nutrient budgets and production (No. 9), and oxygen consumption (No. 10). The corresponding EcoQ elements are: (m) change/kills in zoobenthos in relation to eutrophication, (q and r) phytoplankton chlorophyll *a* and phytoplankton indicator species for eutrophication, (t) winter nutrient (dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphate (DIP)) concentrations, and (u) oxygen concentrations. Each of these elements has a corresponding ecological quality objective (EcoQO):

m) There should be no kills in benthic animal species as a result of oxygen deficiency and/or toxic phytoplankton species.

q) Maximum and mean chlorophyll *a* concentrations during the growing season should remain below elevated levels, defined as concentrations >50 % above the spatial (offshore) and/or historical background concentrations.

r) Region/area-specific phytoplankton eutrophication indicator species should remain below respective nuisance and/or toxic elevated levels (and increased duration).

t) Winter DIN and/or DIP should remain below elevated levels, defined as concentrations >50 % above salinity-related and/or region-specific natural background concentrations.

u) Oxygen concentrations, decreased as an indirect effect of nutrient enrichment, should remain above region-specific oxygen deficiency levels, ranging from 4–6 mg oxygen per litre.

Annex 3 further notes that the "ecological quality objectives for (m), (q), (r), (t), and (u) are an integrated set and cannot be considered in isolation. ICES will give further advice during the implementation phase."

Recent developments

At the November 2001 meeting of the OSPAR Eutrophication Committee, that Committee identified four topics relative to nutrients and eutrophication: nutrients (winter DIN and DIP), phytoplankton (chlorophyll *a* and indicator species), oxygen (oxygen), and benthic communities (benthos kills), which would serve as its assessment criteria. The assessment criteria were classified into four categories: degree of enrichment, direct effects of nutrient enrichment, indirect effects of nutrient enrichment, and other possible effects of nutrient enrichment. OSPAR proposes to use this classification to designate areas as in a problem state, a potential problem condition, or a non-problem condition.

Some preliminary tabular material was made available on historical/background levels of chlorophyll *a*, frequency of occurrence of elevated levels, and presence and abundance of indicator species. However, the information is spatially scattered, from inconsistent historical time periods, and likely to be of variable quality. The tabular material is not yet adequate for setting reference points on EcoQOs. The persons who prepared the tabular material also acknowledged this point.

OSPAR has requested expert, independent feedback from ICES, with regard to their activities to advance these EcoQs and EcoQOs. In light of that request and the material in the Bergen Declaration, several scientific tasks fall to ICES, in order to make these EcoQOs functionally operational both individually, and as an "integrated set". These include:

- assisting Contracting Parties of OSPAR to assemble information for the assessment scheme;
- developing or contributing to the development of standardized reporting forms;
- developing and participating in implementing a coordinated monitoring programme, including standards and protocols for local adaptation where they are needed;
- participating in quality control review of reported information;
- participating in analyses, interpretation, application, and reporting of information submitted;
- classification of water masses and areas into appropriate monitoring and reporting units, including identification of explicit classification criteria (e.g., coastal salinity gradient, degree of stratification), so reporting units remain meaningful and interpretable.
- development of consistent standards for the selection of indicator species for phytoplankton and for benthos kills, and either applying those standards or reviewing their application by others.

A review of the preliminary information provided by the OSPAR Eutrophication Committee, in the context of the provisions of the Bergen Declaration and its Annexes, reveals some potential problems that require discussion and, in some cases, action. In particular, the "Agreed Harmonized Assessment Criteria" require further clarification, and may not be relevant to all sites or all times. Inadequate provision is made for transboundary nutrient transport, which could dominate greatly over local anthropogenic inputs for some nutrients, particularly inorganic nutrients. This could be particularly problematic for seasonally varying nutrients, where both the definition of "winter concentration" and the methods for partitioning local nutrient dynamics (maximum accumulation less minimum primary productivity) do not account for potential transboundary transport effects.

The "assessment criteria" appear likely to be difficult to put into practice on local scales, certainly in a consistent manner and possibly at all. No consistent rationale appears to have been developed for setting the boundaries of "background concentrations" and "elevated concentrations", and the values as currently tabulated may not form a basis for consistent action. Linkages between monitoring results and policy actions are not apparent nor tightly connected, particularly where naturally occurring (and naturally variable) nutrients have locally varying values as diagnostics of eutrophication. Much more attention needs to be given to the spatial and temporal aspects of trend assessment (including if, when, and how to aggregate monitoring results from different sites), and to the statistical complexities of reliable, robust trend detection.

The ACME also notes that there will be difficulties in implementing EcoQ (m), related to no kills of benthic animal species as a result of oxygen deficiency and/or toxic plankton species. The assumed causal chain from nutrient enrichment to phytoplankton blooms to oxygen depletion to benthic mortality is a great over-simplification of the relationships in the system. In practice, there will be few clear-cut causal associations. There may be natural causes of local (or occasionally even widespread) oxygen deficiencies and benthos kills. The EcoQ and EcoQO, taken with the reference point of "no kills" in reactive applications, will trigger management interventions in reaction to even natural variations. Taken in a proactive mode "to prevent all kills" would require management to effectively constrain the range of natural variation more narrowly than has occurred in naturally functioning ecosystems.

Need for further research or additional data

Over the next round of meetings, the appropriate ICES Working Groups should consolidate the available data relative to these EcoQs and EcoQOs, review the proposed Ecological Quality elements and Objectives, and, where necessary, suggest altered or alternative Ecological Quality elements and Objectives. The aim of this work is to understand the properties of the selected indicators, and propose modifications that may make them more operational and well linked to monitoring programmes. WGECO should consider the results of these reviews in the context of the evaluation criteria and screening processes that they have been developing, and the overall goal of supporting an ecosystem approach to the development of scientific advice and management.

References

Anon. 1999. Workshop on Ecological Quality Objectives (EcoQOs) for the North Sea. 1–3 September 1999, Scheveningen, the Netherlands. Nordic Council of Ministers. TemaNord 1999:591. 75 pp.

ICES. 2001. Report of the ICES Advisory Committee on Ecosystems, 2001. ICES Cooperative Research Report, 249: 15–59.

6.6 Data Products for Trace Metals, Organic Contaminants, and Eutrophication in relation to Environmental State Indicators

Request

Item 5 of the 2002 Work Programme from the OSPAR Commission:

5 Provide advice on data products in relation to the preparation of indicators:

5.1 Advise on what data products might be produced as a basis for indicators to be decided upon in the light of the conclusions of the IRF workshop.

Source of the information presented

The 2002 report of the Marine Chemistry Working Group (MCWG) and ACME deliberations.

Status/background information

There is a general need within national as well as international organizations such as ICES, OSPAR, and the EEA (European Environment Agency) to develop indicators of environmental status in order to present complex data in a more accessible and understandable way for the public and politicians.

The ACME recognized the general impetus for the development and use of environmental indicators. First, however, the aims of such indicators need to be clear. They might be intended, for instance, to inform environmental managers of the effects of controls, inform the wider public of the efficacy of regulations intended to control pollution, or for other purposes. For each aim, differently derived indicators may be appropriate. Similar approaches have been implemented successfully in other areas of the world, and ICES should learn from the experience of others. One example specifically mentioned was the joint USA/Canada studies undertaken in the Great Lakes area, where indicators have been developed over the past 25 years. The development of these indicators, and the means to represent them took time, but they have proved useful. Further development of these indicators is under way, and existing indicators are being maintained and updated. For further information, there is a website: www.ijc.org.

Additional examples that would merit study include the report no. 5052, “Coasts and Seas”, prepared by the Swedish Environmental Protection Agency (SEPA, 2000), and the programme “Water Mondrian” being developed by the Rijkswaterstaat in the Netherlands.

Within OSPAR and the EEA, there is a desire to link input data with environmental data on the concentrations and/or effects of chemicals, but it seems that there needs to be some more focus on processes and the development of a holistic approach in order to facilitate this. For instance, input data are not always comprehensive and, currently, environmental sampling is not yet targeted towards those locations that would most directly reflect changes in inputs over time. The design of such a targeted monitoring strategy would benefit from discussions among environmental managers, process modellers and oceanographers, as well as biologists, chemists, and sedimentologists with a good local knowledge, to promote the exchange of ideas and to develop indicators which apply to both spatial and temporal scales, and are likely to provide a rapid response to changes. It is, however, realized that the introduction of any indicator will be a sacrifice towards science and by definition be disputable, but it is preferred that the scientists take an active part in the process where the compromises are made instead of simply criticizing proposals from other sources.

The entire process of the development of each indicator should be transparent, and data should carry information on the quality assurance and a statement of the associated uncertainties. It should be clearly stated which data have been used in preparing the indicators, whether there are gaps in these spatial and/or temporal data, and what aggregation or process has been applied in order to generate the indicators from the data. This is very important because if data are aggregated, e.g., across a large area such as the Northeast Atlantic and the Mediterranean Sea, and if the number of data sets used in the calculation of, e.g., temporal trends is very unevenly distributed geographically, this can lead to misinformation. A more relevant presentation of the trends can be obtained by dividing the information into sub-areas, and by using colours to indicate trend directions (up, down, or no apparent trend) in certain areas. It should also be borne in mind that, if concentrations from different areas are simply summed, a clear upward trend in one area could be cancelled by a clear downward trend in another area, giving no trend as a result. This highlights the importance that the indicators should be scientifically justified, e.g., presenting averages of substances that are very different in their chemical characters and effects is not to be recommended.

It is also important to clearly demonstrate the environmental relevance of the indicators being reported, for instance, in relation to eutrophication and ecosystem effects.

The ACME noted that it had not been possible for the relevant ICES Working Groups to prepare a draft response to this request because the exact use and purpose of the data products had not been made clear in the request. To be able to develop a useful response, this information is required.

The ACME agreed that, to carry forward the work on the development of environmental indicators, a concerted action among ICES, OSPAR, and HELCOM should be initiated, including the conduct of workshops at which the development of indicators can occur.

Reference

SEPA. 2000. Environmental Quality Criteria "Coasts and Seas". Report from the Swedish Environmental Protection Agency, No. 5052.

6.7 Statistical Aspects in relation to the Development of Environmental Indicators and Classifications: Methodological Development

Request

This is an initial consideration of statistical aspects in relation to the development of environmental indicators and classifications.

Source of the information presented

The 2002 report of the Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM) and ACME deliberations.

Status/background information

WGSAEM discussed the current move towards using indicators to reflect different aspects of the environment. A paper (Nicholson and Fryer, 2002) was presented arguing that:

- indicators emphasize the *relevance* of monitoring; however, indicators must also be *effective* and this aspect of indicator development is often forgotten, leading to poor quality monitoring and environmental management;
- the term *indicator* is used in many ways—as a framework, something that is measured, an index, an assessment statistic—and this can lead to confusion (see the comments on the EEA reports below);
- it is important that a clear terminology and framework is established for constructing relevant and effective indicators; however, such frameworks are likely to be context specific.

The paper demonstrated how such a framework might be established in one such context: namely, when the indicator reflects the level of a contaminant in a sentinel organism collected as part of a temporal monitoring programme.

Within the EU Water Framework Directive there are several areas where indicators will be used and where appropriate statistical frameworks need to be established. One area is *operational control*, where a *pressure* has been identified and management measures are required to reduce the pressure. For example, the pressure might be high concentrations of pesticides and the management measure might be some reduction of inputs. Monitoring is then required to assess whether the management measure is succeeding (e.g., is there a downward trend) and finally that it has been effective (e.g., has returned to background levels). The methodology described in Nicholson and Fryer (2002) provides a suitable framework for constructing effective indicators within the operational control context.

Another area is *surveillance monitoring* where, based on a series of measurements, it is necessary to classify water bodies according to their ecological status. Work is required to establish an appropriate statistical framework for this type of monitoring. The issues that need to be addressed include the development of suitable methods for assigning a classification and for estimating misclassification rates, and the design of sampling schemes to limit the misclassification rate to an acceptable level. Such work would have impact independent of the Water Framework Directive, for example, the classification of sites according to OSPAR ecological quality objectives (EcoQOs), and in the construction of sediment quality guidelines.

Comments on EEA indicator fact sheets

WGSAEM had been requested to consider the use of indicators in the assessment of trends by the European Environment Agency (EEA). WGSAEM therefore reviewed several draft 2002 EEA indicator fact sheets (Chlorophyll-*a* concentrations in coastal waters; Hazardous substances (cadmium, mercury, lead, zinc and ΣCB_7) in blue mussels and cod in the North East Atlantic (including the North Sea) and the Mediterranean in the period 1990–1999; Input of hazardous substances (cadmium, mercury, lead, zinc, lindane, and ΣCB_7) into the North East Atlantic (including the North Sea) in the period 1990–1998), which provided a number of assessment results based on various statistics, as summarized in Table 6.7.1.

Table 6.7.1. Summary of the statistics used in the draft 2002 EEA indicator fact sheets.

Parameter	Indicator	Statistics
Chlorophyll *a*	Summer mean concentrations	Mann-Kendall test for monotonic trend.
Nitrogen and phosphorus (river)	Yearly mean per station	Trend of median concentrations over rivers, from different size categories—no test.
Hazardous substances (Cd, Pb, Hg, Zn, ΣCB_7) Concentrations in mussel and cod	Yearly mean over stations	Trend of yearly mean concentrations over stations by region (Northeast Atlantic and Mediterranean Sea)—no test.
Hazardous substances (Cd, Pb, Hg, Zn, Lindane, ΣCB_7) Inputs	Average of yearly high and low input values (in tonnes) by country	*Steps* 1) Sum of averages for Northeast Atlantic per year; 2) % relative to 1990; 3) Mean percentage per year for all parameters aggregated. Decreases = ratios of (1998–1990) values to 1990 values (no estimates of uncertainty).
Nitrogen and phosphorus (coastal water)	Yearly mean of winter concentrations	Mann-Kendall test for monotonic trend.

WGSAEM considered that there are some inconsistencies in the uses of the term "indicator" in the indicator fact sheets provided. These included the following:

- They present different meanings: for instance, chlorophyll *a* is meant as an indicator of eutrophication, without referring to the way chlorophyll *a* data should be processed to offer relevant information to the policy-maker. Here, "indicator" means parameter. In the case of phosphorus and nitrogen, the "main" indicator is a trend.
- They correspond to very different scales of aggregation. Trends in nitrogen and phosphorus are computed over all EU countries by size category of rivers, while trends in chlorophyll *a* are considered by station. There should be some justification of the sampling scale retained for each indicator.
- They are not defined in a precise way. For example, the way satellite information should be used for the sub-indicator "chlorophyll *a* from satellite images" is not presented. The description of the statistics was not clear, especially for inputs.

There also seem to be some problems in the statistical relevance of these indicators, as illustrated by the following examples:

- To illustrate the evolution of nitrogen and phosphorus concentrations in rivers, EEA constructs time series of the median of the stations' yearly means, by category of river (small, medium, large, very large, largest, all sizes). By doing this, it is assumed that the trend in these concentrations should be roughly the same for each river within each category regardless of the actual level of eutrophication for each river. At least this assumption should be acknowledged. In practice, this approach could fail to detect important aspects of trends in individual rivers.
- Visual descriptions of trends are used as indicators with statistical inference in the case of chlorophyll *a* (Mann-Kendall), and without in the case of hazardous substances. A trend should be tested objectively when management action is imposed. Thus, there should be some statement about the risk of having detected a trend when it does not exist (type I error) and, ideally, the risk of not having detected a trend when it exists (type II error). A significance level of 5 % is mentioned for chlorophyll *a* and for the sub-indicator "Long term development in phosphate and nitrate concentrations".
- Means are not computed on the same number of stations; for example, a look at Table 3 (in Indicator Fact Sheet ES2002) shows that Norwegian data have a great deal of weight in the yearly mean estimate, while the Netherlands data have not. Furthermore, there are a large number of missing years, such as for Iceland, possibly leading to biased mean estimates and consequently biased trends.
- The Mann-Kendall test is robust and an accepted approach for judging monotonic trends. For multiple, independent series, the approach can easily be combined into overall formal test levels, by looking at the number of series with significant trends, and comparing it with what can be expected if there is no general overall trend in the "population" of time series (a kind of meta-testing). However, if the series

are not independent, but are influenced by the same events and variations, they do not constitute independent confirmations of a general trend. Increasing the number of stations will still increase the statistical power in testing whether there are real differences between specific years for a region, and give a truer picture of such differences. However, if the overall variation between years is the dominant source of variation, the increasing number of stations will not increase the certainty of the trend assessment. For instance, for nine time series (stations) with independent fluctuations from year to year, the probability of having two or more time series with negative trends that are significant at the 2.5 % level is about 2 % if there really are no trends at all, only random variations. The occurrence of six such series is overwhelmingly significant of real trends occurring (probability $<2 \times 10^{-8}$ if purely random variations). If, on the other hand, the fluctuations of the series are strongly correlated, six series with significant trends at the 2.5 % level could be merely a repeated result, indicating an overall significance level of about 2.5 %.

- Additional, important information includes the length and range of the individual time series, such as mean/median number of values, and mean/median time interval between first and last data point. There might be further statistical information on the distribution of sampling times that is relevant as well.

References

Nicholson M.D., and Fryer R.J. 2002. Developing effective environmental indicators – does a new dog need old tricks? Marine Pollution Bulletin, 45: 53–61.

EEA. 2002. Indicator Fact Sheet ES2002 on hazardous substances (biota). EEA, Copenhagen, Denmark. 9 pp.

EEA. 2002. Indicator Fact Sheet ES2000 on hazardous substances (inputs). EEA, Copenhagen, Denmark. 12 pp.

EEA. 2002. Indicator Fact Sheet on nitrogen and phosphorus in rivers in EU countries and Phare Accession countries. EEA, Copenhagen, Denmark. 15 pp.

EEA. 2002. Indicator Fact Sheet on chlorophyll *a* concentrations in coastal waters. EEA, Copenhagen, Denmark. 6 pp.

EEA. 2002. Indicator Fact Sheet on phosphate and nitrate concentrations in coastal waters. EEA, Copenhagen, Denmark. 6 pp.

6.8 ICES Environmental Status Report

Request

During the past few years, several ICES Working Groups have agreed to contribute to an ICES Environmental Status Report, which will be updated annually or more frequently, depending on the subject matter. The Environmental Status Report is published on the ICES website (http://www.ices.dk/status) as material becomes available.

6.8.1 Oceanographic conditions

Source of the information presented

The 2002 report of the Working Group on Oceanic Hydrography (WGOH), the ICES Ocean Climate Status Summary 2001/2002, and ACME deliberations.

Status/background information

The North Atlantic Oscillation (NAO) index has been slowly recovering to positive values since the extreme negative value of 1996. However, during the winter preceding 2001 it again became negative. The response seen throughout the ICES area to the 1996 switch of the NAO has not been observed in 2001, probably due to a different pattern of sea level pressure over the North Atlantic. In 2001, the pattern exhibited a large weakly positive anomaly stretching from northern Scandinavia to Newfoundland.

The oceanographic conditions in the various ICES areas may be summarized as follows:

- Ocean temperatures off West Greenland showed considerable warming during the summer and autumn of 2001. This warming was similar to that observed during the 1960s. Anomalously high salinities were observed in the off-slope surface waters during the autumn.
- Annual mean air temperatures over all areas of the Northwest Atlantic were above normal during 2001, but decreased compared to the records set in 1999. The amount of sea ice on the eastern Canadian continental shelf continued to be below normal for the fourth consecutive year. Except for southern areas of the Newfoundland and the northern Scotian shelves, ocean temperatures were above normal, continuing the warm trend established in the late 1990s.
- Surface waters over the entire Scotian Shelf have been warmer and fresher than average during the past several years, including 2001. The higher temperatures are due to the warmer atmospheric conditions and the low salinities have been related to upstream influences off Newfoundland.
- The upper layers of the Labrador Sea were observed to be warmer, saltier, and less dense in the summer of 2001 compared with conditions in 2000. These changes seem to be due largely to the inflow of Atlantic waters. There is no evidence that convective overturning during the winter of 2000–2001 reached depths greater than 400–500 m.
- In Icelandic waters, there were relatively high temperatures and salinities, as there have been for the

previous 3–4 years following the very cold years of 1995 and 1996. However, 2001 temperatures and salinities were slightly cooler and fresher than in 1999 and 2000.

- The Bay of Biscay continued to show a progressive decrease in salinity, which began in 1999. Averaged upper water layer temperature was low compared to values obtained during the last decade, whereas the yearly averaged air temperature remained at the same level as in the preceding three years.
- The Rockall Trough began to cool and freshen slightly during 2001, although both temperature and salinity remained high compared to the long-term mean, with values similar to previous peaks in the early 1980s.
- The temperature and salinity of Atlantic water passing through the Faroe Bank Channel and across the Iceland-Faroe Ridge have remained fairly constant since 1997.
- With respect to the past four decades, Atlantic waters in the Faroe Shetland Channel are generally warming and becoming more saline. However, there was little change between 2000 and 2001.
- In terms of the surface temperatures of the North Sea, 2001 was generally warmer than normal. The summer of 2001 exhibited a reduced influence of Atlantic water in the northern North Sea and also in the Southern Bight. The low salinities in the southern North Sea suggest stronger than normal runoff from the continental rivers. The Baltic outflow southwest of Norway in summer 2001 was stronger than normal.
- In the Baltic Sea, surface waters generally became fresher due to high freshwater inputs following a wet winter. Surface temperatures were warmer than average. There were deep-water inflows into the Baltic Sea from the North Sea in the autumn of 2001.
- In the Norwegian Sea, a long-term warming trend continued, and in 2001 the area occupied by Atlantic water was the greatest since 1991.
- The Barents Sea was warmer than average during 2001, but the temperature gradually decreased throughout the year from nearly 1 °C to just 0.1 °C above average. As a result, there was very little ice during the winter of 2001.
- Conditions in the Greenland Sea were generally warmer and more saline in 2001 compared to 2000. Although on average winter convection went down to 800 m, in small isolated patches it reached 2500 m.

6.8.2 Zooplankton monitoring results

Source of the information presented

The 2002 report of the Working Group on Zooplankton Ecology (WGZE), the ICES Zooplankton Monitoring Status Summary 2000/2001, and ACME deliberations.

Status/background information

Area 1: Georges Bank

The plankton displacement volume on Georges Bank in the early spring and early autumn of 2000 was at levels typical for the period since 1971. Since 1997 spring displacement volumes have risen steadily, whereas in autumn they have steadily decreased.

Area 2: Emerald Basin (West Atlantic, Scotian Shelf)

Following the historically low levels of 1994, the *Calanus finmarchicus* population slowly recovered until 1999, when the population reached maximum levels in the autumn of that year. The population has again declined through 2000 and 2001. The temperature anomaly at 50 m in June and the numbers of *Calanus finmarchicus* appear to be related, showing that, as the temperature increased, there was generally an increase in the size of the population.

Area 3: Siglunes (North Iceland)

Zooplankton biomass varies with highs at approximately seven- to ten-year intervals. The highest and lowest values differ by a factor of about 24. The last peak in zooplankton biomass occurred in 2000.

Area 4: Selvogsbanki (South Iceland)

Zooplankton biomass showed a peak during the early 1980s, while a low was observed during the late 1980s. Peaks were also observed around 1995 and 2000. The period between zooplankton peaks has been 5–10 years.

Area 5: Iceland-Scotland CPR line

The mean total copepod abundance in 2000 was just below the overall mean for the series extending back to 1958. There were extended low periods in 1970–1973 and 1988–1990, with only occasional high periods in 1960 and 1985. The time series exhibits considerable variability from year to year.

Area 6: Faroe Islands

Calanus finmarchicus is the dominant species in both warm and cold water masses around the Faroes. Its biomass is usually higher in the cold water mass, particularly so in 2001 when biomass was at its highest observed level. Advection of *C. finmarchicus* onto the Faroe shelf is highly variable each year, the total zooplankton biomass having fluctuated considerably since 1991.

Area 7: Svinøy (Norwegian Sea)

The low biomass in the western part of the area in summer 2001 is consistent with observations in large parts of the Norwegian Sea. In addition, the zooplankton biomass in both Atlantic and coastal water masses in May 2001 was far below those observed in the period 1998–2000, and at the same low level as in 1997.

Area 8: Arkona Basin (Germany)

Peaks of plankton were observed in spring 1992, 1998, and 2000 owing to the mass development of rotifers, which often happens after mild winters.

Area 9: Stonehaven (Scotland, NW North Sea)

Large differences can be seen between years in the observed biomass of many common species of zooplankton, with a general increase from 1997–2000 but a lower observed abundance overall in 2001.

Area 10: Dove (Central-West North Sea)

Analyses have found that the zooplankton community displays strong evidence of top-down control, with the populations of the small- to medium-sized copepods being controlled by the chaetognath *Sagitta*. This mechanism was also found to be responsible for a negative correlation with the Gulf Stream—the signal observed in the zooplankton is inverted by the influence of the predators.

Area 11: Helgoland (Southeastern North Sea)

Acartia clausi population dynamics during 2001, compared with the mean weekly abundances for the years 1975–1994, and small calanoid copepod population dynamics during 2001, compared with the mean weekly abundances for the years 1975–1994, demonstrated no unusual levels.

Area 12: Plymouth (English Channel)

Zooplankton abundance showed a decreasing trend from 1988 to 1995, and then started to increase until 1999. In 1999, there was a decline in the zooplankton population, with most of the top ten species below their typical average values. However, 2000 and 2001 showed a recovery in zooplankton population abundance comparable to that after 1995.

Area 13: Santander (Southern Bay of Biscay)

Annual peaks of *Acartia clausi* and *Calanus helgolandicus* show variations of almost one order of magnitude between years (e.g., high peak of *A. clausi* in 2000 versus low peak in 1998; high peak of *C. helgolandicus* in 1996 versus low peak in 1998). For both species, 1998 was the year when the populations reached the lowest values for the time series.

Area 14: La Coruña (NW Iberian Peninsula)

Zooplankton abundance is higher than in Area 13 and the time series does not show any trend.

6.8.3 Harmful algal blooms

Source of the information presented

The 2002 report of the ICES-IOC Working Group on Harmful Algal Bloom Dynamics (WGHABD) and ACME deliberations.

Status/background information

The ACME has included in previous reports decadal maps of harmful algal events in ICES Member Countries produced by WGHABD. These maps are now part of the ICES Environmental Status Report. A summary of these maps is available on the ICES website (www.ices.dk/status/decadal). The types of events presently covered are: amnesic shellfish poisoning (ASP), ciguatera fish poisoning (CFP), diarrhetic shellfish poisoning (DSP), neurotoxic shellfish poisoning (NSP), paralytic shellfish poisoning (PSP), and cyanobacterial toxin poisoning.

The ACME welcomes the continued effort of WGHABD to update the mapping exercise and long-term trend studies of harmful algal blooms based on the collation and assessment of national reports and contributions.

In its 2002 report, WGHABD proposed to implement nine items, aimed at improving this product. Among several formal improvements to the maps, the group has suggested that annual maps should be presented every year, in order to follow annual trends and to present recent information on the ICES Environmental Status Report. Dealing with the content of this report, WGHABD recommended that the map on ciguatera toxins should be deleted, a map for the “presence of yessotoxins* above limits for closure of shellfish harvesting" should be added, and a new map entitled "Other harmful events" should be added. This map would include events such as masses of foam on beaches, very high abundance of *Noctiluca*, and oxygen depletion due to high biomass blooms.

ICES, through the WGHABD, contributes to the IOC-ICES Harmful Algal Events Database (HAEDAT), which is available at the IOC website: http://ioc.unesco.org/hab/data3.htm#1.

WGHABD has pointed out that inconsistencies still exist in the database, preventing its common use. Therefore, two terms of reference were proposed to identify these inconsistencies in submitted HAE-DAT forms and to examine the possibility of creating HAE-DAT maps directly from the database.

Need for further research or additional data

The improvements proposed by the WGHABD on the harmful algal bloom maps, which are part of the ICES Environmental Status Report, should be implemented for next year.

Recommendations

ICES recommends, in view of producing updated maps of harmful algal blooms and related events, that the submission of national data to the IOC-ICES HAE-DAT be improved, and that the possibility of creating HAE-DAT maps directly from the database be examined.

6.8.4 Fish disease prevalence

Source of the information presented

The 2002 report of the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) and ACME deliberations.

Status/background information

At its 2001 meeting, WGPDMO agreed to update and modify the disease information presented in the ICES Environmental Status Report (www.ices.dk/status) and to review progress made at the WGPDMO meeting in 2002.

Note was taken of progress achieved in the data analysis and suggestions for changes in the presentation of data on diseases (lymphocystis, epidermal hyperplasia/ papilloma, acute/healing skin ulcerations) of North Sea dab (*Limanda limanda*). These concerned:

- an update of the statistical analysis of temporal trends in prevalence, now covering the period 1995 to 2001;
- the colouration of the maps showing the temporal trends;
- the provision of information on the diseases considered (gross appearance, aetiology, significance, effects on the host).

It was suggested that the report should not only provide information on the presence of upward, downward, or stable trends in prevalence, but in addition provide more detailed information on the general prevalence levels recorded in different regions (ICES statistical rectangles) in order to facilitate spatial comparisons. In order to prevent misunderstandings or misuse, it was decided to present relative prevalence information about regional patterns by using a colour grading system, highlighting areas with generally high, medium, or low disease prevalences. It was decided that a method to accomplish this would be developed intersessionally and be made available to WGPDMO members for comment and final adoption. The revised version of the maps and accompanying information will subsequently be submitted to ICES for incorporation on the ICES website, replacing the version presently available.

There was agreement that the maps providing information on diseases and parasites relevant to mariculture should be updated as soon as new information becomes available.

At the 2002 WGPDMO meeting, it was decided not to expand the number of diseases illustrated for the ICES website at the present time.

* Yessotoxin (YTX) was first identified after a shellfish toxicity incident in Japan associated with the consumption of Japanese scallops (*Patinopecten yessoensis*) in the mid-1980s. Initially, YTX toxicity was believed to be part of the "DSP toxicity", but the syndrome does not cause diarrhoea. The toxic symptoms are not well defined in humans, but YTXs are cardiotoxic in rodents. In recent years, research on the occurrence of YTX in shellfish from different marine areas has indicated that YTX contamination is more important and widespread than previously thought and closure limits have been set by the EU (100µ g per 100 g of shellfish).

7 MARINE CONTAMINANTS: DISTRIBUTION, TRANSPORT, AND EFFECTS

7.1 Evaluation of Lists of Priority Contaminants in Regional and International Organizations

Request

This is part of continuing ICES work to keep abreast of new developments in the evaluation and control of chemical contaminants in the marine environment.

Source of the information presented

The 2002 report of the Marine Chemistry Working Group (MCWG) and ACME deliberations.

Status/background information

Owing to the very large number of potential chemical contaminants that may influence the environment, organizations that are responsible for monitoring and control of contaminants in the environment have been developing priority lists of substances to serve as a guidance in their work.

Under OSPAR, an OSPAR List of Chemicals for Priority Action has been developed and background documents are being prepared on a number of the substances, or groups of substances, on this list. Among the many issues that should be covered in these background documents is the provision of information on the possibility to measure their concentrations in the marine environment. To assist in the collection of this information, the Marine Chemistry Working Group (MCWG) was informed of a potential request from OSPAR for advice on whether there are suitable analytical methods available to allow the measurement of environmental concentrations or effects of the substances on the OSPAR list, and whether any information exists on the presence of these chemicals in the environment. MCWG members considered the list provided, and an initial response is given in Table 7.1.1. This reflects the knowledge and experience of MCWG members at the meeting rather than including the results of literature searches, and it may be possible to refine this at a later date, after a formal request has been received.

MCWG also briefly discussed other priority lists from international or regional organizations. The UNEP list of Persistent Organic Pollutants (POPs) is now included in the Stockholm Convention, which was signed in May 2001. A possible priority among those twelve substances, or groups of substances, was discussed without any conclusions being reached. The substances are DDT, aldrin, dieldrin, endrin, chlordane, heptachlor, hexachlorobenzene, Mirex, Toxaphene, polychlorinated biphenyls, dioxins, and furans.

The list of priority substances in the EU Water Framework Directive was also reviewed. It was noted that a meeting was recently held of an EU working group (AMPS—Analysis and Monitoring of Priority Substances and Chemical Pollutants) at which analytical techniques and monitoring strategies for the measurement of these 33 substances in the aquatic environment were discussed.

The present EU legislation requires the analysis of those compounds included in the Dangerous Substance Directive in surface waters. Several EU member states have not as yet fulfilled this requirement, and information should be exchanged on ways to improve that, e.g., identifying laboratories that are able to conduct these analyses.

In view of concerns that inappropriate analytical methods may become mandatory for work in support of EU Directives, the ACME agreed that steps should be taken to ensure that all validated methods that meet the criteria and are fit for purpose will be accepted for use.

Finally, the ACME stated that this section provides a preliminary response to an anticipated request by OSPAR. Further information will be provided next year in response to the formal request.

7.2 Information on Specific Contaminants

Request

This is part of the continuing ICES work to keep under review contaminants of interest in a marine environmental context.

Source of the information presented

The 2002 report of the Marine Chemistry Working Group (MCWG) and ACME deliberations.

Status/background information

The ACME took note of new information on several groups of marine contaminants, as prepared by the Marine Chemistry Working Group.

Table 7.1.1. Preliminary response to the potential OSPAR request for views on the possibility to analyse the substances on the OSPAR List of Chemicals for Priority Action, and whether there are levels of these substances reported from the marine environment.

Chemical (CAS number and/or name)	**Analysis**[a]	**Presence**[b]	**Comment**
85–22–3 Benzene, pentabromoethyl	1	−	
36065–30–2 Benzene, 1,3,5-tribromo-2-(2,3-dibromo-2-methylpropoxy)	1	−	
732–26–3 2,4,6-tri-*tert*-butylphenol (phenol, 2,4,6-tris(1,1-dimethylethyl))	1	−	Blank problems
98–51–1 4-*tert*-butyltoluene (benzene, 1-(1,1-dimethylethyl)-4-methyl-))	1	−	
Brominated flame retardants	3	+	For polybrominated diphenylethers (PBDEs)
	2	+	For HBCD and polybrominated biphenyls (PBBs)
77–47–4 1,3-cyclopentadiene, 1,2,3,4,5,5-hexachloro-	2	+	
Certain phthalates (dibutylphthalate and diethylhexylphthalate)	2	+	Blank problems
115–32–2 Dicofol (benzenemethanol, 4-chloro-α-(4-chlorophenyl)- α-(trichloromethyl)-)	2	+	
115–29–7 Endosulphan (6,9-methano-2,4,3-benzodioxathiepin, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-,3-oxide)	3	+	
2104–64–5 EPN (phosphonothioic acid, phenyl-, O-ethyl O-(4-nitrophenyl) ester)	0	−	
70124–77–5 Flucythrinate (benzene acetic acid, 4-(difluoromethoxy)- α-(1-methylethyl)-, cyano(3-phenoxyphenyl)methyl ester)	0	−	
28680–45–7 and 2440-02-0 Heptachloronorbornene (bicyclo[2.2.1]hept-2-ene, heptachloro-)	1	−	Not a major Toxaphene component
Hexachlorocyclohexane (HCH) isomers	3	+	For α-, β- and γ-isomers
107–46–0 HMDS (disiloxane, hexamethyl-)	1	−	Blank problems
465–73–6 Isodrin (1,4:5,8-dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-, (1.α.,4.α.,4a. β.,5. β.,8. β.,8a. β.)-)	2	−	Environmental levels very low
Organic lead compounds	2	+	For tetra-alkyl lead
Organic mercury compounds	3	+	
72–43–5 Methoxychlor (benzene,1,1'-(2,2,2-trichloroethylidene)bis(4-methoxy)	3	+	
Musk xylene	2	+	
Chlorinated naphthalenes	2	+	Individual isomers should be measured
51000–52–3 Neodecanoic acid, ethenyl ester	0	−	

[a]MCWG members know that (3) there are good validated methods available; (2) there are methods described in the literature; (1) it is possible for some laboratories to analyse the compound; or (0) no methods are known to the group.

[b]MCWG members know that there are environmental levels reported (+), or MCWG members do not have knowledge of any environmental data (−).

Table. 7.1.1. Continued.

Nonylphenol/ethoxylates (NP/NPEs) and related substances	2	+	
140–66–9 Octylphenol (phenol, 4-(1,1,3,3,tetramethylbutyl)-)	2	+	
Organic tin compounds	3	+	For trialkyl- and triphenyltin
1825–21–4 Pentachloroanisole	2	+	
Pentachlorophenol (PCP)	3	+	
603–35–0 Phosphine, triphenyl-	0	−	
Polycyclic aromatic hydrocarbons (PAHs)	3	+	
Polychlorinated biphenyls (PCBs)	3	+	
Polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs)	3	+	
Short-chained chlorinated paraffins (SCCP)	2	+	
79–94–7 TBBA (phenol, 4,4'-(1-methylethylidene)bis[2,6-dibromo]-)	?	?	Unclear structure
2227–13–6 Tetrasul (benzene, 1,2,4-trichloro-5-[(4-chlorophenyl)thio]-)	2	+	
87–61–6 Trichlorobenzene (benzene, 1,2,3-trichloro-)	2	+	
120–82–1 1,2,4-trichlorobenzene (benzene, 1,2,4-trichloro-)	2	+	
108–70–3 1,3,5-trichlorobenzene (benzene, 1,3,5-trichloro-)	2	+	
55525–54–7 Urea, N,N'-bis[(5-isocyanato-1,3,3-trimethylcyclohexyl)methyl]-	0	−	
Cadmium	3	+	
Lead	3	+	
Mercury	3	+	
Organic mercury compounds	2–3	+	
Organic tin compounds	2–3	+	

[a]MCWG members know that (3) there are good validated methods available; (2) there are methods described in the literature; (1) it is possible for some laboratories to analyse the compound; or (0) no methods are known to the group.

[b]MCWG members know that there are environmental levels reported (+), or MCWG members do not have knowledge of any environmental data (−).

7.2.1 Dioxins, furans, and dioxin-like CBs

The ACME took note of new information concerning polychlorinated dibenzo-*para*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and chlorobiphenyls (CBs) including the dioxin-like CBs in foodstuffs, as provided by MCWG. MCWG has, for a long time, kept under review problems in the marine environment due to their toxicity to humans and the ecosystem related to these types of compounds. In the 2001 ACME report, information on available data on the occurrence of dioxins and dioxin-like CBs in fish and fish products was presented together with information concerning Toxic Equivalent (TEQ) values and Tolerable Daily Intake (TDI) levels for dioxins and dioxin-like CBs, especially in relation to fish products (ICES, 2001).

New information was provided on new tolerance levels for dioxins, furans, and dioxin-like CBs in foodstuffs. Two new EC Council Regulations setting maximum levels of PCDDs and PCDFs ("Dioxins") in foodstuffs (Regulation No. 2375/2001), including fish, and in animal nutrition (Regulation No. 2001/102/EC) have been adopted by the European Commission, and apply from 1 July 2002.

In 2001, the European Scientific Committee on Food (SCF) recommended a temporary tolerable weekly intake (t-TWI) of 14 pg WHO-PCDD/F-TEQ per kg body weight (bw), which has been used as a basis for these new standards in foodstuffs.

The maximum limit value for fish muscle meat, fishery products, and products thereof has been set at 4 pg WHO-PCDD/F-TEQ g^{-1} fresh weight. The maximum limits also apply to crustaceans (excluding the brown meat of crabs), and to cephalopods without viscera. Due to a repeated deficiency in the availability of data (some countries do not have methods available for CB123 and CB114, although CB105, CB118, and CB126 can be measured properly), dioxin-like CBs are not yet included in these calculations of total-TEQ values. The potential inclusion of dioxin-like CBs in these limits will be reviewed for the first time by December 2004. In general, however, the PCB contribution to the total-TEQ is higher than the contribution of the PCDDs and PCDFs together. It is therefore recommended to include PCBs in these maximum limit values as soon as possible.

In the 2001 ACME report (ICES 2001), it was reported that concentrations of dioxins and dioxin-like CBs in fish and fish products vary considerably due to differences in fish species, fat content, and geographical differences. Many species contain dioxins and dioxin-like CBs at levels below 1 pg I-TEQ g^{-1} wet weight, although concentrations can be rather high in some species such as Baltic salmon, where concentrations up to 16 pg g^{-1} have been found.

New data on the occurrence of dioxins and dioxin-like CBs in fish were presented. In order to establish baseline values for dioxins in wild and farmed fish, the Food Safety Authority of Ireland and the Irish Marine Institute have determined the concentrations of dioxins and dioxin-like CBs in salmon and trout. Levels of PCDD/Fs in both wild and farmed fish were all well below the new EU regulatory limit value. Even if all concentrations found were low, they found that dioxin levels in farmed salmon appeared to be higher than levels in (proven) wild salmon caught in northwest Ireland. PCB levels in the farmed fish were also on average 2.3 times higher than dioxin levels in wild fish and 3.6 times higher than dioxin levels in farmed salmon. Findings for farmed trout were similar, and they contained 3.4 times higher PCB levels than wild trout.

Furthermore, the concentration of CB153 correlated well with the concentration of dioxin-like PCBs (TEQ) and could therefore be used as a potential indicator for dioxin-like CB contamination in some species.

The ACME noted the initiation of two new European research projects: DIAC (Dioxin Analysis by Comprehensive multi-dimensional gas chromatography) in October 2001, and DIFFERENCE (Dioxins in Food and Feed—Reference methods and new certified reference materials) in February 2002. Both projects will focus on new, alternative methods for the analysis of dioxins and CBs in food and animal feed. The proposed methods include two bio-analytical methods: the CALUX bioassay (chemical-activated luciferase gene assay) and the DELFIA immunoassay, and two chemical analytical methods: comprehensive multi-dimensional gas chromatography (GC) and low-resolution GC/MS-MS. More information can be obtained from the website: www.dioxins.nl.

Need for further research or additional data

There is a need to obtain more information about the occurrence of dioxins and dioxin-like CBs in fish and fish products in all parts of the ICES area.

Reference

ICES. 2001. Report of the ICES Advisory Committee on the Marine Environment, 2001. ICES Cooperative Research Report, 248: 44–45,161–167.

7.2.2 *Tris*(4-chlorophenyl)methanol (TCPM) and *tris*(4-chlorophenyl)methane (TCPMe)

Tris(4-chlorophenyl)methanol (TCPM) and *tris*(4-chlorophenyl)methane (TCPMe) have been shown to bioaccumulate in biota, but their origin is, as yet, unknown. Levels of TCPM are generally higher than those of TCPMe. However, data are sparse, especially for fish, and the toxicology of these compounds is largely unknown. One possible source that has been suggested is the production and/or use of DDT, as traces of these compounds have been found in technical DDT formulation (Lebeuf *et al*., 2002). Co-occurrence could, however, be due simply to a similarity in properties and behaviour.

The results of an intercomparison exercise have shown that comparable data on these contaminants can be produced, at least by a selected group of laboratories. The work within MCWG focused specifically on the concentrations of these compounds in flatfish, both from Canada and from Europe. Flatfish were chosen as species occupying a lower level in the food chain, so as to be able to compare concentrations without the complication of the substantial bioaccumulation that occurs between fish and marine mammals. Detectable levels were found in all of the various species analysed, and concentrations in the liver were generally higher than those found in the muscle tissue and were clearly related to the lipid content of the tissue. All in all, the results showed no clear correlation with DDT levels.

Concentrations of these contaminants in Canada are generally lower than those in Europe and there is no real difference between concentrations in flatfish from the Baltic Sea and the North Sea. Unfortunately, it is not possible to establish whether a similar pattern applies to sediments, owing to the general lack of data.

Another possibility that has been raised is that these could be natural compounds. One way of evaluating this would be to determine the ^{14}C content of these compounds, as it has been shown that synthetic compounds do not contain detectable levels of ^{14}C unless they were prepared from natural products. In practice, however, this could turn out to be very difficult to achieve. Moreover, a clear gradient from the port of Antwerp to the open sea was shown in sediments from the Western Scheldt, which seems to rule out natural sources. Another possibility is that both compounds were present in the earlier technical grade batches of DDT (used in Europe during the Second World War), but not in the later, more refined formulations. Again, the above-mentioned gradient in sediments of the Western Scheldt seems to rule out this possibility as well. A further suggestion was their possible presence as contaminants in Dicofol, a pesticide that is still used in Europe. Further useful information relating to these questions could be obtained by analysis of temporal trends of the concentrations in undisturbed sediment cores.

As mentioned above, very little is known of the toxicological properties of these compounds. A Japanese study (Minh *et al*., 2001) was described in which the concentrations of TCPM and TCPMe in human tissues (adipose tissue, liver, and bile) were determined, and in which the authors observed age-dependent accumulation. The concentrations reported in this study are a fraction of those observed for PCBs, but their general presence seems to warrant further study.

Need for further research or additional data

The ACME stressed that further research on the sources, toxicity, and occurrence of TCPM and TCPMe is needed.

Recommendations

ICES encourages Member Countries to gather more information on the sources, toxicity, and occurrence of TCPM and TCPMe by including these contaminants in research and monitoring programmes.

References

Lebeuf, M., de Boer, J., Haarich, M., Ikonomou, M.G., Law, R.J., and Roy, R. 2002. Global distribution of *tris*(4-chlorophenyl)methanol and *tris*(4-chlorophenyl)methane in flatfish—is technical DDT the most likely source? Organohalogen Compounds, 58: 445–448.

Minh, T.B., Watanabe, M., Tanabe, S., Yamada, T., Hata, J., and Watanabe, S. 2001. Specific accumulation and elimination kinetics of *tris*(4-chlorophenyl)methane and *tris*(4-chlorophenyl) methanol, and other persistent organochlorines in humans from Japan. Environmental Health Perspectives, 109: 927–935.

7.2.3 Polybrominated diphenylethers (PBDEs)

At the 2002 MCWG meeting, data were presented for polybrominated diphenylethers (PBDEs) in the aquatic environment from a recent BSEF-funded study, which involved three European research groups (RIVO, NIOZ, and CEFAS). It was shown that PBDEs, in particular tri- to hexa-BDEs, are accumulating in food chains with biomagnification factors (BMFs) ranging from five to twenty. BDE209 was not found in biota samples, and if this compound bioaccumulates at all, then its BMF must be very low. PBDEs were also found in surface sediments, and some river surface sediments (from the Mersey, Clyde, and the Western Scheldt) showed concentrations of BDE209 above 1 mg kg^{-1} dry weight. As a part of a mass balance study, it was shown that penta-mix formulation-related congeners were higher in the western part of the North Sea than elsewhere, suggesting an input from the east coast of the UK. The PBDE input from UK estuaries was estimated to be 0.3–2 tonnes per year for BDE209 and 0.06–0.2 tonnes per year for the sum of the other BDE congeners. Roughly 50–70 % of that input derives from dredging and disposal activities, and the remainder from natural transport. Recent trend studies have indicated that environmental levels of penta-mix related congeners in Europe are tending to decrease, but exceptions are found in several UK rivers and in cod liver from the central North Sea. Concentrations of BDE209 have increased by 50–100 % in sediments at specific locations over the past six years, and sediment core analyses confirm the increase. A parallel increase of tetra- to hexa-BDE congeners was not seen. Consequently, it is unlikely that tetra- to hexa-BDE congeners are being formed in significant amounts from BDE209 in the environment. Sediment core analyses show a time trend relationship in line with production data and, consequently, it is unlikely that natural production is a major source of PBDEs.

At the 2002 MCWG meeting, data on the influence of hydrographic factors on transport processes of PBDEs in the North Sea were also reported. In Norwegian fjords, optimum hydrographic conditions permit the formation of good sediment cores. Analyses of a sediment core from the Drammenfjord, a branch of the Oslofjord, showed that tetra- to hexa-brominated diphenylethers from the industrial penta-BDE formulation were present from 1970 onwards, whereas BDE209, constituting about 97 % of the deca-BDE formulation, first appeared around 1980. This tallies with the production data for these formulations compiled by the Bromine Science Environmental Forum. Clear geographical gradients existed for the concentrations of BDE congeners from the penta-BDE mixture in invertebrates (seastars, hermit crabs, and whelks) caught in the North Sea in 1999. The River Tees (northeast England) has been shown to be a dominant source for these compounds, which are then transported with the residual currents in that area. In general, the results obtained showed that currents are an important vector of contaminant transport, including PBDEs, on the scale of the North Sea.

The results of studies on PBDEs by the German Federal Environmental Agency (UBA) were reviewed. The Agency covers a wide spectrum of research and monitoring activities regarding PBDEs. Ongoing monitoring studies include the measurement of PBDEs in emissions from consumer goods, in air and airborne particulates, and on the degradation of BDE209 in the environment. Research already completed included the possible substitution of PBDEs by other components, emissions of flame retardants from consumer goods and building materials, the analysis of penta-BDE for compliance testing purposes, and the occurrence of BDEs in breast milk, blood, and in marine and freshwater organisms. Current research projects are dealing with measurements of PBDEs in sediments, and of higher brominated BDEs in biota and sediments from Germany and Italy, and in sediments from the Danube.

As a result of the above studies, the first data generated by UBA show the presence of BDEs in sediments from Eastern Europe, 100 km south of Budapest, with BDE209 predominating. It has also been established that BDEs accumulate to high concentrations in the blood of adult raptors, such as the white-tailed eagle, osprey, sparrowhawk, goshawk, and peregrine falcon. Two different patterns are seen in these birds in relation to species. One is a classic pattern seen also in marine mammals, with BDE47 dominating. The other has BDE99, BDE100, and BDE153 as major components, and BDE183 as significant a peak as BDE47. This may be explained by metabolic differences between species. Regarding fish, PBDEs were determined in bream and eel from the River Elbe. Higher concentrations are seen in bream than in eel, reaching up to 700 ng g^{-1} lipid. BDE209 is also detected in bream tissue.

A second round of the interlaboratory study, involving more than forty laboratories from Europe and North America, is presently under way. In addition, two reference materials (one fish and one sediment) are in preparation and are expected to be available within the next few years. A workshop on analytical methods for the determination of PBDEs is being held during October 2002 in Barcelona, alongside the QUASIMEME Conference. A new European project on flame-integrated risk assessment (FIRE) is starting in September 2002, and will focus primarily on toxicological studies of PBDEs but will also include a large monitoring programme in both the marine and freshwater environments.

Two papers have been published describing the method development and intercomparison studies within the BSEF-funded project (de Boer and Cofino, 2002; de Boer *et al*., 2002).

Need for further research or additional data

The ACME repeated its statement of 1999 (ICES, 2000) that there is an urgent need for data on the long-term toxicity of PBDEs to marine organisms. The ACME pointed out that research should be conducted on the possible effects of PBDEs on the reproductive, endocrine, and immune systems of marine organisms.

Recognizing that in Europe novel flame retardant compounds are now being produced and used as successors to the penta-BDE formulation, specifically hexabromocyclododecane and tetrabromobisphenyl-A, the ACME supports further research into the environmental occurrence, transport, fate, and effects of these compounds.

Recommendations

ICES recommends to Member Countries to encourage researchers to perform experimental studies for implementing the research needs outlined above. ICES also recommends actively carrying out interlaboratory studies on PBDE determination to make further progress in agreement among laboratory measurements.

ICES recommends to OSPAR that PBDEs should be considered for inclusion within the JAMP programme, as fully validated methods for their determination are now available.

References

de Boer, J., and Cofino, W.P. 2002. First world-wide interlaboratory study on polybrominated diphenylethers (PBDEs). Chemosphere, 46: 625–633.

de Boer, J., Allchin, C., Law, R., Zegers, B., and Boon, J.P. 2001. Method for the analysis of polybrominated diphenylethers in sediments and biota. Trends in Analytical Chemistry, 20: 591–599.

ICES. 2000. Report of the ICES Advisory Committee on the Marine Environment, 1999. ICES Cooperative Research Report, 239: 89.

7.2.4 Toxaphene

Data for six toxaphene congeners, P26, P40/41, P44, P50, and P62, were presented for grey, harp, and hooded seals from the Gulf of St. Lawrence, for harbour seals from the St. Lawrence Estuary, and for ringed seals from northern Quebec. Clear differences in concentrations between species were evident, with hooded seals being more contaminated than ringed seals. However, the levels of toxaphene in seals in eastern Canada were not higher than those reported for seals in the Northern Hemisphere in general. Species differences were also evident from the congener patterns observed, especially P50/P62 ratios which reached a value of 20 for harp seals compared to about 2 in ringed seals. *In vitro* studies using microsomes from harbour seals have indicated the elimination of the congener P62, which supported the idea that P62 may be metabolized more easily than P26 or P50 in some seal species. Metabolism of congener P62 was not observed using microsomes from cetaceans, suggesting that for these compounds (as for chlorobiphenyls) cetaceans have a lower metabolic capacity than seals.

Data for some or all of the same congeners in terrestrial and marine biota collected in Greenland as part of the Arctic Monitoring and Assessment Programme (AMAP) were also considered. For marine biota, particularly high levels were found for narwhals from northern Greenland, and in walrus from east and northwest Greenland. This is an important finding, as these animals form an important part of the diet for the indigenous people. The risk assessment model presented in the recent EU FAIR-funded MATT project may assist in assessing the potential risk to the local population.

Data for toxaphene concentrations in a range of animals from Greenland are given in Table 7.2.4.1. This includes information for mussels, fish (cod), birds (murre, Eider ducks, ptarmigan, and guillemot eggs), narwhal, walrus, and three species of terrestrial animals (lamb, musk ox, hare).

Table 7.2.4.1. Examples of concentrations of total toxaphene and several toxaphene congeners (P26, P50, and P62) (µg kg^{-1}) in animals from Greenland.

Organism	% lipid	Total toxaphene	P26	P50	P62	Σ(P26+P40+P41+P44+P50+P62)
Blue mussel	2					0.21
Murre liver		53	0.11	0.16	< 0.05	
King Eider liver		14	0.02	0.19	0.05	
Common Eider liver		12	0.09	0.32	< 0.05	
Ptarmigan liver		0.75				
Ringed seal blubber		265	11	11	3.2	
Ringed seal blubber	92					49
Ringed seal muscle	5.5	8.6				
Cod liver	35					41
Black guillemot egg	10					58
Walrus blubber, East Greenland	84	1,610				
Walrus blubber, Northwest Greenland	85	292				
Narwhal blubber	96	4,260				
Lamb, musk ox, hare muscle		< 0.1				

Need for further research or additional data

There is a need to obtain more information regarding the occurrence, sources and transport, and toxicity of toxaphene in the marine environment. MCWG should also monitor the development and comparability of analytical methods for the determination of toxaphene congeners in marine samples.

Recommendations

ICES encourages its Member Countries to report new information on toxaphene in the marine environment, generated within national monitoring programmes, to ICES.

8 FISH DISEASE ISSUES

8.1 Trends in Diseases of Wild and Farmed Fish and Shellfish

Request

This is part of continuing ICES work to consider new developments with regard to fish and shellfish diseases. This section contains a compilation of the most recent information on new disease trends in fish and shellfish that ACME disseminates to ICES Member Countries in order to inform them of potential future problems.

Source of the information presented

The 2002 report of the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) and ACME deliberations.

Status/background information

The ACME reviewed the sections of the WGPDMO report that provided information on new trends in the occurrence of diseases in wild fish and shellfish stocks based on national reports from ICES Member Countries. Special attention was drawn to the new trends in the distribution of the following diseases in wild and farmed fish, shellfish, and mollusc stocks:

Viral haemorrhagic septicaemia virus (VHSV): In recent years, marine VHSV has been isolated from a large number of marine fish species in the North Sea, Skagerrak, Kattegat, and the Baltic Sea, as well as along the USA and Canadian Pacific coasts and along the Japanese coasts. The host spectrum seems to increase, as VHSV has been isolated from both Japanese flounder (*Paralichthys olivaceus*) and black rockfish (*Sebastes inermis*) in Japan.

Six outbreaks of Viral Haemorrhagic Septicaemia occurred in sea-reared rainbow trout in the Åland Islands and on the southern and southwestern coasts of Finland in May and June 2001. Genetic typing indicates that the virus isolates from the two areas are different, suggesting different sources.

The prevalence of toxicopathic liver lesions in flatfish species in Puget Sound, USA, continued to decrease 92 months after the placement of a sediment cap covering a PAH-contaminated site. However, a sharp decline in the prevalence of liver lesions in English sole (*Parophrys vetulus*) collected from the Seattle waterfront, USA, was also observed despite the fact that PAH levels remained high. This may be explained by the complicated mechanism of PAH bioavailability from sediments, which is dependent on a number of factors, including the feeding modes of different species and the degree to which PAHs are incorporated into sediment pore spaces (Oug *et al*., 1998). Paine *et al*. (1996) also concluded from their studies that sedimentary PAHs present in the form of pitch or coal tar particles in smelter-affected Canadian fjords were of limited bioavailability.

Prevalences of hyperpigmentation in North Sea dab remained high (up to 40 %) and showed an increase in some areas (German Bight, Dogger Bank, Firth of Forth). The aetiology has still not been resolved.

A new host species, tanner crab (*Chionoecetes tanneri*), and extension of the range to British Columbia, Canada, were reported for *Hematodinium* sp. (bitter crab syndrome). The effect of this parasite on tanner crab population dynamics in Canada is not known.

Giant sea scallop (*Placopecten magellanicus*) mortalities reported in 2000 from the Gulf of St. Lawrence were detected in 2001 for the first time in the Bay of Fundy, Canada. The aetiology is so far unknown.

Mortalities were reported in *Ostrea edulis* in Nova Scotia, Canada, but the cause is still unknown.

Need for further research or additional data

The development of the new disease trends in the above-mentioned ICES Member Countries should be followed in the coming years.

The increased number of outbreaks of VHS in farmed rainbow trout in Finland is of serious concern as there are indications of a transfer of the virus from wild to farmed fish stocks. The high prevalence of marine VHSV in herring and sprat, especially in the Baltic Sea, may create a serious hazard for future marine fish farming.

Recommendations

ICES recommends that Member Countries ensure that adequate funding is made available to continue health surveillance of wild fish stocks, as continued disease monitoring is necessary:

a) to be used as an indicator of environmental conditions, including anthropogenic effects;

b) to assess the impact of disease on wild fish stock performance;

c) to assess the potential for disease interactions between wild and farmed fish;

d) to recognize emerging diseases caused by infectious agents and/or contaminants.

References

Oug, E., Næs, K., and Rygg, B. 1998. Relationship between soft bottom macrofauna and polycyclic aromatic hydrocarbons (PAH) from smelter discharge in Norwegian fjords and coastal waters. Marine Ecology Progress Series, 173: 39–52.

Paine, M.D., Chapman, P.M., Allard, P.J., Murdoch, M.H., and Minifie, D. 1996. Limited bioavailability of sediment PAH near an aluminium smelter: contamination does not equal effects. Environmental Toxicology and Chemistry, 15: 2003–2018.

8.2 Status of the M74 Syndrome in Baltic Salmon and Status of *Ichthyophonus* in Herring

Request

This is part of the continuing ICES work of updating the present knowledge on the causes of the M74 syndrome in Baltic salmon (*Salmo salar*) and progress in understanding the implications of relevant environmental factors (this has previously been a request from the Helsinki Commission), and on the status of *Ichthyophonus hoferi* infection in herring (*Clupea harengus*).

As the cause of M74 is still unknown and as fry mortality caused by the M74 syndrome still has a significant impact on the Baltic salmon stock, it is important that ICES advise on the most recent developments within this field.

Source of the information presented

The 2002 report of the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) and ACME deliberations.

Status/background information

The ACME reviewed the sections of the WGPDMO report that provided information on the present knowledge on the cause of the M74 syndrome in Baltic salmon and on the status of *Ichthyophonus hoferi* infection in herring.

M74

Compared to 2000, an increasing trend of higher disease prevalences (defined as the percentage of females producing fry mortality) was observed in most of the Baltic rivers. The disease prevalences for the most important salmon rivers monitored are presented in Table 8.2.1. The prognosis for the 2002 hatch indicates a further increase in the disease prevalences, both in Finnish and in Swedish rivers.

No significant breakthrough has yet been reported in the research on the aetiology of M74.

Recent observations in Sweden indicate that the consequences of the thiamine deficiency are not restricted to the yolk-sac stage of salmon fry. Fry originating from females with insufficient thiamine levels may survive up to the first feeding stage but refuse

Table 8.2.1. Prevalence (%) of M74 in Atlantic salmon (*Salmo salar*) in Swedish and Finnish river systems, 1998–2001.

River system	1998	1999	2000	2001
Simojoki	31	38	22	41
Tornionjoki	25	56	32	41
Lule älv	6	34	21	29
Skellefteälven	4	42	12	14
Ume/Vindelälven	9	53	45	39
Ångermanälven	3	28	21	25
Indalsälven	1	20	14	7
Ljungan	10	25	10	n.d.
Ljusnan	6	41	25	46
Dalälven	9	33	27	33
Kymijoki	42	0	10	n.d.
Mean	13.3	33.6	21.7	30.6

feeding and gradually die off unless treated with thiamine. Bath treatment with thiamine at that stage leads to immediate recovery of the fry. Other observations have demonstrated the importance of early thiamine treatment of fry with insufficient thiamine levels. Populations of yolk-sac fry already expressing the typical M74 symptoms (uncoordinated swimming movements, grayish colour, congestion and fragility of blood vessels, precipitates in the yolk sac, etc.) show rapid recovery after bath treatment with thiamine. At later stages, however, the prevalence of fish with various types of deformities is high in these populations. This is also reflected in an increased prevalence of individuals with deformities among returning spawners in recent years (individuals having been treated with thiamine at the fry stage).

The results of this research have demonstrated that Baltic herring has very high levels of thiaminase compared to sprat. Herring is now considered to be one of the main factors in the development of M74. Recent data support the hypothesis that Baltic salmon might selectively feed on herring with high thiaminase activity. A pronounced seasonal as well as geographical variation in the thiaminase activity of herring has been observed.

Laboratory experiments have shown that a large number of chemicals, as well as substances released in association with algal blooms, can act as co-substrates for the thiamine-splitting reaction (e.g., pyridine, aniline, nicotinic acid, proline, hypotaurine, cysteine), thus influencing the thiamine level in organisms. It has been suggested that changes in the occurrence of suitable co-substrates in the food chain of Baltic salmon might influence the thiaminase activity in the prey fish and, thus, ultimately the thiamine level of salmon.

In North America, work on the aetiology of the Early Mortality Syndrome (EMS) is presently focusing mainly on the thiaminase activity and thiaminase kinetics in salmonid fish.

Ichthyophonus

Ichthyophonus hoferi infection continues to persist at a low prevalence in the European herring stocks examined, i.e., in Icelandic waters, the Kattegat, northern North Sea, Barents Sea, and the Norwegian Sea, without any indication of an epizootic.

Need for further research or additional data

The aetiology of the M74 syndrome is still unclear and the disease remains a serious threat to wild salmon populations in the Baltic Sea. Therefore, it is still important that ICES Member Countries continuously monitor salmonid populations for the occurrence of M74 or M74-like reproductive disorders. In light of the recent trend of seriously increasing disease prevalence, the ACME emphasizes the urgent need for increased research efforts regarding the causes of this disease.

The persistence of *Ichthyophonus* in the European herring stocks makes it necessary to continue monitoring the prevalence of the infection in the herring stocks.

Recommendations

ICES recommends that Member Countries continue to monitor salmonid as well as non-salmonid populations for the occurrence of reproductive disorders similar to the M74 syndrome.

ICES also emphasizes the urgent need for increased research efforts regarding the causes of the M74 syndrome.

ICES recommends that Member Countries continue to monitor the prevalence of *Ichthyophonus hoferi* infection in herring as a part of fish stock assessment work.

8.3 Nodavirus in Aquaculture Fish Species

Request

This is part of continuing ICES work to consider new developments with regard to fish and shellfish diseases. Nodavirus infections are causing serious problems in many fish species of importance for European aquaculture. Therefore, it is essential that ICES provide advice based on the most recent knowledge of this disease problem.

Source of the information presented

The 2002 report of the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) and ACME deliberations.

Status/background information

In recent years, nodavirus infection has caused serious problems in many fish species important for the aquaculture industry and, as the host spectrum is still increasing, many species having potential for aquaculture may be at risk. It is therefore important that ICES provide advice based on the most recent knowledge on this disease problem.

Nodavirus, causing the disease called Viral Encephalopathy and Retinopathy, affects a broad spectrum of fish species such as turbot (*Scophthalmus maximus*), halibut (*Hippoglossus hippoglossus*), Dover sole (*Solea solea*), and seabream (*Sparus aurata*), all of which are species of importance for European aquaculture. However, the host spectrum broadens continuously. Recently, new virus isolates were obtained from non-European, imported ornamental fish. These included the first record of nodavirus infection from wild ornamental fish (*Acanthurus triostegus*, *Apogon exostigma*, etc.). This is of particular significance, since disease interactions between ornamental and aquaculture species have been gaining more attention as a method of the spread of pathogens. These isolates belong to one of the three genotypes described previously. It seems that this genotype has a very widespread geographical distribution (Indo-Pacific area, Mediterranean area, and Scotland) and can infect many species.

The diagnostics can only be performed by using gene technology methods. Cell cultures for the cultivation of nodavirus do not exist so far.

The transmission of nodavirus in sea bass (*Dicentrarchus labrax*) from parent to eggs has been demonstrated experimentally. The virus was detected in unfertilized and fertilized eggs from spawners and in newly hatched larvae, which developed clinical signs of the disease.

It has been shown that nodavirus strains that are pathogenic to sea bass at 25 °C are not pathogenic to turbot (*Scophthalmus maximus*) at 17 °C. Conversely, some strains having low pathogenicity to sea bass at 25 °C were highly pathogenic to turbot at 17 °C. The existence of "cold" and "warm" water nodavirus strains is suspected. The recent isolates from ornamental fish were pathogenic to sea bass at 25 °C.

The nodavirus affects the total blood cell composition. The typical findings are a depletion of B-lymphocyte populations and the increase of the phagocytic cell population from day 7, post-infection. These observations suggest that B-lymphocytes are possible targets for nodavirus. However, as specific anti-nodavirus antibodies were detected in the fish before the changes in the blood composition, it has been suggested that the humoral immune response takes place before the drop in the B-lymphocyte population.

In sea bass, inactivated vaccines failed to provide protection against nodavirus. Alternative strategies, including the use of genetically engineered vaccines, are in progress. In turbot, a recombinant vaccine has been shown to provide significant protection.

Need for further research or additional data

Much work has to be done before effective control measures such as vaccines are developed. In the meantime, screening of broodstock (gonads, sera) in order to obtain nodavirus-free broodstock is recommended. The best preventative action is the application of strict general hygienic measures on farms.

Recommendations

ICES recommends that Member Countries encourage and support research in preventive measures against nodavirus, including improvements in management strategies and the development of vaccines.

8.4 Infectious Pancreatic Necrosis Virus in Salmonid Fish Farming

Request

This is part of continuing ICES work to consider new developments with regard to fish and shellfish diseases. Infectious Pancreatic Necrosis has become an increasing problem in intensive salmon production, as well as in other fish species having the potential for intensive farming. Therefore, the ACME is providing advice on the present status of the epidemiology and preventive measures regarding this disease to ICES Member Countries.

Source of the information presented

The 2002 report of the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) and ACME deliberations.

Status/background information

Infectious Pancreatic Necrosis (IPN) is a viral infection affecting the pancreatic tissue of the fish, causing high mortality and retarded growth in surviving fish.

Historically, IPN has been associated with high mortality in first-feeding salmonid fry and subsequent low mortality in parr up to the smolt stage. However, during the past few years, IPN infection has become a serious cause of acute mortality, and increasing economic impact, in Atlantic salmon shortly after their transfer to sea water in Scotland and Norway. In addition, turbot (*Scophthalmus maximus*), Atlantic halibut (*Hippoglossoides hippoglossodes*), and Atlantic cod (*Gadus morhua*) are susceptible. As these are all species that have considerable potential for intensive farming, the ACME is providing advice on the present status of the epidemiology and preventive measures on this disease to ICES Member Countries.

In Scotland, the IPNV prevalence was lower in freshwater farms than at seawater sites, with an overall prevalence of 8 % and 42 %, respectively. During the period 1998–2001, 30–40 % of Norwegian hatcheries and 40–70 % of seawater farms had clinical IPN.

Based on the number of active seawater sites in Scotland, clinical IPN was affecting 15.4 % of the active producing sites in 2001, compared with 3.7 % in 1990. Most outbreaks of IPN were recorded in fish (S1) having been at sea for one year.

In Scotland, mortality attributed to IPN occurs among S1 post-smolts during the spring months shortly after transfer to the sea. Data indicated that mortality from sites with confirmed IPN, but covering all causes, varied between 0.03–0.1 % per day in May, from 0.04–0.2 %

per day in June, and up to 0.5 % per day in July. Later in the year, losses per day declined to early spring levels.

In Norway, losses at confirmed IPN sites averaged 11.2 % during the post-smolt season, although losses from all causes are included.

Antibody-positive juveniles with no history of IPN-outbreaks in fresh water appear to be protected against later outbreaks of IPN in sea water. However, the efficacy of existing vaccines remains to be proven, and the effect of vaccines on the carrier-state needs to be assessed. In addition, identification is required of the risk posed by carriers in relation to transmission of the virus from parents to progeny and between the individual fish.

Need for further research or additional data

IPN has a significant impact on the salmon production industries in Scotland and Norway, but the reasons for the change in IPN are unknown. The observed trend in IPN prevalence should encourage further investigation with respect to the impact on salmonid fish farming in Scotland and Norway and on preventive measures, e.g., the development of vaccines.

Recommendations

ICES recommends that Member Countries encourage and support research on preventive measures against IPN, including improvements in management strategies and the development of vaccines.

8.5 Studies on the Relationship between Environmental Contaminants and Shellfish Pathology

Request

This is part of continuing ICES work to consider new developments regarding biological effects of contaminants and diseases in marine organisms and is of relevance for national and international monitoring programmes.

Source of the information presented

The 2002 report of the Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) and ACME deliberations.

Status/background information

At its 2001 meeting, WGPDMO reviewed new disease trends in ICES Member Countries regarding wild and cultured shellfish (crustaceans and molluscs) (ICES, 2001). In this context, it was emphasized that there is growing concern that a wide range of anthropogenic contaminants may affect the health of wild shellfish populations and that this issue should be dealt with as part of the WGPDMO work. It was, therefore, decided to present and review a report on the current status of studies on the relationship between environmental contaminants and shellfish pathology carried out in ICES Member Countries at the 2002 WGPDMO meeting.

Due to a lack of information on marine crustaceans, the report (attached as Annex 6) focuses on marine bivalves and gastropods. The report contains information on a number of pathological changes recorded (haemic and gonadal neoplasia, imposex and intersex, parasite intensity, digestive gland atrophy, changes in the immune system) and approaches to elucidate the role of contaminants.

The information provided indicates that several shellfish diseases, with the potential to cause deleterious impacts on shellfish populations, have been associated with exposure to environmental contaminants. However, since most of these conditions have a multifactorial aetiology and may be triggered by a variety of natural and anthropogenic factors (e.g., gonadal neoplasia, intensity of parasite infections, and digestive gland atrophy (see Annex 6)), the studies carried out clearly show the difficulty of establishing cause-effect relationships between contaminants and the diseases. The only clear and generally accepted case so far for such a relationship is the occurrence of TBT-induced imposex/intersex conditions in marine gastropod species.

From the status report, there is evidence that, although a number of field and laboratory research projects have been launched in previous years, the efforts addressing the effects of contaminants on marine shellfish health are still limited and regular monitoring activities have only been carried out on a relatively small regional and temporal scale so far.

Need for further research or additional data

The ACME emphasized that, with the exception of data on imposex/intersex conditions in marine gastropod species following exposure to tributyltin compounds, information on the relationship between environmental contaminants and pathological disorders in marine shellfish is limited so far. However, since some of the known diseases considered to be possibly associated with exposure to environmental contaminants may have a significant impact on shellfish populations, affecting growth, reproduction and survival, further studies are warranted.

The number of currently ongoing studies on the association between shellfish diseases and contaminants is limited and ways should be explored regarding how these can be intensified in the ICES area. Shellfish are of global economic importance and constitute an ecologically significant component of the marine ecosystem; they should, therefore, be incorporated into existing monitoring programmes as biological indicators of ecosystem health. However, before this can firmly be recommended to ICES Member Countries, an appropriate strategy has to be developed.

Recommendations

Due to the ecological and economic significance of marine shellfish and the limited information available so far, ICES encourages Member Countries to increase their efforts to study the relationship between pathological disorders in shellfish and the presence of environmental contaminants.

Reference

ICES. 2001. Report of the Working Group on Pathology and Diseases of Marine Organisms. ICES CM 2001/F:02. 56 pp.

9 INTRODUCTIONS AND TRANSFERS OF MARINE ORGANISMS

9.1 Status of Fish, Shellfish, Algal, and Other Introductions in and between ICES Member Countries

Request

ICES Member Countries may request ICES to review proposed introductions and transfers of marine organisms for mariculture purposes. These proposals receive in-depth review by the Working Group on Introductions and Transfers of Marine Organisms (WGITMO), with final review by the ACME. WGITMO also keeps under review the progress of such introductions and reports the outcome to the ACME.

No new requests for review of proposed introductions were received in 2002, but the status of ongoing introductions and transfers was reviewed.

Source of the information presented

The 2002 report of the Working Group on Introductions and Transfers of Marine Organisms (WGITMO) and ACME deliberations.

Status/background information

The ACME reviewed the WGITMO report and agreed to present the information contained below.

Trade within and between ICES Member Countries continues mainly for aquaculture, restocking, live food sales, and ornamental pet fishes. This trade is summarized in Table 9.1.1. The most commonly moved species in 2001 were Atlantic salmon (*Salmo salar*) and Pacific oysters (*Crassostrea gigas*).

It has to be noted that the figures do not claim to be fully comprehensive as not all ICES Member Countries submitted National Reports to the meeting. Further, the origin of several importations remains unclear as some countries exhibit a lack of import and/or export documentation.

Recommendations

ICES notes that this information is of interest to Member Countries and encourages all Member Countries to submit National Reports on an annual basis.

9.2 Revised Code of Practice on Introductions and Transfers of Marine Organisms

Request

This is part of continuing ICES work on issues related to introductions and transfers of marine organisms.

Source of the information presented

The 2002 reports of the Working Group on Introductions and Transfers of Marine Organisms (WGITMO), the Working Group on the Application of Genetics in Fisheries and Mariculture (WGAGFM), the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 1994, and ACME deliberations.

Status/background information

The ACME notes that new introductions are occurring throughout the ICES region, both between and within Member Countries. The existing Code of Practice on the Introductions and Transfers of Marine Organisms, dating from 1994, needs urgent updating and promotion to assist in controlling the problem of such introductions. Recent issues of concern include the impact and transfers of species intended for the aquarium trade, the bait industry, or for immediate consumption that can result in the release into the wild of such species and any accompanying organisms, including pests, parasites, and other disease agents.

Because of the increasing expansion of trade in exotic species, with consequent accidental or deliberate introductions to the wild, the provision of the updated Code of Practice is an urgent priority to inform stakeholders of measures to reduce unwanted consequences of these activities.

The ACME reviewed a draft of an updated version of the Code of Practice, which will be finalized and published in 2003.

9.3 Selected Examples of Current Invasions, their Consequences and Significance

Request

This is part of continuing ICES work to keep under review new information concerning the introduction and movement of non-indigenous marine organisms.

Source of the information presented

The 2002 report of the ICES/IOC/IMO Study Group on Ballast and Other Ship Vectors (SGBOSV) and ACME deliberations.

Status/background information

The ACME reviewed the report of the ICES/IOC/IMO Study Group on Ballast and Other Ship Vectors (SGBOSV) and took note of information on the invasion of several non-indigenous species, as described below.

Table 9.1.1. Summary of live imports of aquatic species according to National Reports submitted to WGITMO 2002. Ornamental trade is excluded. (Abbreviations: cr = crustaceans, fi = fish, mo = molluscs, Bel = Belgium, Can = Canada, Cze. R = Czech Republic, Den = Denmark, Est = Estonia, Fin = Finland, Fra = France, Ger = Germany, Hun = Hungary, Ice = Iceland, Ire = Ireland, Ita = Italy, Lat = Latvia, Net = the Netherlands, Nor = Norway, Pol = Poland, Por = Portugal, Rus = Russia, S. Afr. = South Africa, Spa = Spain, Swe = Sweden, UK = United Kingdom, USA = The United States of America.)

Country of origin	Import (limited to ICES Member Countries)																
	Bel	Can	Den	Est	Fin	Fra	Ger	Ire	Lat	Net	Nor	Pol	Rus	Spa	Swe	UK	USA
Canada							cr								cr, mo		fi
Czech. R							fi										
Denmark				fi			fi, mo	fi			fi	fi			fi, cr, mo	fi	
Estonia									fi				fi				
Finland				fi							fi		fi		fi		
France	fi						fi	mo			fi	fi			mo		
Germany	mo											fi			fi		
Hungary							fi										
Iceland		mo									fi						
Ireland						fi, mo	fi, cr								cr	fi	
Italy						mo	fi								fi		
Nether-lands	mo	fi				mo	fi								fi, mo		
Norway			fi				cr								fi, cr, mo	fi	
Poland							fi						fi				
Portugal		fi, mo				mo											
Russia				fi			fi										
Spain						mo					fi						
S. Africa												fi				fi	
Sweden	fi, mo		fi, mo	mo	fi, mo	mo	fi, mo	fi		fi, mo	fi, mo	fi		mo		mo	
UK				fi	fi	mo		fi, mo				fi			fi, mo		
U.S.A.		fi					cr								cr, mo	cr	

Red king crab (*Paralithodes camtschatica*)

The red king crab (*Paralithodes camtschatica*) was intentionally released in the Barents Sea during the period 1961–1969 to create a new and valuable fishery resource in the region (Orlov and Karpevich, 1965; Orlov and Ivanov, 1978). It first appeared in large numbers in Norwegian waters at the beginning of the 1990s. Although some biological aspects of this crab have been studied, relatively little is known about the ecological impact of this invasive crab on native bottom communities in Norwegian waters. The crab has become abundant around the Kola Peninsula (Russia) and coastal Finnmark (northern Norway) (Kuzmin *et al.*, 1996; Kuzmin and Sundet, 2000). It is now migrating westwards along the coast of northern Norway and there is concern that scallop (*Chlamys islandica*) and flatfish populations have been reduced by this predatory crab. The red king crab is now known to hatch at several places in Norwegian waters with frequent abundant year-classes, and steadily increasing numbers of crabs are invading new coastal areas (Sundet, 1998, 1999). This progression of the crab in movement and increased abundance now provides a rare opportunity to observe in progress a biological invasion of scallop beds, and to observe community-level alterations as they occur. Research is now being proposed for such a study.

Toxic alga *Pfiesteria piscicida*

The toxic alga *Pfiesteria piscicida* has recently been found in European waters (Norway). It also occurs in several estuaries of the North American east coast, e.g., Chesapeake Bay. *Pfiesteria* prefers shallow, warm, brackish waters, but has a broad salinity tolerance and can occur in fresh water if the water has high levels of calcium. It is believed that there is a possibility that this species could be transported and introduced via ballast water or tank sediment. *P. piscicida* and other dinoflagellates have been responsible for recent estuarine fish kills on the U.S. eastern seaboard and have also caused concern with regard to human health (modified after Gollasch and Leppäkoski, 1999).

The first known fish kills were documented in 1988. Fish kill events linked to *Pfiesteria* can extend for 6–8 weeks, thus potentially affording opportunities for people working in the field to be exposed to this dinoflagellate's toxins. Since 1991, a billion fish have been killed by *Pfiesteria* in eastern U.S. waters and lately shellfish have also been found to be affected (Burkholder *et al.*, 1993).

Humans working with dilute toxin cultures of this organism have sustained mild to serious adverse health impacts through water contact or by inhaling toxic aerosols from the cultures.

Zebra mussel (*Dreissena polymorpha*)

In addition to many other locations, the zebra mussel (*Dreissena polymorpha*) has now appeared in the Ebro River in Spain in 2001, which is believed to be the first record of this species in Spanish waters. The Ebro River is the last stronghold of the giant pearl mussel (*Margaritifera auricularia*), a species once thought extinct. Currently, young zebra mussels are found along a 50-km stretch of the river system.

Asian veined rapa whelk (*Rapana venosa*)

The Asian veined rapa whelk (*Rapana venosa*) was discovered in the Hampton Roads region of the Chesapeake Bay (U.S. Atlantic Coast) in the summer of 1998. The species is native to the Sea of Japan, Yellow Sea, East China Sea, and the Bohai Sea, but was introduced to the Black Sea in the 1940s, and has since spread to the Aegean and Adriatic Seas. There are no major predators on *Rapana venosa* in the Black Sea, and the population has become both very abundant and destructive to native benthos: it has been responsible for the decimation of native oyster, scallop, and mussel populations. There is strong evidence that range extension across oceanic basins is mediated by the transport of pelagic early life history stages in ballast water. The discovery of rapa whelks in the Chesapeake Bay has raised concerns at three levels of space and time:

a) In the Chesapeake Bay, there is concern over the immediate and short-term impact of *Rapana* on both the ecology of local shellfish populations and the economy of the industry that they support;

b) On a larger scale of time and space, there is concern over the long-term establishment and range expansion of the invader on the U.S. east coast; and

c) On a global scale, the increasing opportunity to disperse invasive species via ballast water has stimulated studies of genetic variation within *Rapana* from the Chesapeake Bay, Black Sea, and the native population of the Sea of Japan.

Additional comments

The above information is provided to make ICES Member Countries aware of the implications of the movement of non-indigenous organisms into new areas, and their possible effects on local organisms or ecosystems.

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9.4 Progress in Research and Management on Ballast Water and Other Ship Vectors

Request

This is part of the continuing ICES work to keep under review new information concerning research and management of ballast water and other ship vectors of transfers of marine organisms.

Source of the information presented

The 2002 report of the ICES/IOC/IMO Study Group on Ballast and Other Ship Vectors (SGBOSV) and ACME deliberations.

Status/background information

Assessment of types of ship vectors

Although shipping is certainly an important global vector for species invasions, it is difficult to prove that a species was introduced by shipping. The relationship between hull fouling versus dispersal by ballast (water or sediment) as vectors needs to be better estimated.

It is becoming clear that increasing attention needs to be paid to fouling communities on ships' hulls and in sea chests. Recent surveys of non-native species in the North Sea and certain areas of Australia and the USA suggest that, historically, the number of non-native species likely to have been introduced by hull fouling of ships is greater than that by ballast water-mediated introductions. However, it is important to note that, in some cases, it remains unclear whether the species could have arrived as adult individuals in ship's fouling or as larvae in the ballast water. Further, it is unclear whether hull fouling is currently the most important vector of species introductions or whether it was more important in the past.

To estimate the relative importance of shipping as a vector, it is necessary to have better quantitative estimates on the role of other vectors. Furthermore, a particular species (e.g., the Japanese kelp *Undaria pinnatifida*) may have been introduced by several vectors (in this case, both shipping and aquaculture, unintentionally as well as intentionally), making it difficult to estimate the relative importance of each vector. In this case, drifting might, in many situations, be the main vector for further dispersal (secondary introduction) from the first point of introduction, and could probably be an important vector of species dispersal.

An assessment of different types of ship vectors, with specific attention to determining which of these vectors have been quantitatively sampled in recent years, was undertaken. It was agreed that no data exist to assess the relative importance of vessel types, voyage lengths (see below), voyage routes, seasonal changes, and other pertinent variables to evaluate future species invasions.

To further demonstrate the importance of vectors for species invasions, details on the most likely vector of introduction for recent species invasions were compiled. Table 9.4.1 illustrates what is known about the most common vectors of introductions, and the secondary spread of previously recorded invasions from neighbouring areas. However, it has to be noted that for many newly recorded species the transportation vector remains unknown, as several vectors seem likely for certain species invasions.

Ballast water control and management technologies

It is apparent that it is unlikely that a single method will be able to treat all aspects of ballast water and sediments and that a combination of methods is more likely to be able to treat the range of organisms present in the ballast tanks. It is likely that such a combination would comprise a two-stage approach, such as mechanical removal of organisms followed by a physical or chemical treatment method. The range of treatment methods represents some of the many types of treatment processes that are currently being tested on either a pilot or larger scale. One of the major problems faced by manufacturers has been the "scaling up" of water treatment methods for use on board vessels, and there are several research projects working towards assessing the efficiency of treatment methods with a view to carrying out full-scale trials on board vessels. To date, three main types of techniques to treat ballast water on board ships have been suggested: mechanical technologies, and physical or chemical treatments. Mechanical technologies are based on particle size or specific weight to separate or remove organisms and/or sediment mechanically from the water. Physical treatment techniques use different susceptibilities of organisms to render them harmless. Chemical technologies are being developed, but there is concern regarding the potential negative effects of long-term accumulation of residuals. The option of land-based facilities has also been discussed, but this has not been generally considered to be a feasible option owing to the logistics and costs of pumping large quantities of ballast water ashore. However, although land-based systems have some disadvantages, they are also free of many of

Table 9.4.1. Recent first records on non-indigenous species (including range expansions and secondary introductions).

Species (including higher taxon)	**First record**	**Population status (established, common, etc.)**	**Impact or potential impact**	**Likely introducing vector**	**Native range**
Anadara demiri	Central Adriatic (2000)	unknown	unknown	shipping (hull fouling?)	Indian Ocean
Haminoea cyanomarginata	Mediterranean Sea (2001)	unknown	unknown	shipping (ballast)	Red Sea
Polycerella emertoni	Greece (2000)	unknown	unknown	shipping	Atlantic
Dreissena polymorpha	Ebro River, Spain (2001)	unknown	unknown	unknown	Ponto-Caspian region
Sagartia elegans ssp. *roseacae*	USA, Massachusetts (2000)	unknown	unknown	unknown	Europe
Caprella mutica	USA, Massachusetts and Rhode Island (2000)	unknown	unknown	unknown	Asia
Ianiropsis sp.	USA, Massachusetts and Rhode Island (2000)	unknown	unknown	unknown	unknown
Didemnum sp.	USA, Massachusetts and Rhode Island (2000)	unknown	unknown	unknown	Japan
Gymnodinium catenatum	New Zealand (2000)	recorded during bloom	unknown	unknown	unknown
Pfiesteria piscicida	New Zealand (2000)	unknown	unknown	unknown	possibly native
Pfiesteria piscicida	Oslofjord, Norway (2002)	unknown	unknown	unknown	unknown
Charybdis sp.	New Zealand, Auckland region (2000)	unknown	nuisance to fishers, gets into nets and very difficult to remove	unknown	unknown
Protodorvillea egena	Gulf of Noto, Sicily, Italy (2001)	unknown	unknown	unknown	South Africa
Isolda pulchella	Gulf of Noto, Sicily, Italy (2001)	unknown	unknown	unknown	Atlantic and Indian Ocean
Ampharetidae	Gulf of Noto, Sicily, Italy (2001)	unknown	unknown	Lessepsian migrants or transferred via ballast water	Indian Ocean
Dispio uncinata	Gulf of Noto, Sicily, Italy (2001)	unknown	unknown	unknown	Atlantic, Pacific and Red Sea
Epinephelus coioides	Italy	unknown	unknown	unknown	unknown
Questa caudicirra	Gulf of Noto, Sicily, Italy (2001)	unknown	unknown	range expansion or ballast	Atlantic and Pacific coasts of America

the constraints and problems of ship-based treatment, e.g., limited space for equipment, short time scale in which to treat water, etc., and, as such, should not be excluded from the possible options for treating ballast water. It is also likely that risk assessment and management will continue to play a role in ballast water management.

It should be noted, however, that any system of ballast water treatment or management will not provide an absolute barrier to prevent the introduction of unwanted non-indigenous species, but will rather work in the same way as a quarantine system and reduce the likelihood of such an occurrence.

Ballast management

So far, no universal agreement on ballast water treatment and/or management measures has been reached. However, a limited number of concerned countries have implemented mandatory or voluntary guidelines for ships calling at ports under their jurisdiction. Details of ballast water regulations currently in place are given in the 2001 and 2002 SGBOSV reports.

Additional comments

The above information is provided to make ICES Member Countries aware of the possible mechanisms of movement of non-indigenous organisms via shipping through ballast water and sediments, fouling on ships' hulls and sea chests, or other vectors. Although much is now known about such mechanisms, the causes for the introduction of many species are still unknown.

Although research is being conducted on methods of treatment of ballast water and sediment, no universal agreement on such treatment and/or management measures has been reached.

10 MARINE BIOLOGICAL COMMUNITIES, PROCESSES, AND RESPONSES

10.1 Benthos Issues

Request

This is part of continuing ICES work on benthos ecology issues. This work may also contribute valuable validation of the EUNIS habitat classification system.

Source of the information presented

The 2002 report of the Benthos Ecology Working Group (BEWG), the report of the ICES-BEWG North Sea Benthos Project Workshop, and ACME deliberations.

Status/background information

Progress in the North Sea Benthos Project

The objective of the North Sea Benthos Project (NSBP) is to collate data on the distribution of macrobenthos in the North Sea in 2001/2002 and to undertake a comparison with the results of the 1986 North Sea Benthos Survey. An initial workshop was held in January 2002 in Oostende, Belgium, where the information that was available on the project and protocols for data exchange were discussed. Agreement was reached on data structures and conditions for release of the data. Since the NSBP is relying on existing data from independent national projects, the geographical coverage of the data is very uneven. More national data sets were made available to the project, but efforts are being made to identify and gain access to additional data sets. The NSBP activities are being presented at the ICES Annual Science Conference in Copenhagen, in October 2002, and at the Oceanographic Data Management Conference in Brussels in November 2002.

Need for further research or additional data

Additional data sets have been identified that need to be included in the project. There is a great deal of inconsistency in the taxonomic lists of the various data sets and this needs to be resolved. Similarly, there are inconsistencies with the identification of feeding types, life strategies, etc., that also need to be resolved.

10.2 Phytoplankton Ecology Issues

Request

This is part of the continuing ICES work on coordinating quality assurance activities and reporting on the results of new or improved methods and their implications for monitoring programmes.

Source of the information presented

The 2002 report of the Working Group on Phytoplankton Ecology (WGPE) and ACME deliberations.

Status/background information

The ACME noted that WGPE reviewed the progress in developing quality assurance practices and protocols for phytoplankton measurements in the ICES area. In particular, the development of phytoplankton checklists was discussed intensively. The checklist for the Baltic Sea has been completed. It was pointed out that there are many differences between approaches, systems, taxonomic codes, etc., in regional or national checklists. Due to this incompatibility, the merging of different lists requires a great deal of work. Thus, it was recommended that a Study Group be established to resolve the problems and compile a preliminary European Phytoplankton Checklist, including the integration of information from molecular taxonomists.

WGPE has also proposed that a Mini-Symposium be organized at the ICES Annual Science Conference in 2004 on non-traditional and automated analysis techniques for phytoplankton field samples.

Organizing a joint mesocosm experiment has been under discussion for several years in WGPE. Due to the funding difficulties identified and the lack of a critical mass of interdisciplinary scientists, WGPE agreed to cancel the plans for such an experiment for the immediate future.

WGPE has discussed the scientific merits and operational possibilities of including primary production measurements in environmental programmes. Currently, primary production measurements are supplementary in the HELCOM Cooperative Monitoring in the Baltic Marine Environment (COMBINE) Programme. WGPE pointed out that the information about primary production is relevant for environmental assessments, but that there is a need for standard methodology. The group agreed that the use of models in combination with new direct bio-optical methods and appropriate environmental data to calculate the production is the most successful way to continue.

The Workshop on Contrasting Approaches to Understanding Eutrophication Effects on Phytoplankton was organized by WGPE in March 2002. The workshop was successfully accomplished, and a number of creative and spirited interdisciplinary discussions arose (see Section 10.3, below). The outcome of the workshop will be published as a dedicated volume of the Journal of Sea Research.

Need for further research or additional data

The ACME endorsed the recommendation of WGPE to organize a Mini-Symposium at the ICES Annual Science Conference in 2004 on non-traditional and automated analysis techniques for phytoplankton field samples and recommends that WGPE seek the advice and collaboration of specialists in optics, molecular biology, and image processing techniques.

The ACME recognized the need for a merged checklist of phytoplankton species in the ICES area. However, the ACME recommends that, in order to ensure rapid achievement, an inventory of phytoplankton checklists should be established and problems in merging those lists should be reported. The first step should include detailed identification of all accessible checklists already in use in the ICES area, including lists of synonyms.

10.3 Outcome of the Workshop on Contrasting Approaches to Understanding Eutrophication Effects on Phytoplankton

Request

This is part of continuing ICES work in relation to understanding eutrophication processes; it is also of interest to regulatory Commissions.

Source of the information presented

The report of the Workshop on Contrasting Approaches to Understanding Eutrophication Effects on Phytoplankton and ACME deliberations.

Status/background information

The Workshop was set up as an initiative of the Working Group on Phytoplankton Ecology and took place in The Hague, the Netherlands in March 2002. It was organized as an ICES workshop with the financial support of the RIKZ (the Netherlands) and CEFAS (UK). The Workshop was attended by 43 participants from 15 countries; 33 papers were presented. The main purpose of the Workshop was to compile current knowledge on the impacts of nutrient enrichment on phytoplankton behaviour in coastal waters and inland seas. A wide variety of themes were presented during the meeting, from the direct impacts of nutrient concentrations on the growth of phytoplankton to the societal issues linked to eutrophication. The relations between the regulatory bodies such as OSPAR and the European Commission were discussed as well.

The Workshop had an interdisciplinary character, with marine biologists, chemists, modellers, and representatives from regulatory agencies attending.

The Workshop is thought to have greatly stimulated the future work of the Working Group on Phytoplankton Ecology (WGPE), with so much input from different disciplines and geographical areas. Scientific exchange on the eutrophication issue has been strongly stimulated. This was also due to the invitation of scientists from outside the ICES area who were involved in the Workshop.

In overview, many case studies for specific areas were presented, e.g., for Chinese, Japanese and Korean waters, for the Black Sea, Aegean Sea, and for the Baltic Sea, parts of the North Sea, and Delaware Bay in the USA. Most of these case studies have in common that nutrient enrichment has caused eutrophication-related effects such as enhanced frequency of algal blooms, increased phytoplankton biomass, and changed species composition.

A specific aspect treated was a discussion on the traditional mass balance approach (increased biomass, enhanced primary production) versus the organism approach. The latter might also be a consequence of eutrophication through changes in the phytoplankton species composition.

Part of the Workshop was devoted to the modelling of phytoplankton blooms, even at the species level. Great progress has been made, including improving the predictive properties of such models.

For the Workshop, a group of scientists actively involved in eutrophication issues was invited to participate. Apart from the above-mentioned case histories, driving forces, eco-physiological aspects of nutrients, and mass balance and modelling approaches were also discussed.

In the final plenary session of the Workshop, a series of questions were discussed including whether a definition of eutrophication can be given. Although no decision on a definition was taken, WGPE is now able to contribute to a refinement of a workable definition of eutrophication in collaboration with other ICES Working Groups and regulatory agencies, if called upon. Further points raised in the final discussion are that there is an increasing need to quantify the complex interactions driving marine ecosystems and their trophodynamics. This quantification is required for regulated harvesting of the sea, for managerial purposes, and for accommodating other societal dependencies on the marine habitat. Working Groups could better respond to such societal issues, which are often embedded within their terms of reference, if they have had the benefit of interactive exchanges with other Working Groups in workshops dedicated to themes of mutual interest, but which require interdisciplinary effort.

The questions for which consensus responses were achieved are listed below.

Is there evidence that anthropogenic nutrient supply of coastal waters is leading to altered phytoplankton dynamics and/or communities?

The consensus was that this was generally the case, with supporting evidence available in the case histories presented at the Workshop. In general, an increase in nutrients leads to increases in biomass (chlorophyll) and primary production. With regard to changes in species composition and the selection of erstwhile "good" vs. "bad" species (functional groups), the evidence is mixed. It was emphasized that an adequate time series, including baseline data, is needed to distinguish between the effects of nutrient oversupply and natural variance. Experimental confirmation of purported eutrophication/ phytoplankton responses is also needed, but this is recognized to be difficult to acquire for methodological reasons and owing to the difficulty of achieving relevant simulations of ecosystem structure and processes.

Are these adverse responses generic, e.g., extrapolatable as first principles, or primarily site-specific consequences of narrower interest?

Discussion of this question at the Workshop was intense, with interest in how to interpret the term "generic", i.e., the notion that since a dose-yield relationship occurs between nutrient supply and phytoplankton biomass and primary production levels, then it can be expected that at sites where increases in nutrients occur, an increase in biomass and primary production will result (i.e., the "first principle" extrapolation). With regard to the site-specific reference in the inquiry, it connotes that locally observed responses cannot be generally extrapolated. It was agreed that in order to assess these prospects, there is need to distinguish between mass balance responses and species-specific responses, and to recognize that these responses are non-linear, which obscures the enhanced nutrient supply-phytoplankton response relationship.

With these clarifications, the Workshop consensus was that, while the underlying factors (mechanisms) and ecological principles apply universally, the outcome of the collective phytoplankton response to nutrient loading is often site-specific. Within this behaviour, the majority view was that the mass balance and functional group responses were more likely to conform to expectation than predictions of species-level responses, which are often erratic. Therefore, the Workshop conclusion with regard to the "first principles" portion of the inquiry is that it is appropriate "to some extent", with a much lower degree of confidence for predicting species-level responses than for mass balance responses. With regard to the site-specific issue, the Workshop majority opinion was that the underlying, first-principle factors are not violated at specific sites. However, at these sites local habitat conditions, which include a multiple of physical, chemical, and biological factor interactions, can obscure the role of altered nutrient levels on phytoplankton behaviour. This compromises the regional extrapolation of species-specific behaviours observed at one site to expected behaviour in another habitat at similar stages of nutrient enrichment.

Can nutrification effects on phytoplankton be modelled, with fidelity, for mass balance, species-specific and functional group behaviour?

Workshop participants agreed that this inquiry needed restatement and qualification, and since models are developed for different applications, the required rigour and fidelity of the model will vary with the intended use of the model. Since by this stage the need to distinguish between mass balance, functional group, and species-level responses was recognized, they were incorporated into the inquiry. Acknowledging that there are various types, classes and applications of models, Workshop participants rephrased the question to read:

> *Can reliable (useful) models be made for the effects of nutrification on phytoplankton mass balance, species-specific, and functional group behaviour?*

In this restatement, the term "fidelity" was deleted, since fidelity implies predictive power, a capability which Workshop attendees agreed was limited, if at all attainable, based on current knowledge on the nutrient enrichment/altered phytoplankton behaviour relationship. With this proviso, it was concluded that useful models of the mass balance type are available to managers.

What knowledge and technical gaps are impeding progress towards quantification of nutrient enrichment impacts on phytoplankton?

This question elicited considerable discussion at the Workshop, and demonstrated the great value of convening an interdisciplinary Workshop of biologists, chemists, physical oceanographers and modellers, a particular strength of this Workshop. The need for interdisciplinary collaboration was emphasized, with dialogue on "what biologists want from modellers, and modellers want from biologists". Some of the mutual needs recognized were:

- Field observations need to be carried out on time and space scales that match processes.
- Time series must be of sufficient duration to capture eutrophication effects, which develop over the long term.
- Modellers and biologists must consider the indirect impacts of nutrient supply rates and levels on phytoplankton behaviour, and not only the direct effects.
- Bacteria, other heterotrophs, and macroalgae should not be ignored, since they compete with phytoplankton for nutrients.

- Nutrient thresholds may occur, at which there may be increased potential for significant "bioshifts" in phytoplankton and/or higher trophic level responses. To guide modellers and managers, these thresholds and a "trophic index" or "saprobic system" which classifies habitat nutrient and trophodynamic status need to be established.
- Ecophysiological data on key species are needed, and ecophysiological groupings of phytoplankton at some level intermediate between their species and functional group affiliation would be helpful.
- While there may be increased risk of harmful algal bloom events with eutrophication, there are many instances in which this is not a factor. There should not be *a priori* anticipation that eutrophication will lead to harmful blooms, which are highly unpredictable, in their occurrence and bloom species.
- In modelling eutrophication effects, trophic transfer must be considered. Models need to incorporate food web-grazer interactions, and these trophic compartments need to be monitored in the time series data being collected, particularly where the management of nutrient supply and its effects are the objectives.
- Follow-up monitoring is required at sites where the management of nutrient supply and its effects are the objectives, particularly where the eutrophication process may have been reversed, and where there is a need to establish whether the induced changes have long-term persistence.

Workshop participants, aware of the various definitions currently in vogue, did not seek to define eutrophication, and resisted temptations either to endorse (or reject) existing definitions, or to elaborate a consensus definition in replacement. All agreed that eutrophication is not a "state", stationary, or fixed condition, but a process in which there is a continuum of change and modified response. In this process, the natural habitat and its communities will degrade progressively and increasingly, unless the nutrient supply is diminished. The direction and velocity of this change will vary with the level and rate of nutrient supply, with the biotic responses further influenced by habitat conditions. The extent to which the process is reversible and the kinetics of nutrient-induced change are obscure, however.

The Workshop discussion focused on the failure of the various definitions of eutrophication and their varying criteria to be generally applicable. Examples were presented to show that the application of existing eutrophication criteria could incorrectly designate a habitat as being eutrophicated, or would incorrectly explain observed phytoplankton behaviour as a response to eutrophication. These sobering insights contributed to the decision of Workshop participants to sidestep efforts at defining eutrophication. This decision was influenced by the fact that certain definitions have acquired quasi-legal status in serving as criteria that regulatory agencies are applying in seeking compliance with mandated reductions in nutrient loading. Workshop participants agreed that there is a need to reconcile existing definitions of eutrophication with scientific findings, such as reported at the Workshop, and that more workable definitions will evolve as the knowledge base increases. Just as the Workshop established that increased collaboration between biologists and modellers was needed, a similar need for collaboration between managers, regulatory agencies, and "hard" scientists to develop such workable definitions of eutrophication was recognized.

It is intended to publish the Workshop papers, after review, in a special issue of the Journal of Sea Research, under guest editors.

The ACME agreed with the above conclusions of the Workshop. The ACME noted that, with this Workshop, a large step has been taken to discuss many different issues related to eutrophication. However, this does not mean that all issues are understood or solved. WGPE should be encouraged to work further on these unsolved issues in the future, such as the effects of changing N/P ratios, which are not fully understood, the consequences of natural toxins from phytoplankton for other plankton species, and means to discriminate between natural and anthropogenic-impacted variability.

The ACME encouraged ICES Working Groups to convene similar workshops covering cross-disciplinary themes, and to which scientists who are not affiliated with ICES are also invited.

10.4 Progress in Understanding the Dynamics of Harmful Algal Blooms

Request

This is part of the continuing ICES work to support research and collect information on this issue, owing to the health and economic problems associated with the worldwide occurrence of harmful and/or toxic phytoplankton blooms.

Source of the information presented

The 2002 reports of the ICES-IOC Working Group on Harmful Algal Bloom Dynamics (WGHABD), the Study Group on Modelling of Physical/Biological Interactions (SGPBI), the ICES-IOC-SCOR Study Group on GEOHAB Implementation in the Baltic (SGGIB), the IOC-SCOR GEOHAB Science Plan, and ACME deliberations.

Status/background information

The ACME noted that the joint ICES-IOC WGHABD continued work is acknowledged worldwide as the initiator of IOC-SCOR GEOHAB (Global Ecology and Oceanography of Harmful Algal Blooms). The work of WGHABD contributes to the general issue of environmental and ecosystem assessment.

The ACME welcomes the continued effort of WGHABD to update the mapping exercise and long-term trend studies of harmful algal blooms (HABs) based on the collation and assessment of national reports and contributions. This information is available as part of the ICES Environmental Status Report, on the ICES website under http://www.ices.dk/status/decadal (see also Section 6.8.3, above).

Critical analysis of the first year of functioning of the IOC-ICES Harmful Algal Event Database (HAEDAT) has permitted the identification of sources of inconsistencies in the data entered. Now that the main sources of inconsistencies have been identified, the ACME appreciates that some steps will be taken to prevent them. It is to be noted that this database allows inputs from some countries outside the ICES geographical area, setting a global context.

The ACME recognizes that progress in understanding the dynamics of HABs depends on the development of the global programme GEOHAB. The ICES contribution to GEOHAB is to implement studies either nationally or at the basin scale. Important progress has been achieved in the implementation of a plan for a Baltic GEOHAB. A Canadian GEOHAB National Programme is at the planning stage. In the context of the European Sixth Framework Programme, an Expression of Interest has been issued for a Network of Excellence under the name EXMARECO (Exploitation of Marine Ecosystems) covering in its Work Package 5 all harmful algal bloom oceanographic-related questions at the basin scale (Baltic Sea, southern North Sea and Channel, Irish Sea, Eastern Atlantic Shelf, Bay of Biscay, Iberian coast).

It was noted that several workshops related to HABs have recently occurred or are planned:

- The LIFEHAB Workshop, Calviá (Palma de Mallorca), October 2001, which summarized current knowledge on the life history of harmful species and considered the most appropriate approaches to address the role of life cycles in HAB dynamics; the report of this workshop will be published by the EC;
- A Workshop on Molecular Probe Technology for the Detection of Harmful Algae is scheduled for Galway, Ireland, in May 2002; this covers new developments in this rapidly evolving field;
- A Workshop on Real-Time Coastal Observing Systems for Ecosystem Dynamics and Harmful Algal Blooms is planned to be held in Villefranche-sur-Mer, France, in July 2003, provided that funds are found.

The ACME reiterated the support of ICES for the implementation of GEOHAB.

Need for further research or additional data

The ACME endorsed the proposal for a major workshop in summer/autumn 2003 on "Future Directions for Modelling Physical/Biological Interactions in the Ocean", sponsored by GEOHAB and possibly also by GLOBEC.

10.5 Zooplankton Ecology Issues

Request

This is part of the continuing ICES work on coordinating quality assurance activities and reporting on the results of new or improved methods and their implications for monitoring programmes.

Source of the information presented

The 2002 report of the Working Group on Zooplankton Ecology (WGZE) and ACME deliberations.

Status/background information

The ACME noted that additions to the ICES Environmental Status Report concerning zooplankton monitoring results in the ICES area will include: a) the incorporation of four new data sets: Georges Bank, Faroe Islands, Dove (central-western North Sea), and Helgoland (southeastern North Sea); b) the ordination of data sets into five different subdivisions corresponding to regional seas or basins: Western Atlantic, Iceland-Norwegian basin, Baltic Sea, North Sea and English Channel, and Bay of Biscay and Iberian coast; and c) the inclusion of seasonal and year-to-year variability of two target species: *Acartia clausi* and *Calanus helgolandicus* in some regions (see Section 6.8.2, above).

Time series studies on zooplankton long-term trends and their relationships with climate index and global warming suggest that important changes are occurring in zooplankton processes and community structure as a result of climate change. Observed patterns were: a) effects on biogeography and diversity (e.g., findings on copepod species distribution over a forty-year study period suggest that in the eastern North Atlantic, the geographical distribution of warm-water species was expanding northward, while the distribution of cool-water species was shrinking and receding farther north; in the western North Atlantic, this trend was reversed, with the geographical distribution of cool-water species expanding farther south); and b) effects on biomass production and the onset of plankton population growth revealed a shift in early production (blooms) from fifty days to twelve weeks earlier than they were in the 1970s.

The list of indices of potential value for understanding zooplankton dynamics and ecosystem functioning was further refined. Additional refinement of the list is necessary, including appropriate documentation and justification (including references) for the indices.

WGZE has organized the scanning of six ICES Zooplankton Identification Leaflets (Fiches), concentrating on examples of the Decapoda, for inclusion on a CD-ROM product. The scanning of all remaining Fiches will be completed by the time of the 2002 ICES Annual Science Conference.

The second Workshop on Zooplankton Taxonomy is recommended to take place in June 2003. The Workshop will focus on the taxonomy of copepods and decapods, with the following objectives: a) to improve the current zooplankton taxonomic expertise of scientists within the ICES area; b) to aid the synthesis of existing time series by intercalibration of the taxonomic group analysed; c) to supplement existing taxonomic work with new optical systems; and d) to promote future taxonomic work.

Plans are developing for the Third International Zooplankton Production Symposium, entitled "The Role of Zooplankton in Global Ecosystem Dynamics: Comparative Studies from the World Oceans", which is co-sponsored by ICES, PICES, and GLOBEC. This Symposium will be held in May 2003 in Gijón, Spain. Eight major topics will be covered in scientific sessions, and there are plans for holding a number of specialized workshops in association with the Symposium.

WGZE believes that it is now time to begin the process of bringing together potential collaborative teams in one or more workshops in order to address future developments in trans-Atlantic studies. The object of these workshop(s) would be to discuss the scientific topics and to define concrete steps to evaluate and model the impact of oceanographic and climate-related processes on the dynamics of plankton and fish populations.

The ACME noted that WGZE strongly believes that zooplankton monitoring should be included in the EU Water Framework Directive at the same level as phytoplankton and benthos monitoring, particularly as zooplankton monitoring reveals the quality status of the ecosystem, natural large-scale variability, and regime shifts.

With regard to the identification of appropriate zooplankton variables for operational monitoring purposes, it was noted that new automatic sampling instruments are developing rapidly, but the cost of the equipment strongly limits the use of such technology and the spatial resolution needed for an ocean observation system. In the short and medium term, the bulk of the existing bio-ecological observations in oceanography will be based on standard sampling programmes.

While sympathetic to the need for zooplankton monitoring and studies for scientific purposes, the ACME did not endorse the inclusion at the present time of zooplankton measurements in relation to monitoring programmes for regulatory requirements. The ACME repeated its reservations concerning the potential addition of new monitoring parameters to the full list of existing monitoring requirements without clear operational justification (see also Sections 5.2, above, and 10.6, below).

10.6 Scientific and Operational Merits of Including Primary Production Measurements and Zooplankton Studies in Eutrophication Monitoring

Request

This is part of continuing ICES work to provide information and advice on marine monitoring issues.

Source of the information presented

The 2002 reports of the Working Group on Phytoplankton Ecology (WGPE), and the Working Group on Zooplankton Ecology (WGZE), and ACME deliberations.

Status/background information

Primary production is the first and immediate biological process by which nutrients are converted to biomass and, thus, it is of direct relevance to eutrophication. Therefore, the estimation of the amount of primary production is needed for monitoring programmes. Primary production measurement using the ^{14}C-technique was a mandatory parameter in the former HELCOM Baltic Monitoring Programme, but it was changed to a supplementary measurement in the subsequent HELCOM Cooperative Monitoring in the Baltic Marine Environment (COMBINE) Programme since it proved difficult to obtain observations of sufficient resolution in space and time. Currently, only three out of nine HELCOM countries measure primary production. The most difficult problem to solve is the adoption of a standard methodology for the ^{14}C-technique. HELCOM COMBINE has adopted the ICES standard method.

WGPE agreed that the use of models using measurements of the physiological status of phytoplankton based on new technology, in combination with appropriate environmental data, to calculate the production is the most successful way to continue. New measurements and improved models have the potential to meet the need for improved information on primary production, which is a fundamental measure of ecosystem functioning.

Zooplankton has a central role in marine ecosystems, being the link between primary production and fish production. Currently, zooplankton is not included as a monitoring parameter in the EU Water Framework Directive. WGZE found this to be a very unfavourable situation. WGZE referred to its earlier conclusions to include zooplankton structural parameters, taxonomic identification, and diversity indices as routine measurements in monitoring programmes. Regarding the methodology, WGZE pointed out that the ICES Zooplankton Methodology Manual offers a good basis. However, further recommendations about standardization and guidelines, including QA, are needed.

Need for further research or additional data

The ACME noted that there is a need for the evaluation of measurement strategies and protocols where information obtained from new technologies (bio-optical measurements) and relevant environmental data can be linked with models, in order to obtain estimates of primary production. However, considering the current lack of agreement on optical probe measurements, the ACME suggested that WGPE seek advice from optical physicists in order to choose the proper methodology.

Given that the methodology for primary production measurement is in transition and there is currently no standardization for zooplankton measurements, the ACME did not endorse the inclusion of these parameters in monitoring programmes in relation to regulatory requirements. Furthermore, the ACME expressed grave reservations concerning the potential addition of new monitoring parameters to the full list of existing parameters that are the subject of monitoring, without clear scientific and operational justification (see also Section 5.2, above).

11 MARICULTURE ISSUES

11.1 Environmental Interactions of Mariculture, including New Monitoring Programmes

Request

This is part of continuing ICES work to keep under review environmental issues relating to mariculture.

Source of the information presented

The 2002 report of the Working Group on Environmental Interactions of Mariculture (WGEIM) and ACME deliberations.

Status/background information

The ACME reviewed the WGEIM report and agreed to present the information contained below.

Mariculture has a wide range of potential environmental interactions, ranging from aesthetic impacts, ethical aspects of animal welfare, and effects on wild populations to the impacts of a variety of effluents. These impacts can be harmful to the mariculture operation, as well as to the surrounding environment, and it is a prerequisite for a sustainable industry that the impact is kept within environmentally safe limits. Monitoring of environmental impacts is crucial and must fulfil the needs of the operator as well as the needs of the regulator and the general public.

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP, 1996) has provided a working definition for monitoring in relation to aquaculture, as "the regular collection, normally under regulatory mandate, of biological, chemical or physical data from predefined locations such that ecological changes attributable to aquaculture wastes can be quantified and evaluated". GESAMP (1996) also emphasizes that, in order to have efficient regulatory tools, monitoring programmes must be integrated with simulation models that can predict the impact of a given operation and respond with remedial action if the threshold levels for environmentally acceptable impact are breached.

Appropriate monitoring programmes are essential for achieving and maintaining an environmentally friendly mariculture industry. Monitoring and regulating the production process and the extent of the operation is also a prerequisite to the integration of mariculture into coastal zone planning. It is only when adequate data are available that environmental and mariculture needs can be formulated securely. It follows, therefore, that integration will be successful when all participants (end-users of their coastal resources) are able to identify their environmental needs and impacts while demonstrating a high level of credibility in their assessment. Only then can mariculture achieve acceptance among stakeholders. This will safeguard all users beyond the initial threshold levels agreed by consensus. To increase the public confidence and build trust in the mariculture industry, it is strongly recommended that results from ongoing monitoring programmes be accessible to the public.

Setting threshold levels for environmental impacts or environmental quality standards (EQS) requires a close cooperation between authorities that can define what impact is acceptable, and scientists who understand what this means in measurable parameters. In many countries, the task is determined by environmental quality objectives (EQO) from which EQS values are derived. An EQO/EQS system is highly recommended since it will contribute to transparent regulatory systems that are based on political decisions and public acceptance. This approach opens the possibility of defining zones with different allowable impacts and, accordingly, different EQS values (Ervik *et al*., 1997; Henderson and Davies, 2000; Hansen *et al*., 2001).

Monitoring programmes must concentrate on the main impacts of mariculture. Hansen *et al*. (2001) suggest that the following criteria should be used to select the impacts on which to put the main emphasis:

- the sum of the impacts must have relevance for both the environment and the mariculture operation, including consumer safety;
- the impact must be convenient for monitoring, e.g., routine analytical methods must be available and the signals must be distinguishable from background levels;
- scientific information must be available to set adequate EQS;
- the monitoring must be cost efficient, as most aquaculture operations are small enterprises.

The EU Water Framework Directive (WFD) will be the primary EU driver for the improvement of groundwater and surface water quality over the next decades. Under the Directive, definitions of good ecological quality will be agreed upon for a wide range of water body types covering all surface waters in the EU. Good ecological quality will be the target for improvement guidelines to be adopted by member states and their environmental agencies.

Aquaculture is not specifically mentioned in the Directive. However, it will be viewed as a source of environmental pressures with the potential to adversely affect the primary indices of ecological quality in the transitional and coastal water bodies where mariculture operations are located. As such, it is likely that such areas will be subject to operational monitoring, as defined under the WFD. Fish farms will be assessed as potentially affecting benthic, phytoplankton and angiosperm communities, and also hydrochemical conditions such as nutrient and dissolved oxygen concentrations.

The implications for fish farming are, as yet, difficult to predict. The first critical factor will be the approach taken by national authorities in delineating the boundaries of water bodies. It currently seems likely that water bodies will be defined on the basis of hydrographic and physiographic factors and may be on the scale of individual sea lochs, fjords, or estuaries. Questions then arise as to how the ecological status of such bodies will be determined, taking into account the wide range of seabed, water depth, and plant and animal community types present.

The Monitoring and Regulation of Marine Aquaculture in Europe (MARAQUA) project evaluated the scientific principles underlying environmental impact monitoring of aquaculture (Fernandes *et al*., 2001). The authors recommended a set of regulations for environmentally friendly mariculture. It is recognized that aquaculture requires a framework of regulations to ensure an environmentally acceptable industry and to minimize potential environmental impacts. As part of good environmental management, mariculture operations must be monitored with regard to potential changes in pelagic and benthic systems. The monitoring practice must therefore be adapted to the natural environment as well as to the character of the farming operations. MARAQUA provided a comprehensive overview of different monitoring systems and techniques (Fernandes *et al*., 2001) and recommended that the following factors be taken into account:

- aquaculture methodology (extensive, semi-intensive, intensive, or integrated);
- aquaculture technology (flow-through, open cage, or closed systems, land- or sea-based);
- the type of environment (coastal zone, semi-enclosed systems like the Mediterranean and the Baltic Seas, Norwegian fjords, offshore conditions, deep sea);
- uses and users of the environment (e.g., nature conservation, fisheries, tourism, recreation, navigation).

In addition, new topics such as animal welfare and consumer safety are receiving increasing attention. Mariculture is important socio-economically in many rural districts and management processes, including monitoring, should be transparent, simple, efficient, and cost effective.

MARAQUA (Rosenthal *et al*., 2000) found that mariculture is monitored in most European countries; however, there is no overall system of monitoring and control that is widely applicable throughout Europe. In contrast, there are large differences in consistency, sophistication and complexity of regulations, control, and monitoring procedures. The potential deleterious effects of mariculture are well documented, and it is widely accepted that such impacts could be minimized or negated by adopting environmental safeguards, including regulatory control and monitoring procedures. MARAQUA suggested that research and development conducted in some European countries could be applied to harmonize regulatory control and monitoring in the EU by creating a Best Practice Code. Despite the differences in development in countries like Canada, the U.S., Norway, and Scotland that seem to have established the most comprehensive regulatory control and monitoring systems, the strategies applied are remarkably similar.

Additional comments

This information is presented to ensure awareness of potential environmental interactions of mariculture and the need for proper regulatory management and monitoring of mariculture operations.

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11.2 Guidelines for the Preparation of Environmental Impact Assessments and Monitoring Programmes for Large-scale Shellfish Farm Developments

Request

This is part of continuing ICES work to provide ongoing advice on environmental issues relating to mariculture.

Source of the information presented

The 2002 report of the Working Group on Environmental Interactions of Mariculture (WGEIM) and ACME deliberations.

Status/background information

The ACME reviewed the WGEIM report and agreed to present the information and advice contained below.

11.2.1 Guidelines for preparation of Environmental Impact Assessments (EIA) for large-scale shellfish farm development

Introduction

In EU Member States, Environmental Impact Assessment (EIA) is the subject of an EU Directive, Council Directive 97/11/EC amending Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment. The aim of the Directive is to ensure that competent authorities are provided with relevant information to enable them to make a decision on a specific project's potential impact on the environment. EIA is an open and transparent process, which ensures that all relevant information is considered. The process involves public consultation to ensure that all the relevant concerns are addressed. This facilitates decision-making to the benefit of the regulator, the developer, if approval is given, and concerned parties.

The Directive defines "intensive fish farming" as an Annex II project, thereby permitting individual Member States to determine, on a case-by-case basis or by setting thresholds or other criteria, whether projects should be subject to the EIA process. To date, most EU Member States have determined that only finfish aquaculture projects should be subject to EIA, and few shellfish projects, regardless of scale, have in fact been subject to EIA. The MARAQUA Concerted Action recommended, however, the adoption of the EIA process for **all** aquaculture operations.

In Canada, the establishment of a new shellfish or finfish aquaculture site will generally require an assessment under the Canadian Environmental Assessment Act. An EIA is normally triggered by the requirement for a navigation permit under the Navigable Waters Protection Act. Draft guidelines for proponents of both finfish and shellfish culture sites are available and provide detailed information on both the process and the information requirements for the EIA.

Shellfish industry

A variety of different shellfish species are cultured throughout the ICES area. These can be divided broadly into the following taxonomic groupings and culture methods. The culture methods and locations reflect the broad biological requirements (e.g., infaunal or epifaunal) and the physiological tolerances of the species concerned:

- Mussels
    a. Rope culture (subtidal)
    b. Bottom culture (subtidal/intertidal)
- Oysters
    a. Bottom culture (intertidal and subtidal)
    b. Trestle culture (intertidal)
    c. Suspended culture (subtidal)
- Clams
    a. Net culture (intertidal)
    b. Pen culture (intertidal)
    c. Beach culture (intertidal, subtidal)
- Scallops
    a. Suspended culture (subtidal)
    b. Pens (subtidal; on-bottom)
    c. Bottom culture (specified areas, not penned).

Studies of the environmental impacts of these activities have been published in numerous peer-reviewed publications and were reviewed briefly by the WGEIM in 2000. A number of studies have clearly shown that the sedimentation of faeces and pseudofaeces beneath mussel farms leads to organic enrichment and thus alters macrofaunal communities (Mattson and Linden, 1983; Kaspar *et al.*, 1985; Chamberlain *et al.*, 2001). Impacts on the water column appear to be related to the filtering capacity of shellfish species, which can minimize eutrophication effects by grazing phytoplankton (Rice, 2000, 2001). Other impacts on phytoplankton community structure have been proposed. For example, bivalve excretion and the subsequent increase in nutrient fluxes from the enriched sediments underlying bivalves in suspension or on the bottom may enhance local primary productivity over that of ambient conditions (Archambault *et al.*, 1999; Kaiser, 2000). Some research also suggests that harmful algal blooms may result from an imbalance in nutrients brought about by intensive bivalve aquaculture (Bates, 1998; Bates *et al.*, 1998). Bivalve aquaculture can also influence the composition of zooplankton communities (Lam-Hoai *et al.*, 1997) and possibly decrease the abundance of larvae of commercially important invertebrate and fish species (Davenport *et al.*, 2000). However, the importance of these effects and their cascading effects on the rest of the ecosystem is largely unknown.

Shellfish production in most ICES Member Countries is carried out by small-scale operators producing relatively small volumes in small licensed areas. In certain areas, there can be many licensed operators working in close proximity. For the most part, regulatory authorities have tended to consider license applications in isolation and cumulative impacts of many small operators have not been fully addressed. WGEIM considered that the cumulative impacts of many small operations could be significant and that appropriate management and regulatory strategies need to be developed to minimize these impacts. Such strategies will require the development of carrying capacity models, the setting of Environmental Quality Objectives (EQO) and Environmental Quality Standards (EQS), which ideally should be part of a science-based Integrated Coastal Zone Management system. The development of EQO and EQS are fundamental to the establishment of "acceptable" levels of impact.

The species chosen, method of culture, and production schedule may have a significant bearing on the information required for assessment in an environmental report. For example, rope mussel culture will have different environmental requirements, as well as impacts, than a bottom culture operation. The EIA Directive (97/11/EEC) allows Member States to determine through a) a case-by-case examination, or b) thresholds or criteria set by the Member State, whether the project shall be made the subject of an assessment (EIA). A number of criteria should be addressed.

However, having reviewed the selection criteria, WGEIM agreed that they are extremely vague. There is presently no agreed threshold in EU Member States at which it is decided that an EIS is required.

It is evident that the selection criteria are general in nature and apply to many different types of projects and developments, covering both terrestrial and marine environments. However, such generic criteria may not be appropriate for specific projects, such as large-scale shellfish culture. WGEIM acknowledged that there is a need for the refinement of these criteria to suit shellfish operations explicitly and recommended that further work be carried out to establish appropriate thresholds or criteria to determine which type of shellfish projects should be subject to:

a) an EIA,
b) an environmental report, or
c) no environmental assessment,

in order to obtain appropriate statutory permissions.

1) **An EIA:** In the case where, due to the scale of the proposal, it is concluded that an EIA is warranted, WGEIM reviewed the information required by Environmental Impact Statements (EIS) for salmon farms in Ireland and Scotland and derived a proposed list of information that may be relevant to EIS for marine shellfish farms (Table 11.2.1.1).

2) **An Environmental Report:** WGEIM noted that the preparation of an EIS as part an EIA can be expensive and time consuming. In the EU, if an EIA is required, then legally the process must comply with the requirements outlined in the Directive. EU Member States are required to adopt the necessary measures to ensure that the developer supplies the information specified in Annex IV of the Directive (97/11/EEC) in an appropriate form. There are significant cost implications in carrying out a full EIA for new developments, particularly for smaller operators that dominate the industry in many ICES Member Countries, such as France and Ireland. Such a situation may be resolved somewhat, by implementing a "scaled-down" version of an EIA for proposed developments. As an alternative to a full EIA, Fernandes *et al.* (2001), as part of the MARAQUA project, recommended that in some instances environmental studies of a more limited nature could be carried out and the results provided to the regulatory authorities in the form of an "Environmental Report" when making an application for a shellfish farming permit. Any environmental information and data compiled will provide a background against which any future data and information can be compared. WGEIM reviewed the type of information that could be included in environmental reports and concluded that the report should focus specifically on the list in Table 11.2.1.2. WGEIM noted that the preparation of such reports should ideally be done on a case-by-case basis and the information should be relevant to the specific site and local conditions. WGEIM considered that, as with salmon farming, careful and informed site selection, considering both ecological and environmental criteria, is critical in order to minimize adverse impacts on the environment and other resource users. In addition, early and widespread consultation with all stakeholders is important. These consultations, when carried out in the early stages of the project, can identify potential conflicts with other users, which may be overcome by modification of the project. Consultation at an early stage is strongly recommended to avoid delays caused by requests for further information and to expedite the processing of an application.

Need for further research or additional data

WGEIM concluded that, since baseline information is lacking in many areas, hydrodynamic and environmental capacity models to determine loading should be generated. This carrying capacity or, better, environmental capacity information would form the basis for management plans for discrete areas. In relation to large-scale shellfish farms, this may include the rate of organic flux to the benthos without major disruption to natural benthic processes, but also the reduction in scenic value (visual impact), reduction of natural habitat, and reduction in amenity value. The environmental capacity can be estimated by assessing cumulative or combined impacts and acceptable levels of environmental change compatible with the goals of coastal management.

Quantifying environmental capacity in relation to visual impact is, at least, partly subjective and establishing methods and criteria to determine the visual impact of shellfish farming is becoming increasingly important in areas of high scenic value and tourism potential.

Having reviewed the proposed information set out in Tables 11.2.1.1 and 11.2.1.2, the ACME agreed that these tables should serve as interim guidelines for the preparation of EIA or Environmental Reports, as required, with regard to the development of marine shellfish farms.

Recommendations

ICES recommends that Tables 11.2.1.1 and 11.2.1.2 be adopted as interim guidelines for the preparation of Environmental Impact Statements and Environmental Reports, respectively, with regard to the development of marine shellfish farms.

11.2.2 Review of monitoring activities

Introduction

Historically, shellfish aquaculture was viewed as a benign activity with limited environmental impacts. Monitoring in relation to shellfish culture activities typically has considered the activity from a human health, not an ecological or environmental health, perspective. Typically, regulatory monitoring programmes of shellfish culture have included the sampling and analysis of toxic and harmful algal species, the presence of biotoxins in shellfish, bacteriological quality of shellfish-growing waters and shellfish flesh, as well as trace metals and other contaminants in shellfish. Additional assessment of growth rates, mortality rates, and biofouling levels have been used by producers to monitor crop performance. The 2000 WGEIM report highlighted the fact that environmental monitoring programmes similar to those in place for salmon aquaculture (in place in most ICES Member Countries) did not exist for shellfish culturing activities. This situation has not changed in the interim. Some Member Countries (Scotland, France, and Ireland) have expressed the need to establish shellfish monitoring programmes that should focus primarily on benthic impacts. In Atlantic Canada, a shellfish monitoring programme has been developed in consultation with the industry. This monitoring programme includes benthic components that assist in the evaluation of benthic impacts and pelagic components that contribute to evaluating the holding capacity of the site. The supposition that benthic impacts are the most appropriate measures is examined further below.

Developing guidelines to monitor large-scale shellfish cultures

With the advent of the intensive culture of molluscs, it is now evident that this activity may have a significant impact on the environment (Prins *et al*., 1998). To date, no countries have required that monitoring programmes be established for bivalve aquaculture. WGEIM reviewed and identified some features that are important in considering the establishment of monitoring programmes for bivalve aquaculture. This review was largely based on the recent papers by Read *et al.* (2001) and Fernandes *et al.* (2001) and expands on some of the subjects already discussed therein. Although these papers were largely about the aquaculture of finfish, the recommendations may be extrapolated to the bivalve system. Fernandes *et al.* (2001) pointed out that any monitoring programme must address the needs of the scientists, operators, regulators, and the general public. At the simplest level, monitoring is needed to maintain the integrity of the culture sites and to ensure that production does not surpass the capacity of the site. This will ensure sustainable development of the industry and help in integrated management of the coastal zones (IMCZ).

Considerations

This review will address the following points:

1. What is monitoring?
2. What does "large scale" mean?
3. Scientific and other considerations.

<u>1. What is monitoring?</u>

According to GESAMP (1996), monitoring may be defined as "the regular collection, generally under regulatory mandate, of biological, chemical or physical data from predetermined locations such that ecological changes attributable to aquaculture wastes can be quantified and evaluated." This review will consider this definition to include an initial sampling programme to determine baseline information about the study site (see below). Further, this review will only consider effects within grow-out sites.

Table 11.2.1.1. Proposed information to be included in an EIS for shellfish farming.

Location and dimensions of proposed farm
Location of proposed farm and reasons for its selection

Description of Project
- Dimensions of proposed licence area
- Projected production and maximum biomass
- Type and number of structures (e.g., longlines, trestles)
- Proposed layout, dimensions, orientation, materials, and colours of all structures on the farm
- Arrangement of moorings
- Need for, and proposed location of, any shore-based facilities

Site Characteristics
- Location
- Landscape
- Natural features
- Archaeological features
- Water depths
- Currents (speed and direction)
- Wave climate
- Sediment type—particle size, organic content, physical appearance
- Redox profiles
- Benthic flora and fauna, including in particular any fragile taxa
- Location of main freshwater inputs
- Temperature/salinity
- Occurrence of water column stratification
- Turbidity, Particulate Inorganic Matter (PIM) and Particulate Organic Matter (POM)
- Dissolved oxygen, especially near bottom
- Chlorophyll
- Bacteriological Classification of water body
- History of harmful algal events
- Location of existing finfish farms in the area
- Location of existing shellfish farms in the area
- Fishing activity in the area (gears used)
- Recreational activity in the area (e.g., recreational fishing, sailing)
- Navigation channels and anchoring areas
- Location of piers and harbours
- Access roads
- Special Protection Areas (SPA)
- Special Areas of Conservation (SAC)

Production process
- Production model
- Economic and commercial aspects
- Source of seed
- General site management
- Waste management
- Harvesting method
- Timing of harvest
- Fallowing periods
- The proposed development in the context of Integrated Coastal Zone Management initiatives
- Plans to deal with accidents and emergencies (e.g., failure of moorings, storm damage to structures, mass mortalities)
- Shore-based facilities required
- Boats and service craft

Potential impacts
It should be emphasized that the estimation of potential impact is best performed by modelling the functioning of a farm, both from an ecological and an economic point of view.
- Estimate of the amount of solid waste produced
- Sediment loading
- Estimate of the extent of area of sediment impacted by solid waste
- Potential impacts on:
  - – Benthic flora and fauna
  - – Water quality
  - – Existing aquaculture operations
  - – Fishing activities
  - – Navigation
  - – Tourism
  - – Recreational activities
  - – Wildlife, including birds, cetaceans and other marine mammals
  - – Existing infrastructure (e.g., traffic, use of piers and harbours)
  - – Visual impact
  - – Social interaction

Mitigation measures
Description of measures to mitigate adverse impacts of the project while taking into account:
- Existing Regulations
- Codes of practice (e.g., sediment management)
- Carrying capacity considerations (e.g., stocking density)

Monitoring
- Monitoring of the benthic environment
- Water column monitoring
- Monitoring for validation of models (as required)
- Other monitoring activities, e.g., quality of shellfish, toxic algae (if not at institutional stage)

Difficulties in completion of EIS
- Lack of baseline data?
- Model uncertainty?
- Uncertainty in prediction of impacts?

Consultation
- List of individuals/representative bodies and organisations consulted
- Responses of consultees

Table 11.2.1.2. Proposed information to be included in an Environmental Report for shellfish farming.

Location and dimensions of proposed farm • Location of proposed farm and reasons for its selection **General description of project** • Dimensions of proposed licence area • Projected production and maximum biomass • Type and number of structures (e.g., longlines, trestles) • Proposed layout, dimensions, orientation, materials, and colours of all structures on the farm • Arrangement of moorings • Need for, and availability of, any shore-based facilities **Site characteristics** • Location • Water depths • Currents (speed and direction) • Sediment type—particle size, organic content, physical appearance* • Turbidity levels • Bacteriological Classification of water body • Location of existing shellfish farms in the area • Navigation considerations • Conservation Status of area and occurrence of fragile species **Production process** • Source of seed • Waste management • Harvesting method* • The proposed production in the context of ICZM initiatives	**Potential impacts** It should be emphasized that estimating the potential impact is best performed by modelling the functioning of a farm, both from an ecological and an economic point of view. • Sediment loading • Estimate of extent of area of sediment impacted by solid waste **Mitigation measures** • Description of measures to mitigate adverse impacts of the project **Monitoring** It is suggested that some form of monitoring of the activity be implemented, however, without being able to fully realise the impact's activity—monitoring may have to be considered on a case-by-case basis. **Difficulties in completion of Report** • Lack of baseline data? • Model uncertainty? • Uncertainty in prediction of impacts? **Consultation** • List of individuals/representative bodies and organisations consulted

*Mostly relevant to bottom culture methods where the risk of severe disturbance of the sea floor is highest.

2. What does "large scale" mean?

The importance of most ecological processes is a function of the scale at which they are measured (Levin, 1992). Variables measured at one spatial scale may not be important at another. For example, populations and communities in soft sediments may be less variable at small (~1 m) rather than at larger (10 m to 10 km) spatial scales (Lindegarth *et al*., 1995; Li *et al*., 1996), whereas the converse may be true in rocky habitats (Underwood and Chapman, 1996; McKindsey and Bourget, 2001). Likewise in bivalve aquaculture, the scale at which variables are measured may greatly influence the ability to interpret the results of studies, the importance of a given aquaculture site to the local environment, or the outcome of monitoring programmes. In bivalve aquaculture, "large" may refer to the surface area over which the farming is occurring, the cumulative production of a site, or the density of animals within a site. Any combination of these three possibilities may be considered "large scale".

3. Scientific and other considerations

The purpose of any monitoring programme is to be able to detect whether a given aquaculture activity has changed a site beyond that which is acceptable. Of course, this assumes that the baseline (historic) and spatial data exist for comparison. Typically, a large number of variables need to be measured in an EIA or similar exercise before the aquaculture site is operational in order to determine the variables that may be important for the given location. The initial evaluation also identifies any "special" features that may be present at the proposed site. There are a number of criteria about the culture species, grow-out methods, and proposed site that should be considered when selecting the appropriate variables to measure; these are considered below.

1) Species differences

Different species can differ greatly in their basic ecology and physiology such that effects associated with the culture of some species may not be seen with other species. For example, different bivalve species produce pseudofaeces at different rates. Thus, the accumulation of biodeposits under mussel longlines may be greater than that under suspension culture for oysters, for example.

2) Grow-out conditions

The same species grown under different conditions may also have different impacts. For example, oysters grown on trestles may have a greater effect on the underlying sediments than do oysters growing in bottom culture or those in suspension. This also includes production cycles (seasonal, interannual, fallowing periods, etc.).

3) Depth

All else being equal, depth will modify the extent to which by-products from bivalve culture will be spread and, thus, the area over which we might expect to find an effect of the culture operation.

4) Bottom type

Hard bottoms may be predicted *a priori* to experience greater impacts from bivalve culture because a hard substrate will likely be replaced by a soft-sediment substrate, with concomitant changes to the associated plant and animal assemblages.

5) Hydrography

Hydrography is in part a function of 3) and 4), above; hydrography is also influenced by, among others, weather, larger-scale hydrological processes, and topography. Of course, these differences are largely related to factors other than the one being discussed and there are usually cascading effects of one factor on the others. This serves simply to highlight the point that most of these factors are important and interact in countless ways such that each case should be evaluated on its own merit.

6) Site history

This considers whether or not the site is currently being farmed or has been farmed in the past and, if so, in what capacity. It also considers the geographical location of the site with respect to other similar and/or competing uses for the same resource (other industries, recreation, etc.).

7) Scale/area of impact

Briefly, this questions the magnitude of the impact (e.g., everything dead or replaced) and over what spatial and/or temporal scale the impact of the culture activity is detected.

Variables

The variables that may be measured to detect impacts and routine monitoring fall into three broad categories: physical, chemical, and biological (Table 11.2.2.1). A further possibility is the development of indices of biotic integrity (IBI) that, although usually based on communities of a given group of species (Weisberg *et al.,* 1997; Karr and Chu, 1999; Smith *et al*., 2001), can be extended to include aspects of all three of these large groups. Typically, biological measurements are the most expensive indices to measure owing to the cost involved in processing samples (for population- and community-level variables, due to the actual cost of sorting and then taxonomic identification) or in the time and equipment necessary for other biological indices.

Sampling design

Regardless of the factors deemed most appropriate for monitoring, of fundamental importance is the robustness of the sampling design to reliably detect differences between culture sites and the appropriate control location(s). Emphasis should be placed on the quality of the sampling programme such that it should be able to show that the value of a given variable falls within prescribed acceptable levels rather than not differing from acceptable levels (McDonald and Erickson, 1994), as is done when testing pharmaceuticals. The former requires precise and sufficient sampling, while the latter benefits from less rigorous sampling with large variances.

Inherent in developing an appropriate sampling/ monitoring programme is the ability to analyse the information generated and interpret the output in a meaningful manner. The most appropriate statistical procedure to be used is obviously a function of the variables determined as being the most appropriate to monitor. Basically, the types of approaches fall into two large classes: univariate (i.e., one variable at a time) and multivariate (i.e., multiple variables at a time, parametric and non-parametric methods are commonly used). Numerous authors have outlined various statistical methods and discussed the merits of numerous types of analytical software.

An approach to developing a monitoring programme favoured by Fernandes *et al.* (2001) and Henderson *et al.* (2001) is to first model the system in order to determine the likely spatial and temporal implications of any potential impact, to guide any future monitoring programme. In the absence of scientifically robust carrying capacity models, it may be appropriate for both regulators and shellfish producers to consider surrogate methods of predicting impact. As an example, the growth parameters in the cultured organism may be monitored. Significant decreases in growth rate may reflect over-stocking and reductions in stocking density may result in optimization of yield and minimization of impacts.

Recommendations

ICES recommends that Member Countries adopt the parameters in Table 11.2.2.1 for inclusion in their monitoring programmes in relation to shellfish culture sites.

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Table 11.2.2.1. Variables commonly used in detecting environmental impacts and monitoring (modified from Fernandes *et al.,* 2001).

Physical	Chemical	Biological[b]
Biotope mapping	Redox potential	Species abundance, richness, diversity
Hydrological aspects	Dissolved oxygen[a]	Biomass
Sedimentation	Nutrients[a]	Health/physiology
Erosion/accretion	Particulate/dissolved organic matter	Productivity (1° and 2°)
	Suspended solids	Population/community structure
	Chemicals (metals, antibiotics, etc.)[a]	Trophic interactions
		Rare and threatened species
		Habitat mapping

[a]This applies to both the water column and sediment.
[b]May be measured for phytoplankton, zooplankton, benthos (micro-, meio-, and macro-), fishes, birds, etc.

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11.3 Issues regarding Sustainability in Mariculture, including Interactions between Mariculture and Other Users of Resources in the Coastal Zone

Request

This is part of continuing ICES work to keep under review environmental issues relating to mariculture.

Source of the information presented

The 2002 report of the Working Group on Environmental Interactions of Mariculture (WGEIM) and ACME deliberations.

Status/background information

The role of Integrated Coastal Zone Management (ICZM) for mariculture development and fisheries has been considered on several occasions by the Working Group on Environmental Interactions of Mariculture (WGEIM). In revisiting this issue, WGEIM and ACME welcome the initiatives of the EU in recent years to foster demonstration projects on Integrated Coastal Zone Management, as there is an important need to incorporate all activities in coastal areas, with serious consideration of social and economic factors. There is a definite need for cross-sectorial management approaches that link mariculture, fisheries, tourism, shipping, rural development, and other activities to achieve ICZM objectives. However, the present structure of the ICES system does not yet seem well equipped to deal with multidisciplinary, non-biological management tasks and methodologies.

In light of the need to prepare ICES for the required outreach and cross-linking, WGEIM reconfirmed the content of the ICZM chapter in the 1999 WGEIM report (ICES, 1999). Specifically, the concept of Integrated Coastal Zone Management was addressed. Two major dimensions of the process were highlighted:

- vertical integration of governance in the form of policies and management arrangements from national to local levels of government, including community-based approaches;
- horizontal integration of policies, management arrangements, and development plans across national, district, or local levels of government, as well as among different stakeholders with common interests in coastal areas and resources.

There is a need to create a shift in emphasis away from management that controls solely the end-use of resources derived from coastal ecosystems towards a more balanced approach. Emphasis is given to maintaining the health and productivity of coastal ecosystems so that they can continue to supply flows of resources that sustain different forms of activity, including mariculture.

Several EU projects (outlined in EU FAIR 1994–1998 Synopsis of projects, EUR 18949 EN) are presently under way or have recently been completed to assist in developing scientific criteria for sustainable resource use including aquaculture. These projects cover the following subject areas:

- the development of recirculation systems to minimize environmental impact of mariculture (FAIR-CT98-4160);
- risk assessment of antimicrobial agent use in aquaculture (FAIR-CT96-1703);
- studies on the physiological and behavioural mechanisms affecting the performance of introduced and escaped fish (FAIR-CT97-3498);
- effects of shellfish culture and options for sustainable exploitation (Essense FAIR-CT98-4201).

The CIHEAM Network on Technology of Aquaculture in the Mediterranean (TECAM) has recently published the proceedings on "Environmental impact assessment of Mediterranean aquaculture farms" (Uriarte and Basurco, 2001). This addresses, among other aspects, the issues of wild-cultured species interactions, tools for impact assessment of aquaculture activities on marine communities, aquaculture interactions with tourism, recreational activities and special protected areas, the development of monitoring guidelines and modelling tools for environmental effects from Mediterranean aquaculture, and mitigation strategies for inshore finfish cage farming through the deployment of specifically designed "filters" or "artificial reefs" (a project called: BIOFAQs = BioFiltration and AQuaculture).

A series of symposia, including the ICES Symposium on Environmental Effects of Mariculture (Wildish and Héral, 2001), have addressed a number of issues related to environmental assessment. In particular, the ICES Symposium received papers on:

- benthic and water column monitoring at fish farms;
- regional aspects of environmental impact of fish farming;
- benthic effects of shellfish cultivation, including modelling;
- the design of monitoring programmes;
- remote sensing approaches to monitoring;
- chemical analysis relevant to aquaculture;
- behaviour of escaped fish;
- effects of fish farm waste on algal growth.

A major undertaking to assess the status of monitoring and management of marine aquaculture in Europe was covered by the EU Concerted Action MARAQUA (Monitoring and Regulation of Marine Aquaculture in Europe). The results of MARAQUA contain contributions of all member countries and are published in two special issues of the Journal of Applied Ichthyology (Rosenthal *et al*., 2000).

Estimating site potential

A critical issue in the management of mariculture is estimating the potential productivity of proposed sites, both in terms of their ability to support a commercially viable level of production and in ensuring that the environmental impact of the sites will be sustainable at an acceptable level.

The productivity of shellfish sites is normally limited by the availability of planktonic food, although environmental impacts are increasingly being recognized, especially for large sites. While these sites produce significant quantities of faeces and other wastes, much of their environmental impact arises from physical disturbance associated with the lines, rafts and other structures, and these impacts can be evaluated only on a site-by-site basis. In addition, the importance of shellfish farms in depleting plankton levels that might otherwise be consumed by wild components of the ecosystem is very site-specific.

Similarly, the farming of plants, both planktonic and macroalgal, depletes nutrients and lowers light levels, but there exists no general model for how much these changes affect natural systems that can be used to set threshold levels for development.

The area that has received the greatest attention to date, and for which models currently exist, is in estimating safe limits of finfish production. Because finfish farming requires the introduction of large quantities of nutrients in the form of feed to the ecosystem, the risk of serious environmental damage is significant and must be carefully evaluated in the licensing procedure.

The impacts which are generally perceived as most serious, and which have received the greatest attention, are changes in the benthos due to carbon loading (nutrients and physical disturbance are also significant causal factors, but are generally less important than carbon loading). While low levels of carbon loading can increase benthic productivity, the higher levels usually associated with fish farms generally lead to low biodiversity and a shift of benthic production to bacteria. This can create hypoxic or even anoxic conditions and possibly the production of hydrogen sulphide and other toxic gases immediately under the cages. A halo of increased productivity around this zone may compensate to some extent for the loss of production in the heavily impacted zone.

Several models for the prediction of carbon loading exist, but fortunately they are all variants of the same basic underlying theory and are consistent with each other, other than in the range of effects which they include.

The effect of releasing nutrients into the water column is less well understood, in part because the rapid dispersion of dissolved substances generally makes this a regional rather than a localized effect. The environmental impact is consequently more the effect on total production in the region (inlet, estuary, etc.) rather than that due to a single farm. This means that decisions about new licenses depend on how many sites and other sources of nutrification are in the region; this makes the decision process politically difficult, especially when several applications are made within a short period of time.

One of the major obstacles to dealing with nutrient loading is the difficulty of determining the capacity of an inlet to assimilate additional nutrients without deleterious effects. Low levels of nutrification normally lead to enhanced primary production. In fact, it may be possible to combine shellfish and finfish mariculture so that the increased primary production can be utilized by the shellfish. However, there is also an increased risk of harmful algal blooms and, of course, excessive algal production can lead to anoxia if there is not enough secondary production to utilize the plant material before it decomposes. It is relatively easy to determine how much nutrification will occur from a fish farm, but at the present time we have limited ability to specify threshold values that can be used for regulatory purposes.

Biological Oxygen Demand (BOD) can be modelled in much the same way as nutrification, and in fact BOD can be treated as a negative nutrient.

There are numerous other effects associated with fish farms that are not normally considered in determining site potential. For example, there is a risk of disease transmission between farms, but this is normally dealt with by regulations which specify a minimum spacing between lease sites, and these regulations do not generally relate the spacing to the size of the farms. Oxygen uptake associated with fish respiration is another consideration, but because this is very localized it is often treated as a husbandry issue rather than a matter for regulation.

While there are many models in the scientific literature which address many of the potential environmental impacts of mariculture, these models are of little direct use to farm managers and regulatory agencies as they require considerable scientific expertise and understanding to use correctly. For this reason, there has been increasing interest in the development of Decision Support Systems (DSS). A DSS is a type of expert system that provides an effective interface between the models and people who need to use the models, but who do not have the scientific background to run and interpret the models in the form in which they are normally developed.

Mariculture and sustainability

Sustainable development is certainly a desirable political objective for any human activity. However, in order to derive methodologies to achieve this goal, well-defined objectives have to be identified, and scientific criteria need to be developed that allow objective assessment to be made of the sum of interactions across all activities in a given area, jurisdiction, or larger ecosystem.

Whatever definition is used, it has to be realized that sustainability is not a fixed set of conditions. Because types and intensity of resource use constantly change, as do the constraints, the achievement of sustainability depends on adequate adjustments to constant change in the resource use system, the competing pressure among users of the same or interdependent resources, and changes in the market place. To achieve sustainability, therefore, involves a dynamic and adaptive management approach to environmental, economic, and social demands.

Mariculture systems, environmental interactions, and escapees

To minimize environmental impacts, the development of Codes of Conduct (Codes of Practice) for responsible aquaculture has started in several regions. Following the FAO initiative to develop a Code of Conduct for Responsible Fisheries, several countries have, over the past few years, developed specific codes for the aquaculture industry in coastal waters. Suitable subjects for codes include:

- various guidelines for production systems, environmental guidelines;
- aesthetic/landscape/scenic issues;
- animal welfare issues;
- disease management;
- waste disposal practices;
- harvesting procedures;
- interactions with algal blooms;
- eco-labelling and organic farming;
- improved control and management schemes to reduce impacts;
- technical aspects and opportunities for developing farms in less sheltered areas, or offshore areas.

Possible interactions between fish farms and the occurrence of harmful algal blooms are of considerable current environmental and public interest in several countries. There are few research projects clearly directed at this proposed linkage.

A project AQUATOXSAL has recently been carried out in Chile to investigate possible links between aquaculture and harmful algal events. The overall objective of the project was to provide management tools for the sustainable development of aquaculture in the south of Chile. The rapid, exponential growth of the fish-farming industry during the last ten years produced important socio-economic benefits. Salmon production during the year 2000 was around 250,000 tonnes, placing Chile second in the world after Norway. This industry is, however, adversely affected by recurring noxious phytoplankton blooms in coastal waters throughout the region. The implications are relevant to human and fish health, as well as social and economic effects. The accumulated actual annual losses in the Chilean industry, due to toxic algal blooms affecting fish farming, are greater than US $12 million. The potential losses for the industry due to recurring events are estimated to be greater than US $50 million, and these figures exclude risks for human health and life.

As aquaculture grows, there will be a need to replace fishmeal and fish oils in farmed fish diets since they are limited and have to be shared with other end-users, including components of terrestrial agriculture. Over the years, numerous research projects have shown that it is possible, when growing salmonids as carnivorous species, to partially replace fishmeal (e.g., early studies during the 1970s and 1980s successfully tested the re-use of feather meal from the poultry industry) or totally replace animal protein by plant protein without losing growth or quality. Most studies were undertaken on experimental, and not on commercial, scales.

Numerous projects are presently under way in several ICES Member Countries to better understand the use of alternative energy and protein sources for fishmeal in commercial aquaculture diets. Among these are also several EU projects that have recently been clustered to gain momentum.

Mariculture is currently conducted in coastal waters, and often competes with other activities, such as fishing, navigation, recreational activities, and conservation. These activities are all major competitors for space, as are the coastal fisheries. Coastal areas also support several species of fish that depend on the shallow waters for their feeding or reproduction. Many fish nursery areas are located in these shallow waters. Development of aquaculture may contribute to reducing the space available for these nurseries. On the other hand, mariculture may constitute a physical obstacle to fishing activities (cages, offshore longlines, etc.) and therefore contribute to protecting highly sensitive nurseries from fishing pressure (Bégout Anras *et al*., 2001). Aquaculturists also need to access local harbour facilities for their support vessels and, in some cases, this can create additional pressure on fishing vessels during unloading of their catches.

To solve spatially related competition among coastal activities, the spatial requirements for mariculture should be taken into account in the process of ICZM, in common with the requirements of other activities. Therefore, a spatial analysis of the requirements for the different users using GIS should be considered a prime objective of coastal management. Such analysis can also help to identify opportunities for further development of aquaculture in coastal waters.

Aspects of the interactions of wastes from mariculture operations with coastal ecosystems are the subject of an ongoing discussion. The waste products from cultivated species are the basis for many ecological interactions in the coastal areas. The main impact is currently encountered on the sea bottom, where an excess of organic materials, from faeces and waste food, accumulate beneath installations, thus leading to possible sediment degradation and changes in the infaunal composition. Species composition may also be affected.

As part of any monitoring programme, it is necessary to evaluate the changes in benthic fauna provoked by the deposition of wastes coming from aquaculture installations. Furthermore, the complex interactions between mariculture and fish populations should be investigated with regard to the occurrence of new pathways in food webs related to the development of mariculture, and the role of potential food available for fish on aquaculture installations (biofouling), including the attractive potential of aquaculture sites to attract fish and other organisms, such as eider ducks.

Mariculture tends to provoke negative public perceptions because of its very visible and exposed nature and owing to a general tendency to feel concern about any new intrusion on natural ecosystems, no matter how benign. It is commonly the case that the aquatic component of the coastal zone is in public ownership and subject to various uses (unlike land, which is usually under private ownership before it is developed); thus, the potential for conflict is always present, even if at a superficial level. Furthermore, inlets suitable for mariculture are almost always multiple-use areas, supporting capture fisheries, both commercial and recreational boating, and they are often places where the human tendency to prefer living in sight of the water attracts housing. It is therefore inescapable that mariculture must be considered in the context of coastal zone planning and is thus a natural component of ICZM.

The issue of escaped fish and their potential interaction with native stocks is the subject of ongoing discussion. The issues of escaped/wild fish interactions thus far addressed in the ICES community pertain solely to salmonids, which show a specific migration and homing pattern. However, new species are presently emerging in marine aquaculture, and there is an urgent need to study the potential risks associated with escapes of non-migratory species interacting with native localized populations, the number of which may exceed the native local population by orders of magnitude once the industry becomes established.

Additional comments

The above information is presented to identify issues in relation to the sustainability of mariculture, including interactions between mariculture and other users of resources in the coastal zone. Although there are a number of competing users of the coastal zone, it is important that all issues be put in proper context and that cross-sectorial management approaches that link these various competing users be addressed to achieve Integrated Coastal Zone Management.

Recommendations

ICES recommends that Member Countries that have not yet adopted Codes of Conduct (Codes of Practice) for responsible aquaculture consider the benefits that can be derived from such an international benchmarking exercise.

References

Bégout Anras, M.L., Fillon, A., Robert, S., Lagardère, F., and Lagardère, J.P. 2001. Movements of sole in coastal areas under shellfish culture influence: analysis using G.I.S. and hydrodynamic models. IV Conference on Fish Telemetry in Europe, Trondheim (Norway), June 2001. Abstract book, p. 68.

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11.4 Quantities of Chemotherapeutants used in Finfish and Shellfish Farming

Request

This is part of continuing ICES work to keep under review environmental issues relating to mariculture.

Source of the information presented

The 2002 report of the Working Group on Environmental Interactions of Mariculture (WGEIM) and ACME deliberations.

Status/background information

The preparation of a list of licensed/authorized chemicals for use in mariculture in all ICES Member Countries is difficult to achieve, but Table 11.4.1 lists chemicals used in the UK, Norway, Ireland, and Canada.

In most cases, quantitative information on the amounts of these products used is difficult to obtain, since most countries do not have a central system to record/store data. The primary exceptions are Norway and Scotland (information has been collated for southwestern Scotland for most of the last decade).

The centralized system of medicine supply in the Norwegian salmon farming industry allows comprehensive and reliable data on the usage of medicines to be collected. As a result of extensive vaccination programmes and hygienic measures, bacterial diseases now cause only minor problems. This situation is reflected in the current (2002) low consumption of antibiotics by the Norwegian salmon industry (Table 11.4.2). At present, these drugs are used mainly on broodstock fish (Figure 11.4.1). Usage of antibiotics was at a maximum in 1987 and passed through a secondary maximum in 1990. Since then, usage has declined to low levels, even though production has increased almost continuously over the last two decades.

Sea lice are still the cause of substantial losses in Norwegian mariculture and the use of parasiticides is an important element in the control of infestations. Table 11.4.3 shows that there has been a reduction in the quantities of drugs used, partly due to the introduction of the more effective emamectin benzoate.

Southwestern Scotland accounted for around 17–22 % of the total Scottish production of farmed salmon between 1991 and 1999. Data on medicine usage have been supplied by farms to the Scottish Environment Protection Agency.

Five active antimicrobial compounds were used in Scotland between 1991 and 1999 (Table 11.4.4). The total amount used per year remained relatively constant from 1991–1996 at 2600–4400 kg, but has declined steeply since then. Usage in 1999 was very low (less than 100 kg). In the period 1991–1997, the pattern of use of antimicrobial compounds changed gradually. Potentiated sulphonamides contributed a decreasing percentage (from 65 % to 5 %) of the total mass of antimicrobials used, while the percentage of amoxycillin increased from 20 % to 68 % over the same period. There were dramatic swings in the pattern of use in 1997–1999. In 1998, over 90 % of the mass used was oxytetracycline, while in 1999, only oxolinic acid was used. It is not clear whether this is as a result of greater coordination of medicine use within the industry.

The treatment dose of antimicrobial compounds differs between active ingredients. From knowledge of the standard treatment doses and durations, it is possible to calculate the weight of fish treated by each medicine each year. The total weight of fish treated has declined from 10,000–12,000 tonnes in 1991–1993, to less than 200 tonnes in 1999.

The ratio between the tonnage of fish treated with antimicrobials and the tonnage produced reached a maximum in 1992 of almost two. This ratio has subsequently declined by a factor of around 100 to very small values, and indicates that a very significant improvement has occurred in some aspects of fish health, i.e., in conditions treatable by antimicrobial compounds. This is at least partly due to the introduction of effective vaccines against furunculosis in the early to mid-1990s.

In Norway, the total amount of antimicrobials used declined from 48.6 tonnes in 1987 to 0.7 tonnes in 1997–1998. This is equivalent to 0.04–0.002 kg tonne^{-1} of production in the period 1993–1997, a reduction from 0.81 kg tonne^{-1} in 1987. Although these figures are not directly comparable since there are differences between Scotland and Norway in the antimicrobial agents used and treatment regimes, the equivalent figures for SEPA South West Area for the period 1996–1999 are 0.18–0.007 kg tonne^{-1}, a reduction from 0.69 kg tonne^{-1} in 1992.

Table 11.4.1. Chemicals used in mariculture in some ICES Member Countries.

Therapeutant group	UK	Norway*	Ireland	Canada
Antibacterials	Amoxycillin		Amoxycillin	
	Florfenicol	Florfenicol		Florfenicol
		Flumequin		
		Oxolinic acid		
	Oxytetracycline	Oxytetracycline	Oxytetracycline	Oxytetracycline
	Potentiated sulphonamides (i.e., sulphadiazine – trimethoprim)		Potentiated sulphonamides (i.e., sulphadiazine – trimethoprim)	Potentiated sulphonamides (i.e., sulphadiazine – trimethoprim, and sulphadimethoxine – ormetoprim)
	Sarafloxacin		Sarafloxacin	
Parasiticides (sea lice control)	Azamethiphos			Azamethiphos
	Cypermethrin	Cypermethrin	Cypermethrin	
		Deltamethrin		
		Diflubenzuron		
	Emamectin benzoate	Emamectin benzoate	Ememectin benzoate	Emamectin benzoate
	Hydrogen peroxide			
	Teflubenzuron	Teflubenzuron	Teflubenzuron	
Fungicides	Bronopol	Bronopol		Hydrogen peroxide
				Formalin
Anaesthetics	Tricaine methanesulphonate			Tricaine methanesulphonate

*In Norway, medicines authorized for use in agriculture may also be used in mariculture.
The substances listed are those most frequently used in 1999–2000 (WGEIM Report, 2002, Norway Country report).

Table 11.4.2. Amounts of antibiotics used in the Norwegian mariculture industry from 1996 to 2000. Quantities are given as kilograms of active component. Source: Norwegian Directorate of Fisheries.

Year	Enrofloxacin	Florfenicol	Flumequin	Oxolinic acid	Oxytetracycline	Others	Total
1996	-	64.0	97.0	844.0	19.0	19.8	1043.8
1997	-	26.5	71.4	445.5	11.8	0.5	555.7
1998	-	128.6	116.8	421.7	4.2	-	671.2
1999	-	65.0	7.0	494.0	25.0	-	591.0
2000	0.02	146.2	16.8	434.5	2.1	-	599.6

Figure 11.4.1. Antibiotic consumption from 1980 to 2000 and production of Atlantic salmon and rainbow trout. Source: Norwegian Directorate of Fisheries.

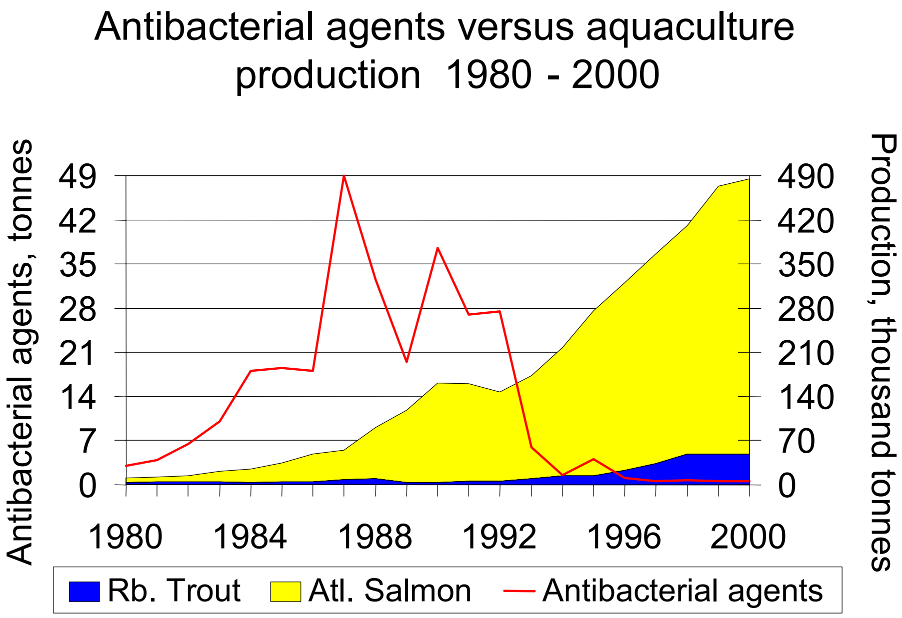


Table 11.4.3. Usage of ectoparasite and endoparasite drugs (in kg of active component) from 1996 to 2000. Source: Norwegian Directorate of Fisheries.

Year	Cypermethrin	Deltamethrin	Diflubenzuron	Emamectin benzoate	Teflubenzuron	Others
1996	-	0.1	103.0	-	547.0	968.0
1997	0	0	462.1	-	1429.7	386.4
1998	8.5	28.4	585.1	0	1186.9	128.3
1999	19.0	11.0	50.0	3.5	231.0	14.0
2000	68.7	17.6	12.4	33.6	61.5	-

Table 11.4.4. Annual production of farmed Atlantic salmon, and use of antimicrobial agents, in SEPA South West Area, Scotland, 1991–1999.

Year	Production (tonnes)	Amoxycillin (kg)	Furazolidone (kg)	Oxolinic acid (kg)	Oxytetracycline (kg)	Potentiated sulphonamides (kg)	Total (kg)
1991	8,005	602.2	65.0	272.8	705.3	1401.2	3046.5
1992	6,458	992.8	63.0	503.0	1561.4	1315.1	4435.3
1993	8,675	842.0	-	673.5	1169.5	1093.8	3778.8
1994	13,184	747.0	-	108.7	560.8	1208.6	2625.1
1995	15,777	860.3	-	468.2	721.8	750.8	2801.1
1996	17,223	2026.7	-	89.1	549.0	503.5	3168.3
1997	17,194	845.8	-	151.6	202.0	50.3	1249.7
1998	23,722	-	-	79.9	858.0	8.3	946.2
1999	23,929	-	-	16.5	-	-	16.5

Table 11.4.5. Quantities of sea lice control medicines used in Atlantic salmon farming in SEPA South West Area, Scotland, 1991–1999.

Year	Azamethiphos (kg)	Cypermethrin (kg)	Dichlorvos (kg)	Hydrogen peroxide (kg)	Teflubenzuron (kg)
1991	-	-	1914.8	-	-
1992	-	-	1573.4	-	-
1993	-	-	898.7	11,118.9	-
1994	-	-	637.0	127,569.9	-
1995	-	0.058	396.8	327,962.0	-
1996	-	0.037	382.4	193,196.2	3.8
1997	-	0.071	809.4	164,589.8	-
1998	0.3	0.055	645.3	356,470.8	-
1999	0.6	0.923	128.3	203,697.0	-

Note: Teflubenzuron is the active ingredient of an in-feed treatment that was used on a trial basis in 1996. Its use did not constitute a significant proportion of the sea lice control effort during that year, and is omitted from subsequent calculations.

Table 11.4.6. Use of medicines and parasiticides (for sea lice control) in Canada in 1999.

Antibacterials	Kg	Parasiticides	Kg
Erythromycin	6.0	Azamethiphos	10.9
Potentiated sulphonamides	1,016.2	Ivermectin	6.1
Oxytetracycline	18,345.3	Emamectin benzoate	415.0
Florfenicol	26.1	-	-
Total	19,393.6	Total	432.0

The active ingredients in the main medicines used to control sea lice in Scotland in 1991–1999 were dichlorvos, azamethiphos, hydrogen peroxide, and cypermethrin, which are all used as bath treatments (Table 11.4.5). The use of newer in-feed treatments (such as those containing diflubenzuron or emamectin benzoate) was not yet significant during the period covered by the study. To obtain an impression of the total annual usage, it is possible to calculate the volume of water treated each year, assuming compliance with standard treatment concentrations. The volumes range from 1,910,000 m^3 in 1991 to 455,000 m^3 in 1999. The volumes of water treated have declined by a factor of four, even though the weight of salmon produced was three times greater in 1999 than in 1991. Dichlorvos was used to treat the greatest volumes of water in all years except 1999.

The volume of water treated per tonne of fish produced has decreased from 240 m^3 in 1991–1992 to 19 m^3 in 1999. This indicates that, in 1999, fish were being treated at only 10 % of the frequency of treatment in 1991–1992 (assuming that stocking densities were similar in the two years). This may indicate a parallel improvement in the prevalence and/or severity of sea lice infection.

It is clear that the Norwegian and Scottish industries are showing parallel trends in reductions in the need to use parasiticides. In the period 1993–1997, the volume of water treated per tonne of production in Norway was around 18–37 m^3, and the data suggest similar usage rates in the preceding four years. Since 1997, there has been a marked change in the Norwegian industry away from bath treatments in favour of in-feed treatments. A parallel shift in practice in Scotland started to occur a few years later. It should also be noted that Norwegian farms make more extensive use of species of wrasse as cleaner fish. There are limited stocks of the appropriate species in Scottish waters, and therefore the opportunities for the Scottish industry to adopt the use of wrasse are much more restricted.

Limited data are available on the usage of medicines (and pesticides) in Canadian aquaculture for 1999 (Table 11.4.6). At this time, the annual production was around 86,000 tonnes for the east and west coasts combined.

The rate of use of antibacterial compounds is equivalent to 0.23 kg $tonne^{-1}$ of production. This is rather less than the maximum of 0.7–0.8 kg $tonne^{-1}$ observed at the peaks of usage in Scotland and Norway 10–15 years ago, but is substantially higher than the current usage rates in Norway of 0.002–0.04 kg $tonne^{-1}$. Anecdotal information suggests that antibacterial use is also relatively high in Chile.

It seems that, with respect to sea lice bath treatments and antimicrobial medicine use, the salmon industries in Norway and Scotland have followed generally the same path of development and decreasing use of medicines, with the Scottish industry following a few years behind the Norwegian. This pattern may be characteristic of maturing marine fish farming industries. The relatively high use rate (particularly of antibacterials) in the younger industry in Canada is consistent with this interpretation. Disease management strategies develop from attempted cures to preventive approaches as the industry matures, and operators gain access to better information on the priority diseases and more experience in the particular health problems affecting their industries. This interpretation suggests that procedures in the Canadian industry could be improved and the usage of antibacterial compounds reduced.

Additional comments

The above information is presented to demonstrate the types and amounts of chemicals used in mariculture.

Although the data presented are from but a few of the ICES Member Countries, there appears to be a general decline in the use of such chemicals overall.

References

Burridge, L.E. 2002. Chemical use in marine finfish aquaculture in Canada: A review of current practices and possible environmental effects. Unpublished.

Davies, I.M., and Henderson, A. 2002. Use of medicines in the Scottish fish farming industry. In prep.

12 EFFECTS OF EXTRACTION OF MARINE SAND AND GRAVEL ON MARINE ECOSYSTEMS

Request

This is part of continuing ICES work on ecosystem effects of marine aggregate extraction.

Source of the information presented

The 2002 report of the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT) and ACME deliberations.

Status/background information

The ACME reviewed and accepted several sections of the report of the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT) containing information and discussions on the effects of marine sand and gravel extraction on marine ecosystems, including quantities of material extracted, review of approaches to environmental impact assessment, and related environmental research.

The ACME decided to present the information below, summarizing this material.

12.1 ICES Guidelines for the Management of Marine Sediment Extraction

The draft guidance for the management of marine sediment extraction, which was prepared last year, had been circulated widely and comments had been received from a number of authorities including OSPAR. Following discussion of these comments at WGEXT, relevant changes were incorporated into the document, and WGEXT agreed that these should represent the final guidelines, even though WGEXT would continue to examine risk assessment and risk management approaches in the context of the management of extraction activities. Previously published work by ICES (ICES, 1992, 1994), and the more recent guidance by HELCOM (HELCOM Recommendation 19/1), were taken into account in preparing these guidelines. The new, finalized guidelines are designed to be an update of both the previous Code of Practice and the Guidelines on Environmental Impact Assessment.

The ACME expressed its appreciation for the finalization of these Guidelines and adopted the Guidelines for the Management of Marine Sediment Extraction for use within ICES. The new guidelines are appended to this report as Annex 7 and are designed to be an update to both the previous ICES Code of Practice on Commercial Extraction of Marine Sediments and the ICES Guidelines for Environmental Impact Assessment of Marine Aggregate Dredging.

Recommendations

ICES recommends that Member Countries adopt the new ICES Guidelines for the Management of Marine Sediment Extraction for use within their countries.

References

ICES. 1992. Code of Practice for the Commercial Extraction of Marine Sediments. *In* Effects of extraction of marine sediments on fisheries. Cooperative Research Report, 182: 48–50.

ICES. 1994. Guidelines for Environmental Impact Assessments of Marine Aggregate Dredging. *In* Report of the ICES Advisory Committee on the Marine Environment, 1994. ICES Cooperative Research Report, 204: 67–69.

12.2 Current Marine Extraction Activities and Results of Assessment of their Environmental Effects

The status of marine extraction and dredging activities was presented to WGEXT by participating countries. Particular emphasis was given to a review of approaches to environmental impact assessment and related environmental research.

Marine extraction activities

Almost all of the material extracted from the seabed is sand and gravel (99 % by volume), with the remainder comprising rock, maerl, shell, or shelly sand. The majority is used for construction purposes (including bulk fill), although significant amounts are also used for beach replenishment, as explained below and summarized in Table 12.2.1. The relative proportion of sand and gravel extracted by different countries varies depending on the geology and hydrodynamics of the areas being dredged and the extraction techniques used (e.g., whether the material is screened to select particular size fractions).

Extraction activity in 2001 was fairly similar to that in 2000. The Netherlands continued to extract by far the largest quantities of sand and gravel, with a total of 36.4×10^6 m^3 in 2001. Of this, more than 23×10^6 m^3 was supplied to their construction industry, 13×10^6 m^3 was used for beach replenishment projects, and a further 1.5×10^6 m^3 was exported to Belgium. The UK extracted a total of 13.7×10^6 m^3, of which 9.3×10^6 m^3 was supplied to its construction industry, 0.15×10^6 m^3 was used for beach replenishment, and 4.2×10^6 m^3 was exported (mainly to ports in France, the Netherlands, and Belgium). In Denmark, approximately 7.8×10^6 m^3 of sand and gravel was extracted, of which 5.4×10^6 m^3

Table 12.2.1. Summary table of national marine aggregate extraction activities in 2001.

Country	Aggregate extracted (m^3)	Non-aggregate extracted (m^3)	Aggregate exported (m^3)	Beach replenishment (m^3)	Maps published in 2001	New legislation	EIA initiated	EIA ongoing	EIA finished	EIA published
Belgium	1,911,000	0	0	0	No	No	Yes	Yes	No	No
Canada	0	0	0	0	—	—	—	—	—	—
Denmark	7,829,000	0	0	2,460,000	Yes	No	Yes	—	Yes	Yes
Finland	0	0	0	0	—	—	—	—	—	—
France	2,427,000	470,000	0	0	Yes	No	Yes	—	—	—
Germany	No data	No data	No data	No data	—	—	—	—	—	—
Ireland	0	No data	0	No data	No	No	No	*	No	No
Netherlands	36,400,000	282,000	1,500,000	13,140,000	Yes	—	—	—	Yes	Yes
Norway	No data	No data	No data	No data	—	—	—	—	—	—
Poland	No data	No data	No data	No data	—	—	—	—	—	—
Sweden	0	0	0	0	Yes	No	No	—	No	No
United Kingdom	13,712,000	0	4,212,500	148,000	No	No	Yes	Yes	No	No
United States	3,509,000	0	0	2,209,000	Yes	—	—	—	—	—

*A strategic study of aggregate extraction is being undertaken.

was used as construction aggregate (mainly bulk fill). A further 2.5×10^6 m^3 of sand was used for beach replenishment projects. Sand and gravel extraction from the USA, France, and Belgium in 2001 was 3.5×10^6 m^3, 2.4×10^6 m^3, and 1.9×10^6 m^3, respectively. Canada, Finland, and Sweden reported no extraction activity in 2001. Finland indicated that there was an unimplemented permission to extract 8×10^6 m^3 of sand from Helsinki Harbour, and an application had been made to extract 12×10^6 m^3 off Helsinki. The federal Canadian Government will shortly make a decision about whether to continue to develop a framework to permit and control extraction. There has been no extraction of sand and gravel for construction purposes in Sweden since 1992. As indicated above, much smaller quantities of non-aggregate material are extracted by some countries. France recorded the extraction of 0.47×10^6 m^3 of maerl and shelly sand, and the Netherlands extracted approximately 0.28×10^6 m^3 of shells.

WGEXT reviewed a draft form for submitting national data by regions through the Internet. The submission form will be tested in reporting data to WGEXT.

Review of approaches to environmental impact assessment and related environmental research

The national reports demonstrate a great deal of activity on the assessment of the effects of dredging activities. This includes individual Environmental Impact Assessments (EIAs) associated with specific applications for new dredging areas, the results of monitoring the effects of ongoing dredging, a strategic assessment study in Ireland, and relevant research projects. Belgium indicated that changes to their legislation in 1999 meant that an EIA is required for every new application, although legislation to enforce this requirement is in preparation.

There is no aggregate dredging activity in Canada at present. However, studies have been undertaken of the effects of disposal of dredged sediments and the effects of seabed trawling and clam dredging on seabed habitats. A study to define and map essential fish habitats on the Scotian Shelf was started in 2001. A pilot study has been completed. Another pilot study was undertaken in 2001, which used a QTC (Quester Tangent Corporation) seabed acoustic characterization system with high-resolution fish detection systems, to evaluate, in part, the ability of QTC to characterize and differentiate the variety of benthic habitats in comparison with high-resolution side-scan sonar data. The evaluation of data is ongoing.

Denmark reported on a study of the effect of extracting 8×10^6 m^3 of sand from the Harbour of Århus, and the preparation and publication in 2001 of a new EIA for a project to dredge a further 7×10^6 m^3 from the harbour. A number of earlier EIAs are also recorded. Denmark also reported on a number of research projects including one on the impact of dredge spill on benthos and a study to evaluate different seismic and diver techniques to develop reliable low-cost screening methods for identification of the most important benthic flora and fauna communities. The Forest and Nature Agency and the Coastal Protection Agency have also initiated a monitoring programme off the west coast of Jutland to study the effects of dredging for beach protection.

France reported on a research programme aimed at developing a better understanding of the impact of sandpits on seabed morphology in shallow waters. The aim is also to develop a methodological guide to define a number of indicators to be investigated as part of an environmental impact study, along with accepted values for these indicators. An update was also given of the results of last year's monitoring at the Dieppe Case Study site (which has been monitored since 1980), including initial findings. A further study initiated in 2002 seeks to assess the impact of marine aggregate extraction, and includes monitoring of fish in the extraction and surrounding areas, the assessment of trophic relationships between benthic and demersal fish species and benthic prey, and assessment of rehabilitation processes within the former extraction site.

The Netherlands reported on the fourth and final year's monitoring of the recovery of the benthic community on an infilled borrow pit located in 7 m of water. It was concluded that, within such a dynamic environment, the sediment recovers within one year, but it takes four years to have complete recovery of the benthic community. Another study of physical parameters in an extraction pit, in order to qualify and to quantify the ecological effects of sand extraction pits (PUTMOR), is looking at the effects of a large extraction pit on surrounding areas. Measurements are being taken of bathymetry, flow velocities, water levels, temperature, conductivity, turbidity, oxygen content, and seabed sediments. A study to improve knowledge on the relationship between different natural processes affecting benthic life was started in 2000 and continues. A study to integrate present knowledge and site-specific information in order to understand and predict the possible environmental impacts of different human activities started in 2001. Ecotope maps will be produced at a scale applicable to detailed EIAs. Ongoing EIAs have been reported for areas off the coast of South-Holland, the Cleaverbank, and off the coast of Zeeland.

The UK provided updated information on: 1) the Southern North Sea Transport Study, which is due to finish in July/August 2002; 2) the Marine Life Information Network (MarLIN project), which seeks to identify sources of marine biological data and to assess, grade, and use those data to identify distributions of biotopes and species; 3) a study on the potential for cumulative environmental effects arising from marine aggregate extraction, which is due for completion in April 2002; 4) an assessment of the rehabilitation of the seabed following marine aggregate dredging; and 5) progress with the procedural guidelines for the conduct of benthic studies at aggregate dredging sites. A number of new studies were reported, including one to develop and test hypotheses on the impact of climate change on rocky intertidal animals and plants, a scoping study to assess the applicability of a development plan for the seabed, a study assessing the utility of seabed habitat mapping for the monitoring and management of several human activities that disturb the seabed (including aggregate dredging), and a study examining the direct and indirect biological impacts of aggregate extraction in the southern North Sea.

The USA is undertaking research to produce a predictive desktop package that links the various phases of sediment plumes that arise from aggregate dredging.

Two projects funded by the European Union were reported. A study of the physical implications in time and space of large-scale extraction of marine sand (SANDPIT) seeks to assess the physical implications of large-scale marine sand extraction and to produce a handbook synthesizing scientific results and practical guidelines for sandpits, and to produce publications on sand transport in coastal areas. The second, integrated strategies for the prospecting and extraction of marine aggregates, including environmental effects (EUMARSAND), seeks to establish a European research trainee network to develop integrated strategies for the prospecting and extraction of marine aggregates, including assessment of the physical and biological impacts of dredging activities. A third EU-funded research project, SUMARE, has been reported previously at WGEXT 2001 and will provide a further report of progress next year.

12.3 Methods to Assess Localized Impacts from Aggregate Extraction on Fisheries

A presentation to WGEXT, from IFREMER, showed a significant lack of correspondence between generalized thematic maps of fish spawning grounds in the English Channel, particularly for plaice. Observing the importance placed by WGEXT in its guidelines and work generally on the protection of biologically sensitive areas and in particular for spawning fishes, the authors concluded that such information conflicts required careful examination, particularly where the assessments of specific projects were making use of such maps. The presentation suggested:

- a large uncertainty in the outlines of spawning areas in such thematic maps, and that these uncertainties had resulted in the use of presence/absence of spawning grounds instead of a measure of intensity as mapping parameters;
- that a large number of aggregate extraction applications overlapped biologically sensitive areas such as spawning grounds;
- that such sensitive areas in any event cover large areas of the seabed and, hence, avoiding such overlaps is a practical impossibility.

Furthermore, it is unlikely that new studies could rapidly resolve such uncertainties or provide significant new information, and thus the assessment of applications for aggregate extraction would have to take into account the uncertainties and make judgements of acceptable risk. Further discussion led to the following observations, detailed below.

There was some doubt that spawning grounds could be precisely located in space and time, or in terms of the nature of the sediment and behaviour of the fish stock. There is often a suggestion that there is a strong relationship between stocks of herring and localized spawning grounds. The number of spawning grounds for herring in the North Sea seems to have decreased in recent years and has shown a great deal of variability. WGEXT was uncertain of the usefulness of any project that tried to pinpoint all actual spawning grounds from recent data, though obviously specific grounds were identifiable in this way (for example, herring egg surveys have been used to identify protected areas for herring spawning in the Baltic Sea). It was suggested that, instead, it would be desirable to develop a clearer picture of potential spawning grounds, but using information on known locations (past and present) and by looking to correspondence with other physical parameters such as substrate. In the Baltic Sea, there appears to be a correlation with oxygen conditions; elsewhere, current velocity ranges may have a bearing. One suggestion was to identify areas where herring were unlikely to spawn.

In France, the concept of potential nursery grounds has been used to identify corresponding areas of biological sensitivity using actual survey data, bathymetry and sedimentology, and outline boundaries of potential coastal nursery areas have been delineated in this way for several species such as plaice, sole, dab, and bass. It has also been shown that areas of successful scallop settlement appear to have a very specific granulometry.

After further consideration, WGEXT agreed that it would be useful to attempt the following (commencing work intersessionally and refining and discussing the outcomes at its next meeting):

Employ a risk assessment approach (similar to that on risk management being developed at CEFAS) by taking about twenty species and, for each species, separating life histories into adults (feeding grounds), migrations, spawning grounds, juvenile drift, and nursery grounds. For each of these, the risk matrix would use "potential sensitivity" of the species at this stage in its life history and "actual vulnerability" to dredging operations. An attempt to undertake a deterministic calculation of the likely magnitude of the direct and indirect effects of dredging activity at each stage on the subsequent fish stock was considered worthwhile; while it would require caution, it may assist in developing a better appreciation of the scale of any likely effect, and the identification of the nature of effects which are essential to risk mitigation.

In addition, a case study of plaice spawning grounds in the English Channel should be attempted, drawing on the literature of surveys conducted in this area and any recent data that could be made available. The purpose is simply to examine the extent to which this knowledge is captured in the thematic maps, and the variability between such maps. Some comparison might then be undertaken with sediment and bed load transport maps for these areas.

Based on the above, the ACME noted that there are various approaches proposed for the establishment of methods to assess localized impacts of aggregate extraction on fisheries. It is unlikely that new studies could rapidly resolve such uncertainties or provide significant new information, and thus the assessment of marine aggregate extraction authorization applications will have to take into account the uncertainties and make judgements of acceptable risk.

13 GLOBAL PROGRAMMES

13.1 Global Ocean Observing System (GOOS)

Request

This is part of the continuing work of ICES on issues related to monitoring the marine environment.

Source of the information presented

The 2002 reports of the ICES/IOC Steering Group on GOOS (SGGOOS), and the ICES-EuroGOOS Planning Group on the North Sea Pilot Project (PGNSP), and ACME deliberations.

Status/background information

SGGOOS initiated a workshop, co-sponsored by IOC, ICES, OSPAR, the North Sea Conferences, and EuroGOOS, in September 2001 to agree on a strategy for a pilot North Sea Ecosystem GOOS project. To meet the challenges identified at the meeting, the workshop agreed to increase the efficiency and effectiveness of the use of data products from current relevant national and international monitoring, and therefore invited the national agencies responsible for monitoring of the North Sea to:

- establish a coordinated mechanism that could add value to existing activities by integrating data from various sources (physical, chemical, biological) to aid the development of an ecosystem approach;
- collaborate by means of a pilot project sponsored by ICES and EuroGOOS to demonstrate the usefulness of this approach by integrating data on oceanography and fisheries.

Further efforts will be required, in consultation with appropriate bodies, to develop a strategy for establishing and implementing the coordinated mechanism. Although considerable progress has been made recently by a variety of national agencies and through EuroGOOS on monitoring, modelling, and forecasting physical parameters, until now no attempt has been made to establish an integrated information system including ecosystem parameters for the North Sea. Such an approach would have the synergistic effect of integrating many current national activities.

The present monitoring of the North Sea is insufficient to discriminate between human impacts and natural variation for many important components of the ecosystem. There is a need for improved, integrated monitoring through coordination and harmonization of existing national and international monitoring activities, as well as through implementation of new methods and technology.

For marine ecosystems, meteorological and climatic variability are primary driving forces for ecosystem variability. Improved knowledge of the relationship between climate and changes in ecosystems would greatly assist the difficult task of distinguishing between anthropogenic impacts and natural variability in environmental assessments. A challenge will be the use of environmental data within the annual assessment cycle for fish stocks by the fisheries research and management community. Such an approach will involve the bringing together of diverse data sets and the application of new approaches to fishery assessment modelling.

The North Sea, because of the intensive work that has already been carried out in this area, is an obvious candidate for a pilot project. Developing an ecosystem approach for the management of the North Sea will need an integrated monitoring and information system and continuous updating of information, which could be seen as a North Sea ecosystem component of GOOS.

At its meeting, the ICES-EuroGOOS Planning Group on the North Sea Pilot Project (PGNSP) prepared an implementation plan for an ICES-EuroGOOS North Sea Ecosystem Pilot Project (NORSEPP) (for details, see http://www.ices.dk/reports/occ/2002/pgnsp02.pdf). The overall objective was to increase the efficiency and effectiveness of current relevant national and international monitoring systems, so as to facilitate the application of an ecosystem approach to fisheries management. The Planning Group also prepared eight specific objectives and developed a work package for each of them, in addition to suggestions for different products from the project. The focus on living resources was intended to limit the scope of the project to something achievable within a time frame of 3–5 years. If the project succeeds, its remit could be expanded to determine the usefulness of this approach as a tool for comprehensive environmental analysis in support of improved environmental assessments.

The Planning Group strongly recommended that SGGOOS take the necessary action at its meeting in April 2002 to follow up the initiative from the Planning Group. At its meeting, SGGOOS reviewed the NORSEPP implementation plan and suggested some minor changes in the content of the eight work packages developed by PGNSP. The suggestion to utilize the resources of the ICES GLOBEC office to support this project was viewed as a very good idea. SGGOOS agreed that the scope of NORSEPP should be limited to physical oceanography and fish instead of being broadened to include other ecosystem components, contaminants, etc. It was argued that the scope should be limited initially to ensure success and that the fisheries component is, after all, an ICES niche. It was also reiterated that the pilot project would pull together existing monitoring activities, and not create new ones. A potential European Union Framework 6 Programme (FP6) Integrated Project was discussed and it was recommended to submit an "Expression of Interest" to the EU FP6 in order to help formulate the scientific priorities of the first call in FP6. NORSEPP is considered an ideal candidate for an Integrated Project under the framework

The ACME noted that people active in GOOS are becoming increasingly concerned about the very slow rate of implementation of GOOS initiatives. Regional development of GOOS may help to capture community and government interest provided that it involves the creation of GOOS-labelled activities such as pilot demonstrator projects like NORSEPP and global system components whose value can be demonstrated.

14 DATA HANDLING

14.1 Handling of Data on Contaminants in Marine Media

Request

Item 4 of the 2002 Work Programme from the OSPAR Commission: to carry out data handling activities relating to:

4.1 contaminant concentrations in biota and sediments;

4.2 measurements of biological effects;

4.4 data on phytobenthos, zoobenthos and phytoplankton species.

Contract from the Helsinki Commission (HELCOM) to serve as a Thematic Data Centre for the Cooperative Monitoring of the Baltic Marine Environment (COMBINE) Programme data for a three-year period beginning on 1 July 1998, and extended for a second three-year period.

Contract from the Arctic Monitoring and Assessment Programme (AMAP) to serve as Thematic Data Centre for the marine component from 1998–1999, extended to 2000–2001.

Source of the information presented

Progress report from the ICES Marine Data Centre and ACME deliberations.

Status/background information

14.1.1 Future data structure for environmental data within the ICES Marine Data Centre

Based on the plan endorsed by the ICES Bureau for the database development within the ICES Secretariat, the work outlined in the 2001 ACME report has been continued. The plans are as follows:

To provide user-friendly, seamless, and dynamic access to all ICES products (data, documentation, and information) associated with both the scientific and administrative sides of the Secretariat. This goal will be met by:

a) employing web technology to provide the interface between the Secretariat and users (primarily marine scientists concerned with ICES activities);

b) developing as far as possible, and desirable, common database solutions to meet all Secretariat data, information, and administrative needs;

c) instigating an active training programme to raise the capability of all Secretariat members, in particular those currently concerned with database activities, in order to enhance the availability of resources;

d) ensuring that all future recruitment of staff focuses on the need for relevant IT skills;

e) employing a Web/database manager to provide the necessary technical and managerial skills.

The ICES Marine Data Centre has reviewed options for a common policy on database software and agreed that future databases in the Secretariat will be developed in MS SQL SERVER. The Secretariat is now building expertise in this software and is using it, for example, in the Database Trawl Surveys (DATRAS) and environmental contaminants database projects. ICES investigated three general packages: DB2, ORACLE, and MS SQL SERVER. While all these packages seemed appropriate for the tasks, as suggested by trial and reading of documentation, MS SQL SERVER was chosen as it seemed to have lower establishment costs, and also because the Secretariat already possessed some experience with this software. MS SQL SERVER is used by a wide range of laboratories, but not all of those with which the Secretariat cooperates.

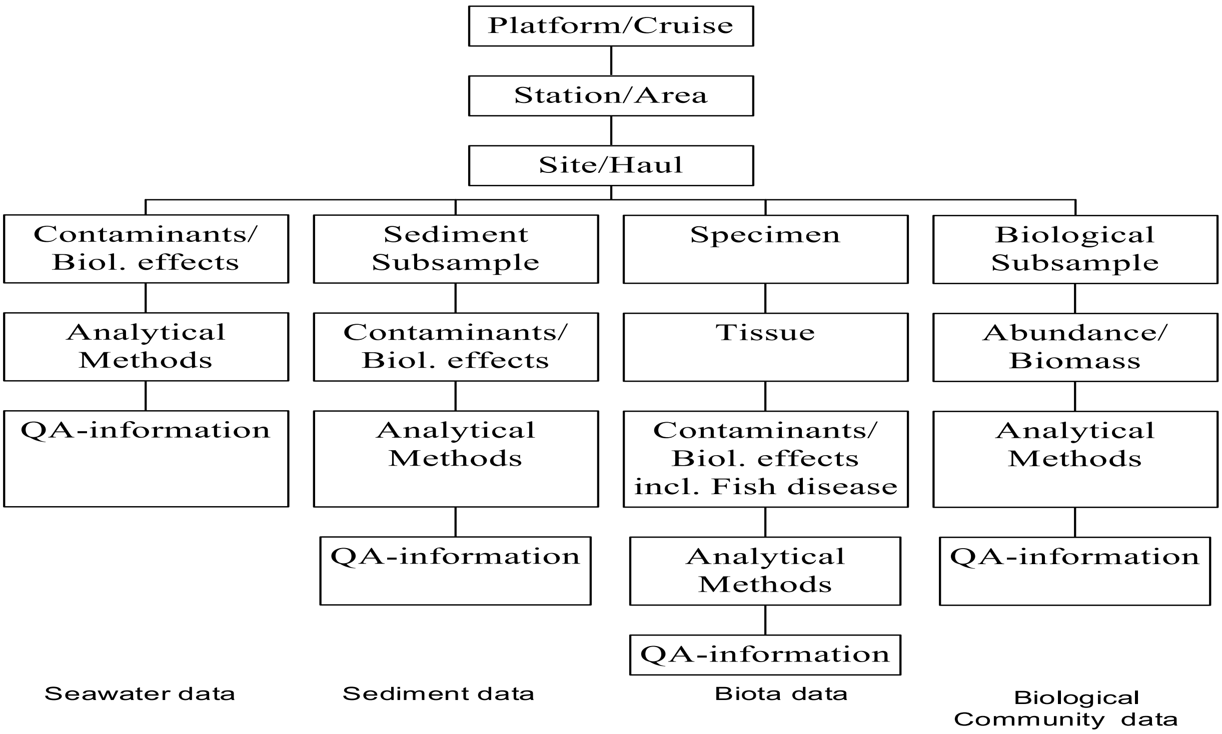
Several limitations in the present structure of the environmental database held in ICES and the growing requests to integrate information from several databases has led to the initiation of developing a new data structure for the ICES environmental databases, as well as all the databases held in ICES. The extent to which this integration will develop has not been decided, but several changes will occur in order to improve the functionality and the data products.

The obvious limitations in the present Environmental Data Reporting Format, such as field size, will be solved. There is also a need to change some inconsistencies in the present data structure, including the lack of a depth cycle record for sediment and sea water. Finally, the need to include multiple QA information will be included in the new data structure.

The ability to be able to link information on contaminants in, for example, a fish specimen to information on biological effects and fish disease in the same specimen will furthermore be included in the structure of the database. A simplified overview of the new data structure is presented in Figure 14.1.1.1.

The integration of data on biological communities (phytoplankton, zooplankton, phytobenthos, and zoobenthos) is made possible as the databases on these parameters follow the same structure from platform/cruise down to site/haul.

Figure 14.1.1.1. Simplified diagram of the future structure of the environmental database in ICES.



The development of a more flexible reporting format than the present fixed format is under consideration, but at present it is not clear which kind of format will be chosen. Regardless of this development, it will still be possible to submit data in the old format for several years ahead.

14.1.2 Databases on contaminants in marine media, biological effects of contaminants, fish diseases, and biological communities

The environmental data held by the ICES Marine Data Centre include the following types:

1) contaminants in marine invertebrates, fish, birds, and mammals (approximately 418,000 records);
2) contaminants in sea water (approximately 283,000 records);
3) contaminants in marine sediments (approximately 80,000 records);
4) biological effects of contaminants (approximately 4,000 records);
5) fish disease prevalence (approximately 80,000 records);
6) biological communities (phytoplankton, zooplankton, phytobenthos, and zoobenthos) (only a few submissions have been received so far).

The number of data submissions remains lower than expected based on commitments to OSPAR, HELCOM, and AMAP. Nonetheless, the number of submissions of data on contaminants in biota has been rather high during the past year, primarily related to the recent AMAP assessment of data on persistent organic pollutants (POPs) and heavy metals. The status of submissions of environmental data to the ICES Marine Data Centre can be found on the website at: http://www.ices.dk/env/index.htm.

14.1.3 Major data products

The ICES Marine Data Centre has provided data to the European Environment Agency (EEA) based on a requested access to raw and integrated data collected in OSPAR and HELCOM monitoring programmes from 1985 to the present. The data sets handled were: 1) harmful substances in biota; 2) harmful substances in sediment; and 3) eutrophication-related parameters in water. These data are intended to be used to prepare indicator fact sheets, and all the raw data utilized in the derivation of the indicators will be published by the EEA Water Topic Centre.

Several large data extractions have been carried out during the past year, e.g., in connection with the work of the ICES/AMAP Study Group for the Assessment of AMAP POPs and Heavy Metals Data (SGPOP) and the OSPAR request on an assessment of existing data on hazardous substances in the ICES area.

14.2 Handling of Nutrient Data for the OSPAR Commission

Request

Item 4 of the 2002 Work Programme from the OSPAR Commission: to carry out data handling activities relating to:

4.3 the implementation of the Nutrient Monitoring Programme.

Source of the information presented

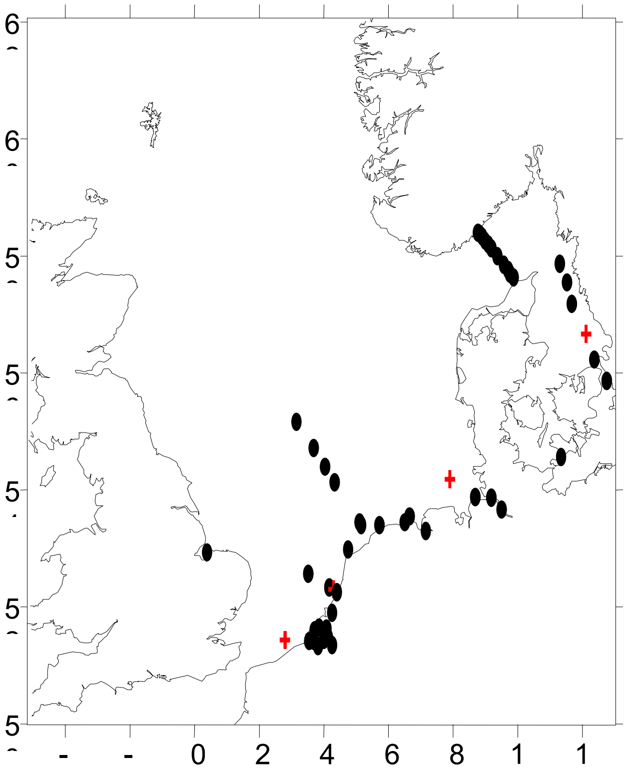
Report from the ICES Oceanographer and ACME deliberations.

Status/background information

The situation as presented in some detail in Section 15.2 of the 2001 ACME report remains virtually unchanged. Consequently, an increasing number of relevant nutrient data sets from almost all OSPAR countries are still not available. There are a number of reasons for this, the main one being that most countries have not provided any new data since the last report. In some cases, data have been received, but the work of transferring them to the database has not been completed. This particularly applies to some additional data submissions triggered by a large request from the EEA for nutrient data and other data for the period from 1980 to the present. Unfortunately, most of these data, including the supporting metadata, have been of poor quality. Discussion with the data providers in order to improve quality is still ongoing some six months after the original submissions.

The Data Centre was unable to meet the request of the EEA in full because their requirement was mainly for data from stations that had been regularly and frequently sampled in each season over a period of years. Figure 14.2.1 shows the distribution of the stations in the ICES database for the 1990s that were potentially of use to the EEA for trend analysis. These represented only a very small fraction of the stations that are being used in the analysis of eutrophication status for OSPAR.

Figure 14.2.1. Distribution of North Sea stations repeated more than 100 times during the 1990s. Circle: >100≤250 stations in 1990s; cross: >250 stations.



In recent months, two nutrient data sets acquired from research vessel cruises have been provided. Both are "donations" from retiring scientists. One of these consists of some 8,000 nutrient stations from the North Sea during the period 1980–2001. About 10 % of these data are already in the ICES database and some of them have been obtained during International Bottom Trawl Surveys (IBTS). The existence of these data has been known for quite some time. Once they have been processed and entered into the database, revisions of all products already produced for both OSPAR and ICES purposes will be required. The second data set was received via the British Oceanographic Data Centre and consists of 12,000 stations from the Bristol Channel/ Severn estuary region for the 1960s, 1970s, and 1980s. None of these data have previously been released and their eventual introduction into the database will greatly enhance data coverage in what has been a data-sparse area. Clearly, the backlog of data for inclusion in the database is now quite considerable.

14.3 Advice and Standard Data Products for Developing the Common Procedure for Identification of the Eutrophication Status of the Maritime Area

Request

Item 3.1 of the 2002 Work Programme from the OSPAR Commission: Provide assistance in the preparation of data products based on the relevant data series available in ICES databanks, for inclusion in an assessment report of the eutrophication status of the OSPAR maritime area.

Source of the information presented

Report from the ICES Oceanographer and ACME deliberations.

Status/background information

Section 11 of the 2001 ACME report presented the results of analysis work undertaken at the request of OSPAR on this issue during 2001. This work in particular showed the multi-annual trends in concentrations of the major dissolved inorganic nutrients, and attempted to put them into a climatic context. This work had previously been presented to OSPAR through its Eutrophication Task Group (ETG).

There has been no further analysis undertaken beyond that presented in last year's report. However, it is useful to recall that ACME reacted to this study by repeating a recommendation that it had made several times before, namely, that the estimation of pools and fluxes of water and nutrients should be conducted in further development of the OSPAR Common Procedure. The ACME view then and now is that such a study will allow an ecologically meaningful comparison between nutrient inputs and fluxes in the receiving coastal water masses.

The above recommendation has not been acted upon, mainly because an ICES subsidiary group to take this issue forward has not been identified. However, the ACME notes that considerable work concerning the calculation of nutrient budgets is being developed within the framework of LOICZ (Land-Ocean Interactions in the Coastal Zone). In particular, the LOICZ Modelling Team advocates that a single general approach be used for building budgets to describe the coastal marine environment, in order to maximize comparability among the budgets. LOICZ has already developed budgets for dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) for locations in areas such as the Iberian coast, the Celtic Sea, and the North Sea. LOICZ has also developed nutrient budgets for many coastal areas of the Baltic Sea. Their budget calculation includes water flow and mixing, as defined by the water and salt budgets, and an additional term representing the fluxes of nutrients, which describes net uptake or release of nutrients within the system. These nutrient fluxes are non-conservative as nutrients do not exactly follow the flux pathways of water and salt. An overview of the LOICZ budgeting procedure is given below.

Need for further research or additional data

The work of the LOICZ Modelling Team should be further reviewed with a view to ascertaining its usefulness in support of the OSPAR Common Procedure. Relevant ICES Working Groups should undertake this review in consultation with the LOICZ community.

Overview of the LOICZ Biogeochemical Budgeting Procedure

This material has been adapted from http://data.ecology.su.se/mnode/Methods/OVERVIEW.HTM.

Budgeting the fluxes of materials to and from a system may be undertaken by many different procedures, but there are inherent similarities among these procedures. Basically, a budget describes the rate of material delivery to the system ("inputs"), the rate of material removal from the system ("outputs"), and the rate of change of material mass within the system ("storage"). Some materials may undergo internal transformations of state which lead to the appearance or disappearance of these materials. Such changes are sometimes referred to as "internal sources or sinks" (Figure 14.3.1).

It is also useful to describe such a budget in terms of a simple equation:

$$dM/dt = \Sigma inputs - \Sigma outputs + \Sigma[sources - sinks] \qquad (1)$$

where "dM/dt" represents the change of mass of any particular material in the system with respect to time (and sources and sinks are internal sources and sinks). It is often assumed that $dM/dt = 0$; that is, the system mass is assumed to be at steady state. While this assumption is not necessary, it simplifies a discussion of equation (1) and will be used in the math laid out here.

Many so-called budgets deal with only one set of the fluxes in equation (1) (e.g., inputs); in some cases, only a subset of the inputs (e.g., inputs from land into a bay, without consideration of the oceanic inputs) is considered. In the terminology applied here, such a description without an attempt to estimate each of the terms in equation (1) is not a budget. Many different approaches can be taken to budget a particular system. The LOICZ Biogeochemical Modelling Guidelines (Gordon *et al*., 1996) advocate that a single, general approach be used for building budgets to describe the coastal marine environment, in order to maximize comparability among the budgets. Basically, this approach has three parts:

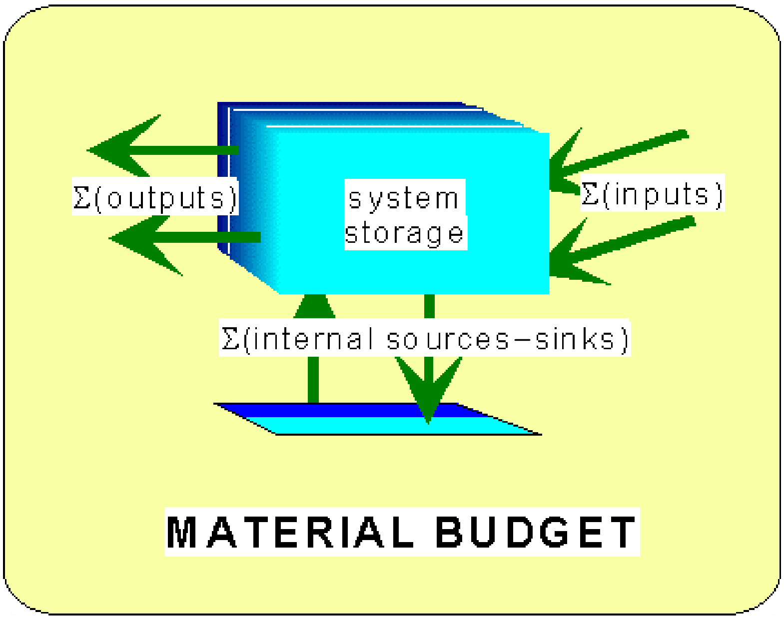
1) How fast does water move through the system of interest?

2) How fast do the nutrient elements carbon, nitrogen, and phosphorus move with the water?

3) What can be inferred about system performance by discrepancies between the movement of water and the movement of nutrients?

Consider a coastal water body which is of interest. The rate of water exchange between that system and adjacent

Figure 14.3.1. Generalized diagram characterizing material budgets.



systems is estimated by one of several procedures. The simplest procedure to describe water exchange in many coastal marine systems is the construction of combined water and salt budgets for those regions. Water flows into the system from land; water is gained and lost through precipitation and evaporation. If it is assumed that the volume of the system (averaged over time, to remove short-term variations like tide height) remains constant, then the net water outflow balances the water inflow. In addition to this budget for water itself, a salt budget can also be established. Water mixes back and forth between the system of interest and adjacent systems. Each of the water inputs and outputs described by the water budget and described by the mixing has a characteristic salinity. Water and usually salt in a system can be assumed to have no internal sources or sinks. That is, the inputs and outputs just outlined account for the water and salt budgets. The term for internal sources and sinks therefore becomes 0 in equation (1), and the budget simply describes water exchange. This combined water and salt budget does not provide a dynamic, quantitative understanding of the processes controlling the characteristics of water exchange in a particular system, but it is often a quick and simple way to describe the exchange.

Reference

Gordon, Jr., D.C., Boudreau, P.R., Mann, K.H., Ong, J.E., Silvert, W.L., Smith, S.V., Wattayakorn, G., Wulff, F., and Yanagi, T. 1996. LOICZ Biogeochemical Modelling Guidelines. LOICZ Reports and Studies, 5: 1–96.

14.4 Data Products on Nutrients in the Baltic Sea

Request

Item 3 on the 2002 requests from the Helsinki Commission, as stated below.

Source of the information presented

Progress report from the ICES Marine Data Centre and ACME deliberations.

Status/background information

The second meeting of the HELCOM Monitoring and Assessment Group (MONAS) recognized nutrients as essential eutrophication indicators. Several of the HELCOM Contracting Parties and observer organizations were requested to develop test cases on such indicators. ICES was requested, in cooperation with Denmark, to consider the possibilities to meet the requirements to:

- download the DAS program from Stockholm University and make maps of the geographical distribution of winter inorganic concentrations and summer TN and TP concentrations in the whole Baltic Sea region;
- make plots from representative stations of the measurements in relation to average seasonal variation;

- analyse the trends of winter nutrient concentrations at representative stations.

A test version of a website that covers some of the responses to this request can be found on the web page: http://www.ices.dk/ocean/asp/helcom/helcom.asp. The inventory has been developed as a collaborative effort between the Danish National Environmental Research Institute and the ICES Marine Data Centre.

Contact has been made with Stockholm University concerning the use of the DAS program to produce maps on nutrient concentrations. There seems to be a basis for cooperation between Stockholm University and the ICES Marine Data Centre concerning this issue.

This test version should be regarded as the first trial version, which contains only the basic outline of the web inventory. The inventory will, however, be developed according to the request received from HELCOM MONAS and other bodies. Comments and suggestions on this test inventory are welcomed and should be directed to the ICES Marine Data Centre (joergen@ices.dk or janus@ices.dk).

Guide on how to use the inventory

The first page consists of a map of the Baltic Sea from which the user can make selections of parameters, the number of measurements, etc. Figure 14.4.1 shows a screenshot of this page.

This example shows the station map based on the choice of more than 20,000 measurements on each station. You can choose which stations the map should show by entering a lower limit for the amount of data available on the station and by selecting the parameter type to which the criteria should be applied. Click “redraw” to update the map according to the selections. Hover the mouse above a station to view the station name. Click on the stations to obtain statistical information about the data available and to view time series and seasonal mean plots. Click “List stations” to view a list of all the HELCOM monitoring stations.

By clicking on one of the stations, the system displays a table containing information on the number of measurements, and the number of years with data for each parameter for that station. Figure 14.4.2 shows a screenshot of this table.

The table (Figure 14.4.2) shows the various parameters measured on this HELCOM station in the first column. The second and third columns list the total number of measured values and the number of years for which the parameter has been measured. If there are data (winter values) in two or more years, the fourth column contains a link to a smoothed time series plot of the winter values. If there are data during the past ten years, the fifth column contains a link to a seasonal mean plot of data since 1979. You can choose which year (last ten years) you want to plot together with the mean. Only years with data appear in the combo-boxes.

The figure below this table (obtained by scrolling downward) shows the data density, i.e., the number of measurements per year of each parameter versus time. Figure 14.4.3 shows a screenshot of such a plot.

By clicking on the **Jan+Feb Mean** in the table (Figure 14.4.2), a time series plot of the selected parameter is displayed. One example is shown in Figure 14.4.4.

The ACME recognized that this software was at an early level of development and members could foresee a number of expansions to it, including overlay facilities, which are offered in most GIS systems. The ACME, however, cautioned against developing this system too rapidly, considering that priority must be given to updating and improving the quality of the HELCOM data sets, for which much work remains to be done.

14.5 Handling of Biological Community Data

Request

Item 4 of the 2002 Work Programme from the OSPAR Commission: to carry out data handling activities relating to:

4.4 data on phytobenthos, zoobenthos and phytoplankton species.

Source of the information presented

Progress report from the ICES Marine Data Centre and ACME deliberations.

Status/background information

The Biological Community Data Reporting Format was issued in May 2001, after several years of development and an extensive comment period. Several small corrections have subsequently been made based on feedback received from users of this reporting format. Only one laboratory has so far submitted biological community data to the ICES Marine Data Centre. The reasons for this disappointing lack of submissions of data on biological communities are unknown.

Comments and questions concerning the reporting format for biological community data, as well as the Environmental Data Reporting Format, are welcomed and can be submitted using the ICES Forum, which can be found on the website at:
http://www.ices.dk/env/index.htm.

Biological community data from the former HELCOM data bank are in the process of being included in the ICES database and it is assumed that these older data

Figure 14.4.1. Screenshot of the entry page for the HELCOM inventory of hydrographic and hydrochemical data in the Baltic Sea.

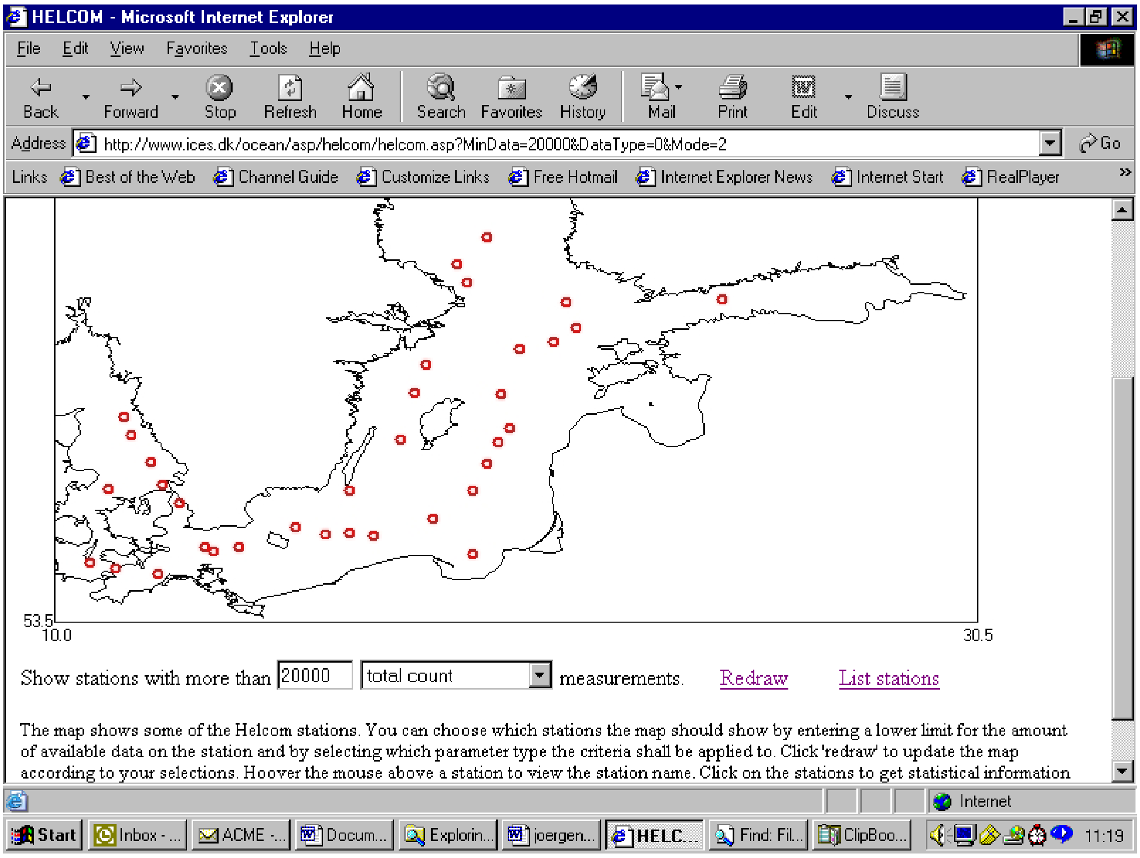
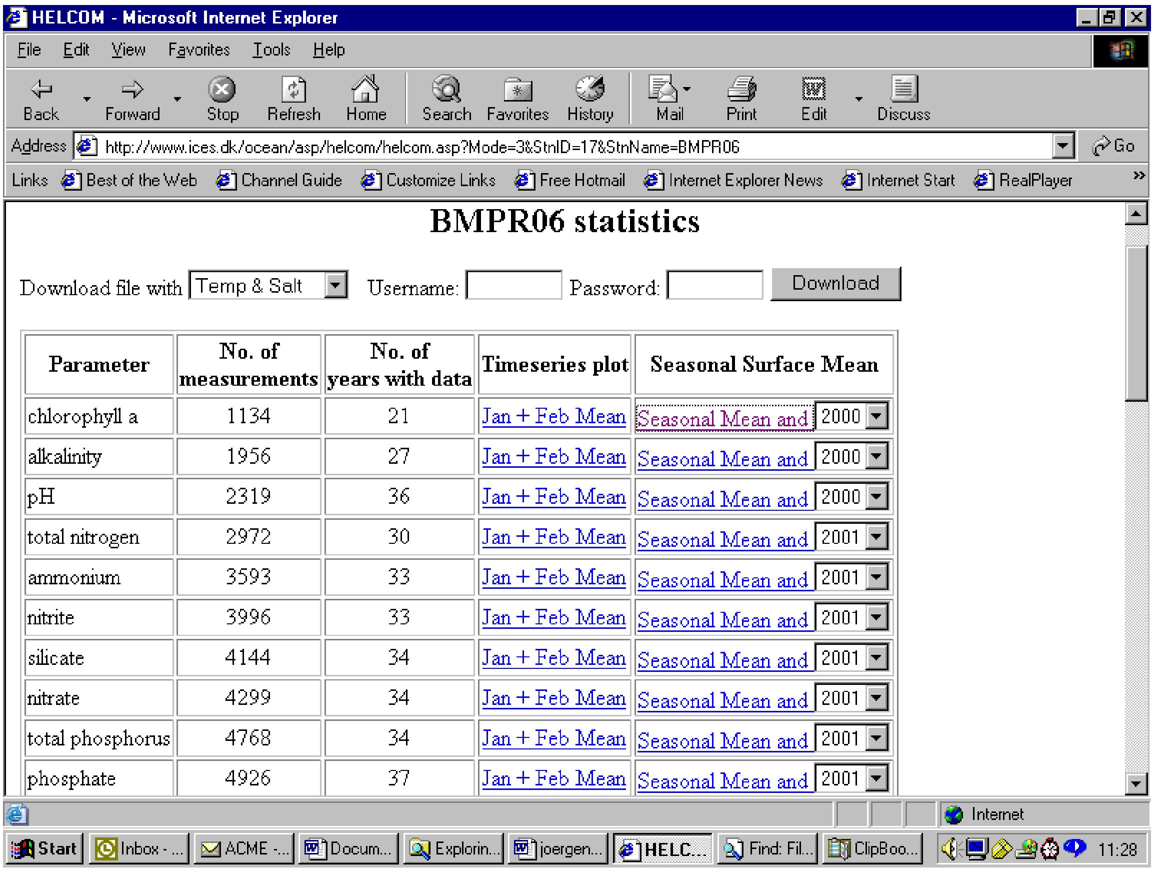


Figure 14.4.2. Screenshot of a table containing the statistics for a selected station (obtained by clicking on a station on the map).



Parameter	No. of measurements	No. of years with data	Timeseries plot	Seasonal Surface Mean
chlorophyll a	1134	21	Jan + Feb Mean	Seasonal Mean and 2000
alkalinity	1956	27	Jan + Feb Mean	Seasonal Mean and 2000
pH	2319	36	Jan + Feb Mean	Seasonal Mean and 2000
total nitrogen	2972	30	Jan + Feb Mean	Seasonal Mean and 2001
ammonium	3593	33	Jan + Feb Mean	Seasonal Mean and 2001
nitrite	3996	33	Jan + Feb Mean	Seasonal Mean and 2001
silicate	4144	34	Jan + Feb Mean	Seasonal Mean and 2001
nitrate	4299	34	Jan + Feb Mean	Seasonal Mean and 2001
total phosphorus	4768	34	Jan + Feb Mean	Seasonal Mean and 2001
phosphate	4926	37	Jan + Feb Mean	Seasonal Mean and 2001

Figure 14.4.3. Screenshot of the temporal distribution of the data (data density) on the station selected according to the different parameters. This screenshot is only a part of the display—the other parameters can be found by scrolling.

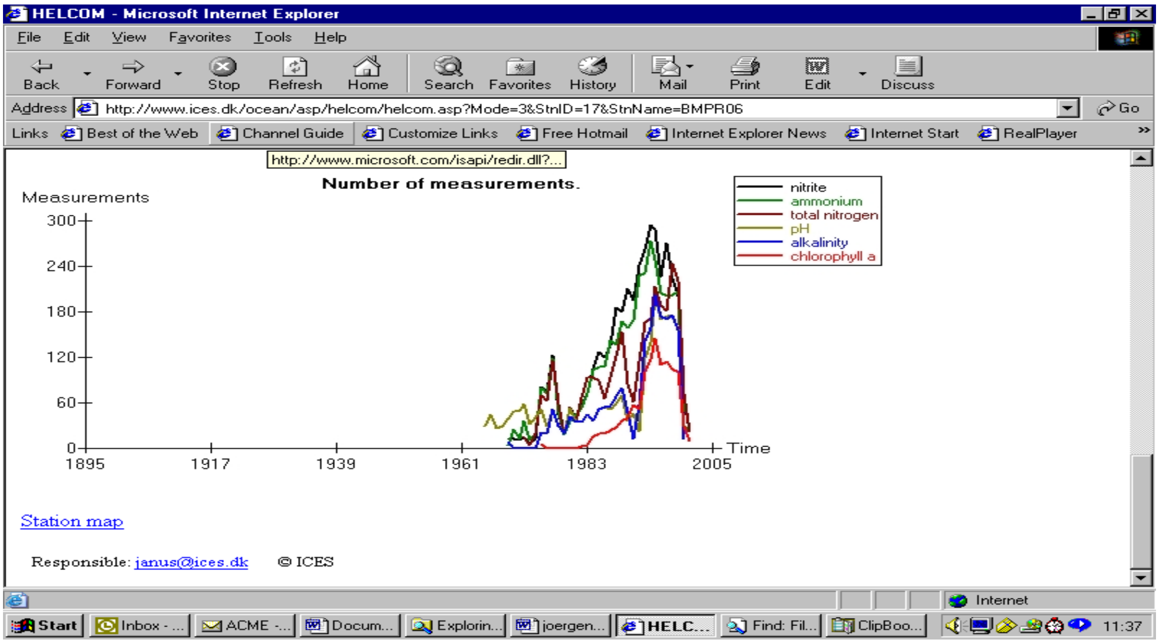
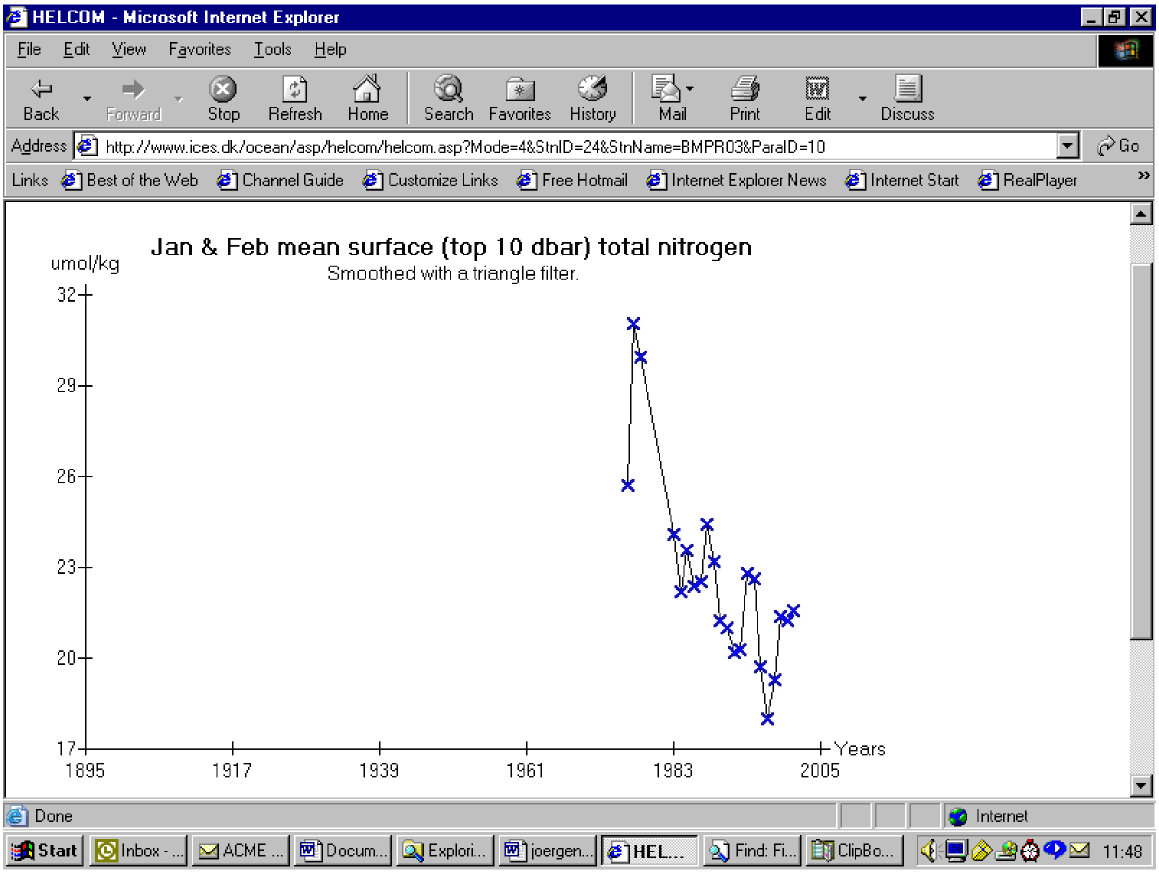


Figure 14.4.4. Screenshot of a time series plot of mean winter concentrations of total nitrogen at the station selected.



will be transferred to the database by early 2003. These data will, together with new submissions, be used as test data sets for the development of new data products.

In this connection, the ACME agreed that the need to complete the ICES/IOC Checklist of Phytoplankton and other Protists remains a matter of urgency. The preliminary checklist has been prepared, but there are some incompatibilities with other relevant checklists in terms of taxonomy and format. The ICES/IOC Phytoplankton Checklist should be complete after review and additions from other checklists available on European waters, including those relevant to harmful algal species. The final product will be a checklist with suitable nomenclature for database inclusion. The combined, merged checklist for phytoplankton will be then handed over to the ICES Marine Data Centre for the control of the format.

Recommendations

ICES recommends that Member Countries, particularly those that are also OSPAR Contracting Parties, submit their data according to the Biological Data Reporting Format <u>or</u> report to the ICES Marine Data Centre if they have difficulties in applying the format.

14.6 Development of Reporting Format for Biological Effects Measurement Data

Request

Item 6 of the 2000 Work Programme from the OSPAR Commission.

Source of the information presented

Progress report from the ICES Marine Data Centre, the 2002 report of the Working Group on Biological Effects of Contaminants (WGBEC), and ACME deliberations.

Status/background information

OSPAR has requested ICES to develop a reporting format that covers the new biological effects measurements that are included in the Joint Assessment and Monitoring Programme (JAMP). The list of measurements in relation to biological effects has been considered by the Working Group on Biological Effects of Contaminants (WGBEC) during its meetings in 2000 and 2001. WGBEC was asked to consider whether this list is appropriate for inclusion in the reporting format and whether any relevant and applicable measurements, data parameters, or metadata are lacking on this list. The drafting of a detailed reporting format has, however, been dependent on the finalization of the Biological Effects Quality Assurance in Marine Monitoring (BEQUALM) project, which is testing the use of the methods and determining QA protocols.

A draft of the detailed reporting format for biological effects measurements in relation to biota, sea water, and sediment was presented to WGBEC during its meeting in 2002. The participants in WGBEC were asked to review the parts of the reporting format that covered their field of expertise.

WGBEC recommended that the reporting format should also include PAH metabolites and lysosomal stability. These techniques have now been included based on inputs from the relevant members of WGBEC during and after the meeting. In order to facilitate the finalization of the reporting format, the Chair of WGBEC encouraged the various experts to act as reviewers and contact persons in this process, and a roster of experts who accepted to act as contact persons was agreed.

WGBEC expressed the need for a continuous update of the reporting format in accordance with the development and acceptance of new biological effects measurements in the future. Such an update should take place every second year.

The reporting format for biological effects measurements will be finalized before the end of 2002 and will be integrated into the general restructuring of the data within the ICES environmental databases.

ANNEX 1: AGGREGATION PERIOD AND WEIGHTED LOESS

1 INTRODUCTION

This annex considers the weighted LOESS smoother with weights calculated from the within-year variance (see Uhlig, 2001). The within-year variance can be considered as an estimate which includes not only sampling variance and environmental variance, but—apart from constant bias—also the analytical variance, and it can be used to estimate the uncertainty of the annual index. It is assumed that this index is an annually aggregated mean value, e.g., the mean of measured concentrations or the annual load (which in many cases can be considered as a mean value of transport figures). If the uncertainty weights are based on the within-year variances, the comparison with the actual residual variance of the LOESS smoother allows one to examine whether or not the underlying model is consistent with the empirical result. In this annex, it is shown that random fluctuations of the seasonal cycle may highly affect the actual residual variance, and it is further shown that an appropriate selection of the aggregation period may highly affect the performance of the trend detectability.

In case of significant differences of the within-year variances and under the assumption that there is no other source of uncertainty, the standard deviation of the arithmetic mean may be calculated $\sqrt{\frac{s_t^2}{n_t}}$, and the corresponding uncertainty weight equals $u_t = \frac{n_t}{s_t^2}$. The residual variance of the weighted smoother is defined

$$s_{error}^2 = \frac{1}{df_{error}} SS_{error} = \frac{1}{df_{error}} \sum_{t=1}^{n} u_t \left(y_t - z(x_t)\right)^2 ,$$

where $df_{error} = n - tr(2S - S'USU^{-1})$ and U denotes the diagonal matrix with entries u_t.

In case of uncertainty weights $u_t = s_t^2 / n_t$, the variance of the arithmetic mean of year t can be estimated $\frac{s_t^2}{n_t} = \frac{1}{u_t}$. Then the covariance matrix of Y equals U^{-1}, and df_{error} equals the mean value of SS_{error}:

$$\begin{aligned} E[SS_{error}] &= E\left[Y'(I-S')U(I-S)Y\right] = tr\left[(I-S')U(I-S)U^{-1}\right] \\ &= tr(I) - 2tr(S) + tr\left(S'USU^{-1}\right), \end{aligned}$$

Therefore, the theoretical mean of the residual variance s_{error}^2 equals 1, if the following assumptions hold:

- $Var[Y_t] = \frac{s_t^2}{n_t}$ for all t (neglecting estimation errors of the within-year variance),
- stochastic independence of observations, and
- smooth underlying trend.

Under these assumptions, the distribution of SS_{error} can be approximated by the chi-squared distribution with df_{error} degrees of freedom. Therefore, if SS_{error} exceeds the 95 % quantile of the chi-squared distribution with df_{error} degrees of freedom, it can be concluded that either the model assumptions do not hold or the estimated standard deviations s_t do not comprise all sources of uncertainty.

2 CONSEQUENCES OF A TEMPORAL FLUCTUATION OF THE SEASONAL CYCLE

If the start and end times of the seasonal cycle are randomly fluctuating, the stochastic behaviour of the annual mean can be different from standard assumptions. In order to explore this effect, a simulation study with 5,000 runs for different settings of the following two-seasons model (assuming a year with 360 days) was performed. Assume that the middle of the winter season m_i is fluctuating around the beginning of the year, and assume that m_i is Normally distributed with a standard deviation of two months. Assume further that the winter season starts two months (= 60 days) before m_i and ends two months after m_i so that the seasons expressed in days are as follows (Table A1.2.1):

Table A1.2.1. Definition of summer and winter season. Length of winter season = 120 days. Length of summer season = 240 + $m_2 - m_1$.

Year	End of winter = Start of summer	End of summer = Start of winter
1	m_1+60	m_2+360−60
2	m_2+360+60	m_3+2x360−60
:	:	:
i	m_i+(i−1)x360+60	m_{i+1}+ix360−60
:	:	:

Because of $m_i \sim N\left(0, 60^2\right)$ the length of the summer season in year i is the difference between two truncated Normally distributed random variables. The length of the winter season is constant (120 days). Let μ_W denote the concentration mean of the winter season and μ_S that of the summer season, respectively. The corresponding standard deviations are denoted σ_W and σ_S. Assume further that the weights for the LOESS smoother are derived from the within-year variance, disregarding any seasonality. The following Tables A1.2.2 and A1.2.3 contain the mean and standard deviation of the residual variance s^2_{error}. The last row contains the probability that the test statistic $s^2_{error} df_{error}$ exceeds the critical value of the corresponding chi-squared distribution at the 5 % level. The parameters are calculated for different ratios $\frac{\mu_W}{\mu_S}$, assuming that $\frac{\sigma_W}{\mu_W} = \frac{\sigma_S}{\mu_S} = \frac{1}{3}$. A relative standard deviation of 1/3 is relatively high for many nutrient time series, but relatively low for many organic compounds and heavy metals. All calculations are performed for a time series of monthly data measured over ten years. Table A1.2.2 shows the results for the aggregation period January–December.

It turns out that, for the setting used here, considerable inconsistency between within-year variance and between-year variance, expressed by the residual variance, can appear. The residual variance derived from the LOESS smoother can be much higher than expected from the within-year variance, and the consequence is that for these types of setting the determination of uncertainty weights by the within-year variance is not appropriate. However, if the arithmetic mean is not calculated over the calendar year, but from July to June, results are completely different (Table A1.2.3). In this case, the residual variance is lower than one, and the critical value will (almost) never be exceeded.

It can be concluded that an appropriate choice of the calculation period is crucial for the performance of the monitoring programme, if there is a temporal drift of the seasonal cycle. This holds not only for the LOESS smoother with uncertainty weights, but also for the unweighted LOESS smoother.

A more general model for the seasonal cycle

In order to obtain a better understanding of the impact of the seasonal cycle, consider the following more general description of the two-seasons model. Let a_i denote the start time of the summer season and b_i the start time of the winter season in year i, respectively (expressed in days of a year with 360 days). Assume that both variables are random variables with mean values $\mu_a + (i-1)\times 360$ and $\mu_b + (i-1)\times 360$, and variances σ_a^2 and σ_b^2, respectively. Assume further that the correlation of start and end time of the summer period, a_i and b_i, is denoted by ρ_S, whereas the correlation of start and end time of the winter period, b_{i-1} and a_i, is denoted by ρ_W. Assume finally that the start of the summer period in year i falls in the first half of year i, whereas its end falls in the second half of this year. Under these assumptions, the length of the summer season, $b_i–a_i$, is a random variable with mean $\mu_b–\mu_a$ and variance $\sigma_a^2 + \sigma_b^2 - 2\rho_S\sigma_a\sigma_b$. The length of the winter season, $a_i–b_{i-1}$, is a random variable with mean $360–(\mu_b–\mu_a)$ and variance $\sigma_a^2 + \sigma_b^2 - 2\rho_W\sigma_a\sigma_b$.

Table A1.2.2. Impact of a temporal drift of the seasonal cycle; aggregation from January to December. $\frac{\mu_W}{\mu_S}$ denotes the ratio of the mean concentration of the winter to the respective mean in the summer. Calculations are based on 1000 simulation runs for each setting. The actual significance limit refers to the probability that the residual variance exceeds the critical value derived from the chi-squared distribution.

Parameter	No seasonality	$\frac{\mu_W}{\mu_S} = 2$	$\frac{\mu_W}{\mu_S} = 4$	$\frac{\mu_W}{\mu_S} = 0.5$
Mean of residual variance (s.d. in brackets)	1.13	1.86	2.20	1.76
	(0.67)	(0.99)	(1.04)	(1.08)
Actual significance limit	9 %	38 %	55 %	33 %

Table A1.2.3. Impact of a temporal drift of the seasonal cycle; aggregation from July to June. $\frac{\mu_W}{\mu_S}$ denotes the ratio of the mean concentration of the winter to the respective mean in the summer. Calculations are based on 1000 simulation runs for each setting. The actual significance limit refers to the probability that the residual variance exceeds the critical value derived from the chi-squared distribution.

Parameter	No seasonality	$\frac{\mu_W}{\mu_S} = 2$	$\frac{\mu_W}{\mu_S} = 4$	$\frac{\mu_W}{\mu_S} = 0.5$
Mean of residual variance (s.d. in brackets)	1.13	0.54	0.30	0.64
	(0.67)	(0.32)	(0.23)	(0.38)
Actual significance limit	9 %	0 %	0 %	1 %

Table A1.3.1.1. Results of the Levene test for the examination of heterogeneity of within-year variances. F denotes the F statistic of the one-way ANOVA based on the absolute deviations from the annual mean, df1 and df2 the corresponding degrees of freedom. The P value refers to the empirical significance level. For almost all time series, significant heterogeneity of the within-year variances can be detected.

Time series	Location	Compartment	Unit	F	df_1	df_2	P value
Chlorophyll	Zijpe, Oosterschelde	Water	$\mu g\ l^{-1}$	2.002	23	334	0.005
Flu	Eijsden ponton (Maas)	Suspended matter	$mg\ kg^{-1}$ dry weight	6.308	12	427	0.000
InP	Eijsden ponton (Maas)	Suspended matter	$mg\ kg^{-1}$ dry weight	6.377	12	427	0.000
N at Haringvliet	Haringvliet	Water	$\mu g\ l^{-1}$	3.350	28	520	0.000
N at IJsselmeer	IJsselmeer	Water	$\mu g\ l^{-1}$	1.160	25	370	0.274
N at Maassluis	Maassluis	Water	$\mu g\ l^{-1}$	2.783	34	808	0.000

If μ_W and μ_S denote the long-term mean concentration during the winter season and the summer season, respectively, the mean from January to December has the long-term mean

$$(\mu_b - \mu_a)\ \mu_S + (360 - (\mu_b - \mu_a))\ \mu_W$$

and the variance

$$(\mu_W - \mu_S)^2 \left(\sigma_a^2 + \sigma_b^2 - 2\rho_S \sigma_a \sigma_b\right).$$

The mean from July to June has the same long-term mean

$$(\mu_b - \mu_a)\ \mu_S + (360 - (\mu_b - \mu_a))\ \mu_W$$

and the variance

$$(\mu_W - \mu_S)^2 \left(\sigma_a^2 + \sigma_b^2 - 2\rho_W \sigma_a \sigma_b\right).$$

The only difference between the variances is the correlation coefficient. It turns out that the aggregation from July to June is to be preferred if the length of the winter season is less varying than the length of the summer season.

3 STATISTICAL ANALYSES OF SIX TIME SERIES, BASED ON ARITHMETIC ANNUAL MEANS

In order to obtain a better understanding of the results of the preceding section, six real time series are analysed in the following subsections.

3.1 Examination of Heterogeneity of Within-year Variances with the Test of Levene

In order to decide whether the inclusion of the within-year variance is required for the determination of uncertainty weights, the test of Levene[1] is applied. Table A1.3.1.1 represents the results.

It turns out that for nitrogen at IJsselmeer the incorporation of different within-year variances into the uncertainty weights is not required. For the other time series, significant differences of the within-year variances are observed. For these series, it is highly recommended to take into account the within-year variances.

3.2 Calculation of the Error Variance of the LOESS Smoother for Two Different Basic Periods

In order to examine whether apart from the within-year variation there are further variance components, for the six time series the error variances are calculated for the LOESS smoother with estimated weights and with weights proportional to the sample size. In order to examine whether drifting seasonal cycles affect the result of the trend analysis, the calculation is performed not only for the concentration mean value based on the calendar year, but also for the concentration mean from July to June. The results are presented in Tables A1.3.2.1 and A1.3.2.2 for weights proportional to the sample size and for estimated weights, respectively. Since for nitrogen at IJsselmeer no significant heterogeneity of the within-year variances could be detected, the calculation of the LOESS smoother with weights proportional to the

[1] The test of Levene is a robust alternative to the test of Bartlett: It is a one-way ANOVA based on the absolute residuals.

Table A1.3.2.1. Error variances for the LOESS with weights proportional to the sample size. The P value limit refers to the probability that the residual variance (=error variance) exceeds the critical value derived from the chi-squared distribution.

Time series	Basic period	$df_{residuals}$	Error variance	P value
Chlorophyll	Jan–Dec	15.72	0.54	0.926
Chlorophyll	Jul–Jun	15.64	0.40	0.981
Flu	Jan–Dec	8.26	1.72	0.085
Flu	Jul–Jun	8.20	2.42	0.012
InP	Jan–Dec	8.26	2.74	0.005
InP	Jul–Jun	8.20	2.06	0.035
Haringvliet N	Jan–Dec	21.07	1.27	0.186
Haringvliet N	Jul–Jun	20.18	0.77	0.754
IJsselmeer N	Jan–Dec	17.87	0.48	0.969
IJsselmeer N	Jul–Jun	17.10	0.85	0.642
Maassluis N	Jan–Dec	25.30	1.99	0.002
Maassluis N	Jul–Jun	24.56	1.34	0.123

sample size for these series appears to be appropriate and hence they are highlighted in Tables A1.3.2.1 and A1.3.2.2. For the other time series, a calculation with estimated weights appears to be more appropriate.

For N at Maassluis and inorganic phosphorus (InP) (calculated on a calendar-year basis), it can be concluded that there are additional variance components, which are not included in the within-year variance (at significance level 5 %). However, if for N at Maassluis the basic period would be from July to June, the error variance would be smaller and at the significance limit.

An appropriate choice of the basic period for the calculation of the annual mean may reduce the inter-annual variability not only for Maassluis, but also for Haringvliet: a reduction of 40 % of the error variance is possible if the basic period would be from July to June. The situation is vice versa for N at IJsselmeer. For this series, it is also apparent that the trend line itself is highly determined by the basic period. This demonstrates the need for detailed analyses for an optimized choice of the basic period for each time series.

3.3 Calculation of Confidence Bands

In order to further compare the impact of selecting another basic period and the different weighting strategies, confidence bands are calculated for each time series. The $(1-2\alpha)$ confidence interval for the systematic trend $z(m)$ in year m is calculated

$$\left[z(m) - t(df_{error}, 1-\alpha) s\,\tau(m) \quad , \quad z(m) + t(df_{error}, 1-\alpha) s\,\tau(m)\right]$$

where

$$\tau(m) = \sqrt{\left(SU^{-1}S'\right)_{mm}} \ ,$$

$$s = \sqrt{\frac{1}{df_{error}} SS_{error}} = \sqrt{\frac{1}{df_{error}} \sum_{t=1}^{n} u_t \left(y_t - z(x_t)\right)^2}$$

and $\left(SU^{-1}S'\right)_{mm}$ denotes the m^{th} diagonal entry of the product matrix $SU^{-1}S'$. It is an implicit assumption of this formula that an eventually existing additional variance component of the annual mean concentrations (at least for time series where the error variance exceeds the critical value) is proportional to the within-year variance. The confidence band reflects both the actual variability of the annual mean concentration and the relative uncertainty weights.

Table A1.3.3.1 contains the average length of the 95 % confidence intervals for three weighting strategies. All entries representing a length which does not exceed the minimum length of all three strategies by more than 5 % are highlighted in bold. Apparently the method with estimated weights outperforms in most cases the other weighting strategies. However, differences are relatively small and in few cases above 20 %.

It should be noted that the use of appropriate uncertainty weights is not only relevant with regard to optimized confidence bands with a direct link to improved trend sensitivity, but also with regard to a statistically sound treatment of different samples sizes and uncertainties.

Table A1.3.2.2. Error variances for the LOESS with estimated weights. The P value limit refers to the probability that the residual variance (=error variance) exceeds the critical value derived from the chi-squared distribution.

Time series	Basic period	$df_{residuals}$	Error variance	P value
Chlorophyll	Jan–Dec	16.68	0.604	0.863
Chlorophyll	Jul–Jun	17.15	0.495	0.955
Flu	Jan–Dec	8.551	2.103	0.021
Flu	Jul–Jun	8.267	2.849	0.003
InP	Jan–Dec	9.318	2.521	0.005
InP	Jul–Jun	8.601	2.107	0.020
Haringvliet N	Jan–Dec	21.6	1.304	0.135
Haringvliet N	Jul–Jun	20.89	0.787	0.689
IJsselmeer N	Jan–Dec	18.36	0.565	0.919
IJsselmeer N	Jul–Jun	17.43	1.001	0.424
Maassluis N	Jan–Dec	25.59	1.814	0.006
Maassluis N	Jul–Jun	25.03	1.504	0.050

Table A1.3.3.1. Average length of confidence band for the LOESS smoother. Figures not exceeding the respective minimum by more than 5 % are highlighted in bold. It turns out that the LOESS with estimated weights performs very well in almost all cases.

Time series	Basic period	Unweighted	Weight =Sample size	Weight = estimated uncertainty
Chlorophyll	Jan–Dec	1.179	1.174	**1.030**
Chlorophyll	Jul–Jun	0.982	0.978	**0.899**
Flu	Jan–Dec	**0.2258**	**0.2236**	**0.2285**
Flu	Jul–Jun	**0.2517**	**0.2632**	0.2788
InP	Jan–Dec	0.1787	0.1514	**0.1235**
InP	Jul–Jun	0.1289	0.1182	**0.09669**
Cu	Jan–Dec	2.491	2.657	**1.563**
Cu	Jul–Jun	4.764	4.614	**3.249**
Haringvliet N	Jan–Dec	0.27	**0.2546**	**0.2456**
Haringvliet N	Jul–Jun	0.2075	0.1927	**0.1831**
IJsselmeer N	Jan–Dec	**0.2653**	**0.2594**	**0.2617**
IJsselmeer N	Jul–Jun	0.3563	**0.3392**	**0.3522**
Maassluis N	Jan–Dec	0.2857	0.2811	**0.2546**
Maassluis N	Jul–Jun	**0.2313**	**0.2311**	**0.2301**

For Flu and InP the average length of the confidence band becomes considerably smaller, and this is caused by higher uncertainty in the first half of the time series. If one does not take into account these differences, the calculated confidence interval is too small at the beginning, and too large at the end, of the series.

The following charts (Figures A1.3.3.1 to A1.3.3.6) represent the trend and the lower and upper confidence limits of the 95 % confidence interval for the LOESS trend with estimated weights. The squares represent the annual mean concentrations. All calculations are performed for the calendar year (left) and for the period July–June (right).

For the time series Chlorophyll, Flu and InP (Figures A1.3.3.1 to A1.3.3.3), the varying uncertainty in the mean concentration is clearly reflected in a varying length of the confidence band. The pattern of the mean

Figure A1.3.3.1. LOESS trend and corresponding confidence bands for the annual mean chlorophyll concentrations.

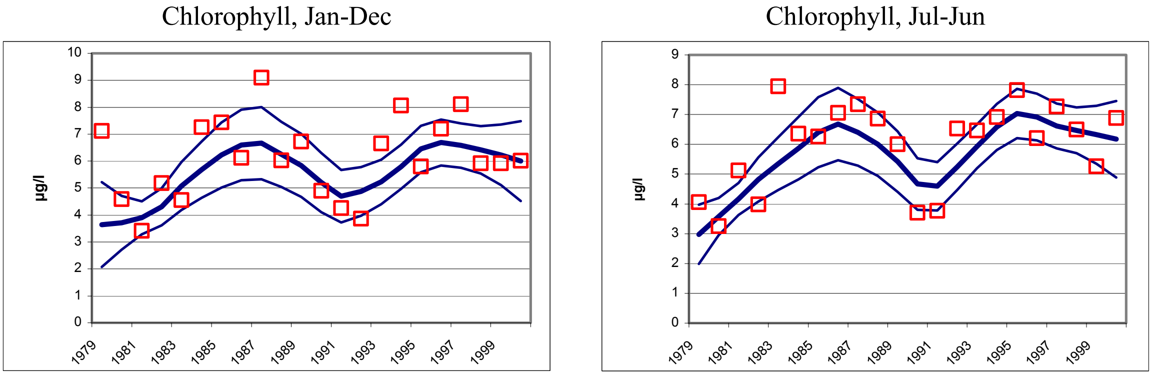


Figure A1.3.3.2. LOESS trend and corresponding confidence bands for the mean Flu concentrations.

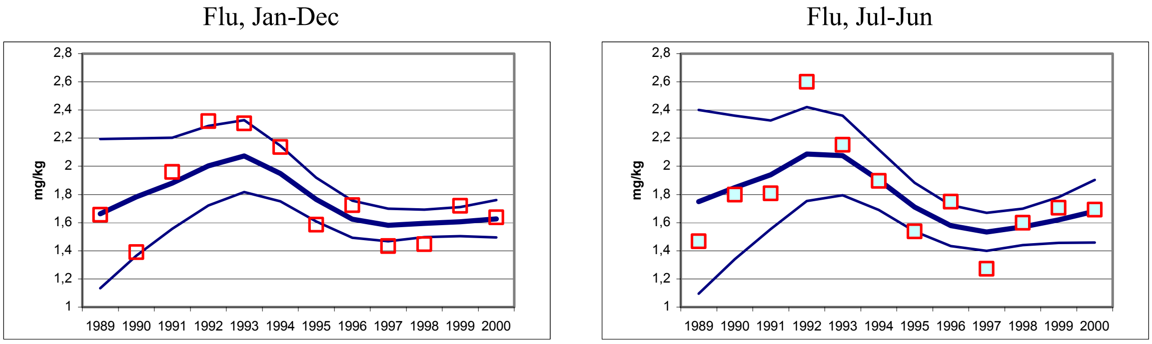
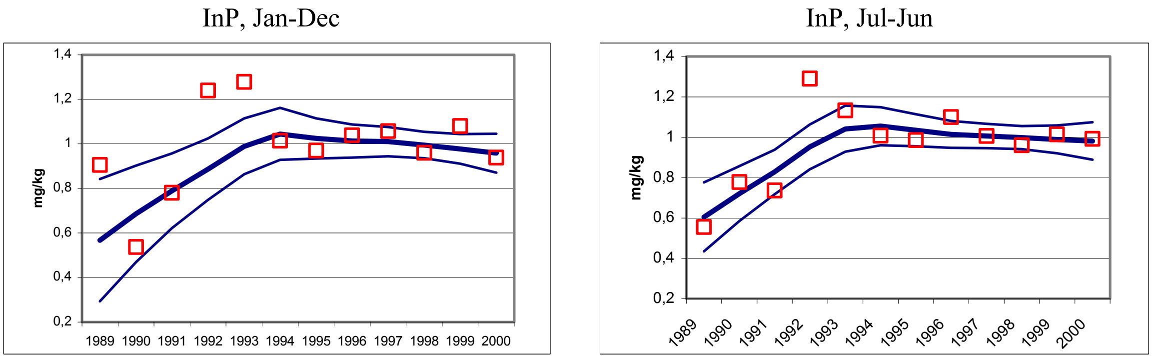


Figure A1.3.3.3. LOESS trend and corresponding confidence bands for the mean InP concentrations.



concentrations for the two different basic periods is quite different, but the trend is similar. For the N_{total} time series (Figures A1.3.3.4 to A1.3.3.6), the length of the confidence band is less varying, and the patterns of annual data look similar, but this is at least partly a consequence of having more data.

4 CONCLUSIONS

If the start and end times of the seasonal cycle are randomly fluctuating, the stochastic behaviour of the annual mean can be quite different from what is expected under standard assumptions. The inter-annual variability may be larger or smaller, and this depends on the aggregation period. Hence, it is recommended to check the within-year correlation structure and to select the basic period so that the variance of the annual mean is minimized. An appropriate choice of the aggregation period may lead to considerable improvement of the trend sensitivity of the monitoring programme.

This is not only relevant with regard to trend analyses based on the annual mean, but also for trend analysis methods based on monthly data. An efficient analysis based on monthly data should take into account the random fluctuation of the seasonal cycle. Otherwise, it may happen that a trend analysis based on aggregated

Figure A1.3.3.4. LOESS trend and corresponding confidence bands for the mean nitrogen concentrations at Haringvliet.

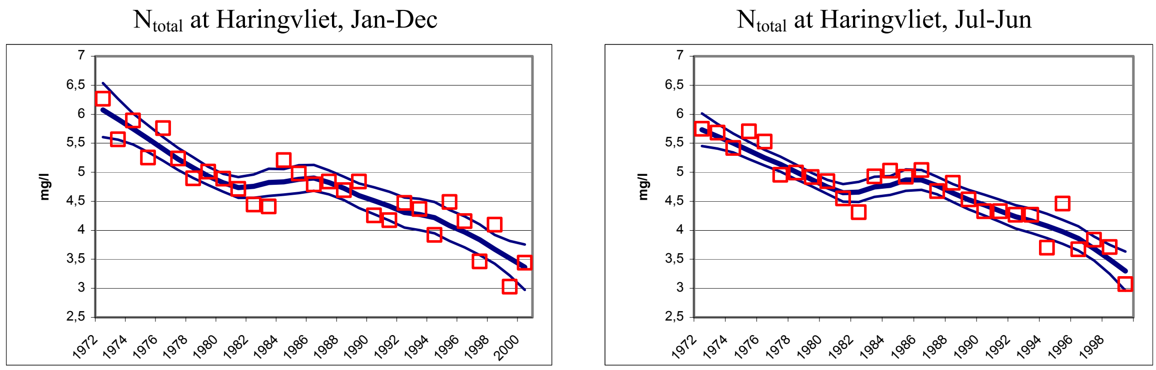


Figure A1.3.3.5. LOESS trend and corresponding confidence bands for the mean nitrogen concentrations at IJsselmeer.

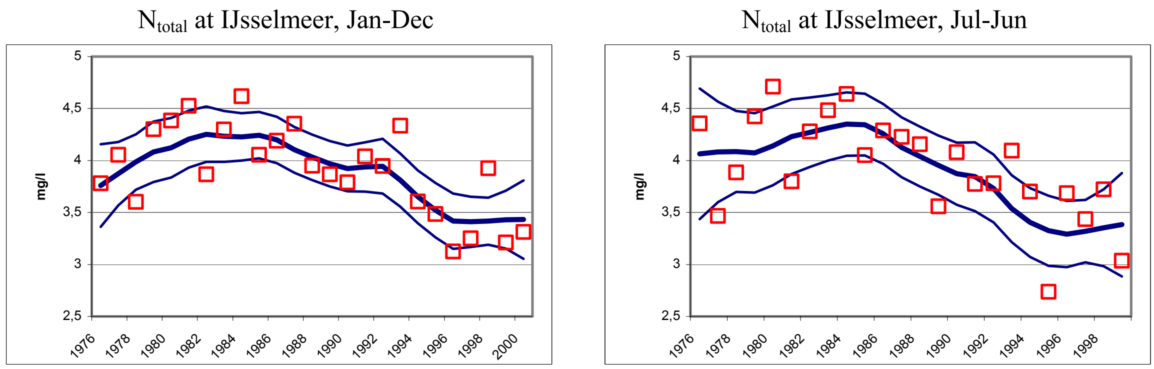
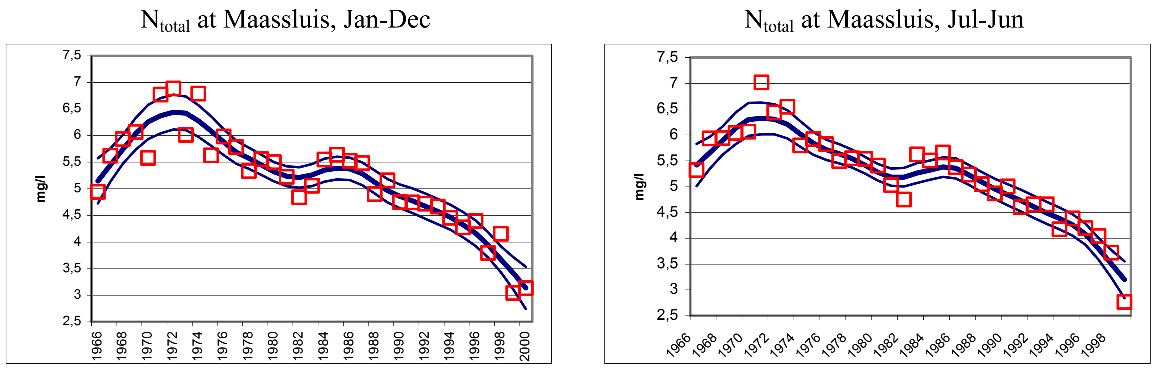


Figure A1.3.3.6. LOESS trend and corresponding confidence bands for the mean nitrogen concentrations at Maassluis.



annual data is (much) more powerful than an analysis based on monthly data.

5 ACKNOWLEDGEMENT

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ANNEX 2: WEIGHTED LOESS SMOOTHER WITH DISCONTINUITIES

1 INTRODUCTION

In this annex, an extended weighted LOESS smoother is proposed which allows one to take into account discontinuities of the trend. It is assumed that this index is an annually aggregated mean value, e.g., the mean of measured concentrations or the annual load (which in many cases can be considered as a mean value of transport figures). If the uncertainty weights are based on the within-year variances, the comparison with the actual residual variance of the LOESS smoother allows an examination of whether or not the underlying model is consistent with the empirical result (see Uhlig, 2001, 2002). In this annex, it is shown that discontinuities in the trend may highly affect the actual residual variance, and it is further demonstrated that an inclusion of a method to detect discontinuities may lead to a better model fit.

2 THE IMPACT OF DISCONTINUITIES FOR THE RESIDUAL VARIANCE

Single outlier measurements do not seriously affect the trend calculation based on the weighted LOESS, since the outlier causes automatic down-weighting of the corresponding arithmetic mean. If there is, however, not only one outlying measurement value, but a break or even a shift in the temporal trend, the between-year variance can be much larger than the variance calculated on the basis of the within-year variance. In order to explore these effects quantitatively, a simulation study was performed. All calculations were performed for a time series of monthly data measured over a span of ten years. It is assumed that the trend line is constant, and that there is a shift after five years of 0.5σ, 1σ or 2σ, where σ denotes the (within-year) standard deviation of the Normally distributed measurement values (Table A2.2.1). Apparently a break or a shift in the trend line may cause considerable inconsistency between within-year variance and between-year variance.

3 LOESS SMOOTHER TAKING INTO ACCOUNT DISCONTINUITIES

It is an implicit assumption of the LOESS smoother that the distance between any pair of years x_i and x_t is treated in the same way. This is apparent from the definition of the weights:

$$w_{ti} = \begin{cases} u_i \left(1 - \left(\frac{|x_t - x_i|}{\Delta_t}\right)^3\right)^3 & \text{for } 0 \le \frac{|x_t - x_i|}{\Delta_t} \le 1 \\ 0 & \text{otherwise} \end{cases} .$$

According to this definition, the temporal development is considered to be uniform and smooth. Breaks in trend cannot be described properly by the common LOESS smoother. In order to allow a better description of breaks in the trend, it is therefore necessary to allow changes in the dynamics, i.e., in the flow of time. Mathematically this can be achieved by introducing a pseudo year r_t, with $r_1 = x_1$ and $r_t < r_{t+1}$ for all t. Subsequent differences $r_{t+1} - r_t$ represent the pseudo time span between subsequent observations and hence the actual dynamics in year x_t. If there is a shift or a break in the trend, $r_{t+1} - r_t$ can be quite large. The dynamics are directly related to the smoothness of the trend, and therefore one could try to estimate the dynamics by the extent of smoothness. If discontinuity exceeds a critical value, the dynamics assumed should be increased, and this procedure can be repeated until no more exceedance of critical values is indicated. A mathematical concept for this idea is presented in this section.

Table A2.2.1. Impact of a shift in the trend. Model: Linear trend with a shift after five years, no seasonality, monthly data. Calculations are based on 1000 simulation runs. The actual significance limit refers to the probability that the residual variance exceeds the critical value derived from the chi-squared distribution based on the within-year standard deviation.

Parameter	no shift	shift =0.5σ	shift =1σ	shift =2σ
Mean of residual variance	1.13	1.30	1.92	4.28
(s.d. in brackets)	(0.67)	(0.76)	(0.99)	(1.71)
Actual significance limit	9 %	15 %	39 %	95 %

3.1 LOESS Smoother with Varying Dynamics

Let y_i (i=1,…,n) denote the observation for year x_i , let p_i denote the pseudo year describing the dynamics, and let u_i denote the "uncertainty weight" of the observation.

The smoother matrix S of the LOESS smoother is constructed from a series of weighted regressions for each year x_t. The weight of the observation y_i in the local regression for year x_t is determined by the uncertainty weight u_i and by the pseudo distance between year x_i and year x_t ,

$$w_{ti} = \begin{cases} u_i\left(1-\left(\dfrac{|p_t - p_i|}{\Delta_t}\right)^3\right)^3 & \text{for } 0 \le \dfrac{|p_t - p_i|}{\Delta_t} \le 1 \\ 0 & \text{otherwise} \end{cases}$$

where Δ_t is defined as for the common LOESS smoother. With the notation introduced for the LOESS smoother with uncertainty weights, the value of the smoother in year x_t is given by

$$S_t^{'}Y ,$$

where $S_t^{'}$ is the t^{th} row of

$$X\left(X'W_tX\right)^{-1}X'W_t .$$

3.2 Measuring Discontinuities in the Temporal Trend

If there is a shift in the trend between year x_t and x_{t+1}, most of the residuals in the years before will be negative (positive), and most of the residuals after will be positive (negative). The LOESS trend at $\frac{x_t + x_{t+1}}{2}$ based on the residuals $r_1,\ldots, r_t, -r_{t+1} ,\ldots, -r_n$ with negative sign from year x_{t+1} onwards, can therefore be considered as a characteristic for a possible shift in the time series at $\frac{x_t + x_{t+1}}{2}$.

It can be calculated as follows:

The weight of the observation y_i in the local regression for $\frac{x_t + x_{t+1}}{2}$ is determined by the uncertainty weight u_i and by the distance between x_i and $\frac{x_t + x_{t+1}}{2}$:

$$w_{ti} = \begin{cases} u_i\left(1-\left(\dfrac{\left|\dfrac{x_t + x_{t+1}}{2} - x_i\right|}{\Delta_t}\right)^3\right)^3 & \text{for } 0 \le \dfrac{\left|\dfrac{x_t + x_{t+1}}{2} - x_i\right|}{\Delta_t} \le 1 \\ 0 & \text{otherwise} \end{cases}$$

where

$$\Delta_t = \max\left\{\frac{\text{span}+1}{2}, \text{span - min}\{\text{t - 1, n - t}\}\right\}$$

and *span* denotes the window length of the LOESS smoother. Then, writing X for the design matrix of the simple linear regression model,

$$X = \begin{pmatrix} 1 & x_1 \\ 1 & x_2 \\ \vdots & \vdots \\ 1 & x_n \end{pmatrix},$$

R_t for the following diagonal matrix with +1's in the first t diagonal entries and –1's in the remaining $n-t$ entries,

$$R_t = \begin{pmatrix} I_t & 0_{t\times n-t} \\ 0_{n-t\times t} & -I_{n-t\times n-t} \end{pmatrix},$$

and W_t for the corresponding diagonal matrix of weights,

$$W_t = \begin{pmatrix} w_{t1} & 0 & \cdots & 0 \\ 0 & w_{t2} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & w_{tn} \end{pmatrix},$$

the value of the smoother in $\frac{x_t + x_{t+1}}{2}$ is given by

$$shift\left(\frac{x_t + x_{t+1}}{2}\right) = \left(1, \frac{x_t + x_{t+1}}{2}\right)\left(X'W_tX\right)^{-1}X'W_tR_t(Y - Z),$$

where Y denotes the vector of measurements and $Z = SY$ the corresponding predicted values. In this formula, R_t is required for changing the sign of the residuals for the entries t+1,…,n. If Y has covariance matrix U^{-1}, and if the mean of $Y - Z$ is zero, the mean of $shift\left(\frac{x_t + x_{t+1}}{2}\right)$ is zero, too, and its variance can be computed

$$Var\left[shift\left(\frac{x_t + x_{t+1}}{2}\right)\right]$$

$$= \left(1, \frac{x_t + x_{t+1}}{2}\right)(X'W_tX)^{-1} X'W_tR_t(I_n - S)U^{-1}(I_n - S')R_t'W_tX(X'W_tX)^{-1}\begin{pmatrix}1\\ \dfrac{x_t+x_{t+1}}{2}\end{pmatrix}.$$

If

$$t(x_t, x_{t+1}) := \left|shift\left(\frac{x_t + x_{t+1}}{2}\right)\right| \Bigg/ \sqrt{Var\left[shift\left(\frac{x_t + x_{t+1}}{2}\right)\right]}$$

exceeds 2, it can be concluded that there is a significant shift in $\frac{x_t + x_{t+1}}{2}$ which cannot be described by the LOESS smoother applied. In order to avoid problems due to multiple testing, it is recommended to use a reduced significance level. For alpha=0.01 the critical value would be 2.575.

It should be noted that there are other methods for estimating discontinuities, as described by Loader (1999). However, the procedure described by Loader focuses on the discontinuity itself, aiming to split the time series into different intervals which then will be analysed separately. In the approach presented here, discontinuities are considered as sections in the time series with higher temporal dynamics.

3.3 Determination of Dynamics

The pseudo year indices p_t are calculated iteratively as follows:

Step 1: Let $p_t^{(0)} = x_t$ for $t = 1,...,n$ and let k=1.

Step 2: Calculate trend and proceed with Step 3.

Step 3: For all $t = 4,...,n-3$ calculate $t(x_t, x_{t+1})$ and select the interval [t,t+1] where $t(x_t, x_{t+1})$ attains its maximum under the condition
$p_{i+1}^{(k-1)} - p_i^{(k-1)} \le span - 1$ for all i=1,…,n-1.

If $t(x_t, x_{t+1})$ exceeds the critical value 2.575 (under Normal distribution, 1 % significance level), let
$p_{t+1}^{(k)} = p_{t+1}^{(k-1)} + 0.5, ..., p_n^{(k)} = p_n^{(k-1)} + 0.5$ and increment k=k+1.

Otherwise stop iteration.

Step 4: Go to Step 2.

Remark: The condition $p_{i+1}^{(k-1)} - p_i^{(k-1)} \le span - 1$ guarantees that local trend calculation is based on at least four values. The parameter *span* denotes the window length of the LOESS smoother. In the example presented below, a *span* of eleven years is chosen.

3.4 Examples

The algorithm presented in the preceding section was applied to the mean nitrogen concentrations at Haringvliet and Maassluis. For both series, the mean was calculated from July to June. Apparently for both series there is an upward shift (approximately 0.7 mg l^{-1}) in 1982–1983 (Figures A2.3.4.1 and A2.3.4.2). Due to this shift, the width of the confidence band is increased in the years around 1982–1983.

The shift of the trend is reflected both in the t values of the discontinuity characteristic and the resulting dynamics (Figures A4.3.4.2 and A4.3.4.4). The dynamics in 1982–1983 are estimated 4.5 years, i.e., the dynamics are 4.5 times higher than in the other years.

The time series for Maassluis (Figure A2.3.4.3) has not only a discontinuity in 1982–1983, but also another discontinuity (downward shift of approximately 0.7 mg l^{-1}) and a trend reversal in 1973–1974. It appears that the intervals 1966–1973, 1974–1982, and 1983–1999 are governed by different conditions. It would be worthwhile investigating the reasons for this.

4 CONCLUSIONS

Discontinuities may cause considerable increase in the residual variance of the LOESS trend. It is therefore crucial to examine such discontinuities especially in series that are longer than fifteen years. The method presented allows one to detect and to model discontinuities by a simple extension of the weighted LOESS smoother, where the weights are based on the within-year variance of monthly or bi-weekly data.

5 ACKNOWLEDGEMENT

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Figure A2.3.4.1. LOESS trend with discontinuities and varying uncertainties for the mean nitrogen concentrations at Haringvliet. The blue squares represent the mean concentrations, the upper and the lower lines represent the upper and the lower confidence limits, respectively, and the line in the middle represents the corresponding trend.

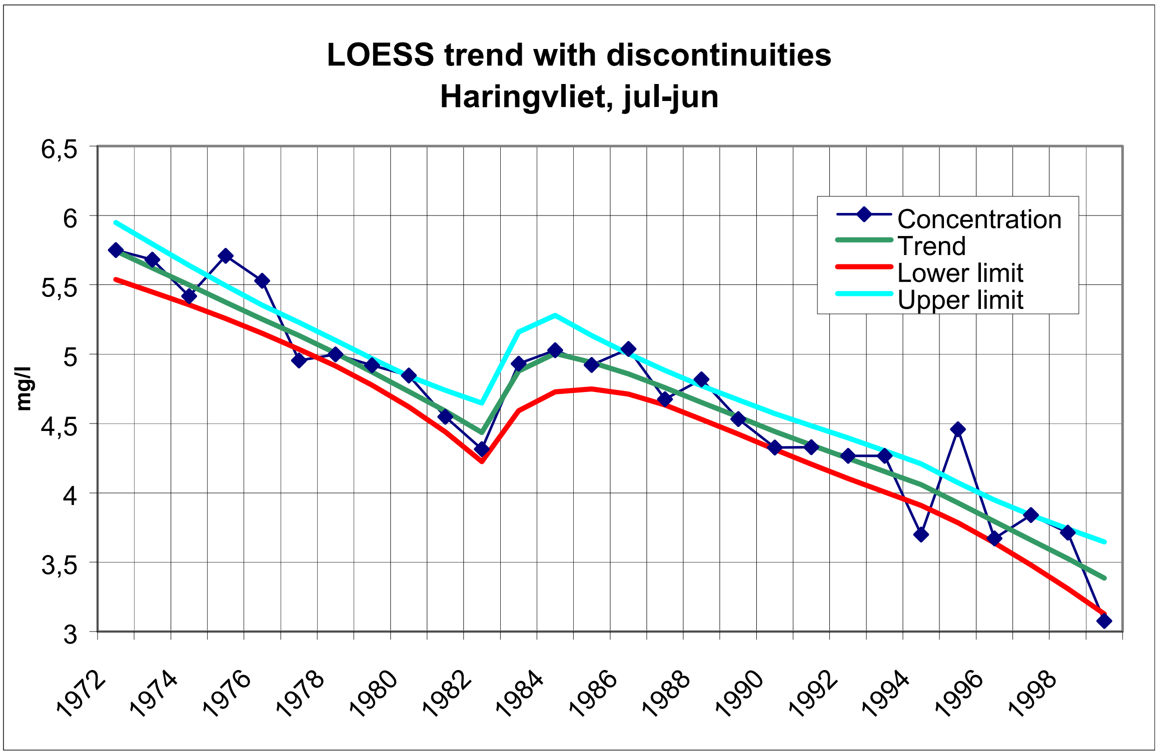


Figure A2.3.4.2. Discontinuities and dynamics for the mean nitrogen concentrations at Haringvliet. The years represent the time interval *year*−1 to *year*, e.g., "1983" means "1982–1983". Discontinuities are presented for the first iteration step (k=1).

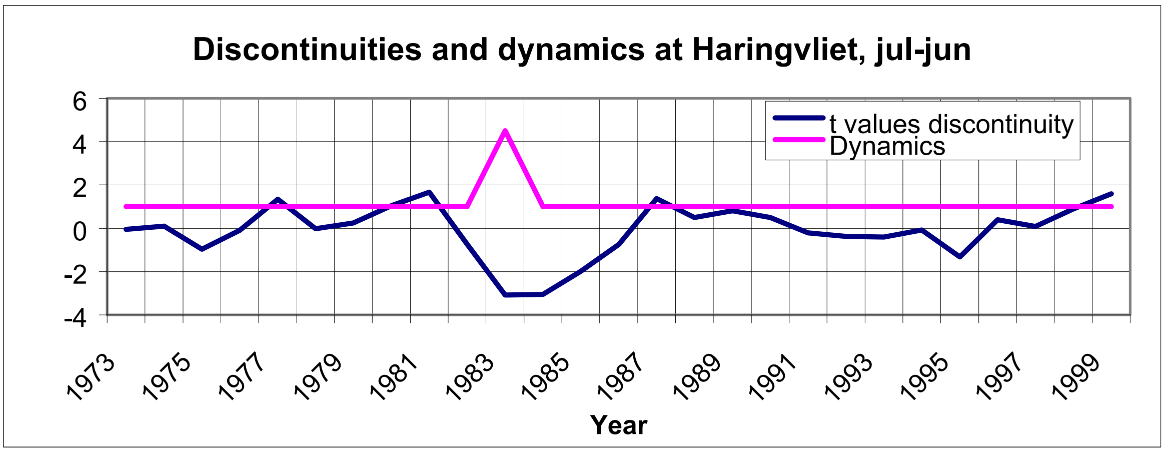


Figure A2.3.4.3. LOESS trend with discontinuities for the mean nitrogen concentrations at Maassluis. The blue squares represent the mean concentrations, the upper and the lower lines represent the upper and the lower confidence limits, respectively, and the line in the middle represents the LOESS trend, taking into account varying uncertainties and discontinuities.

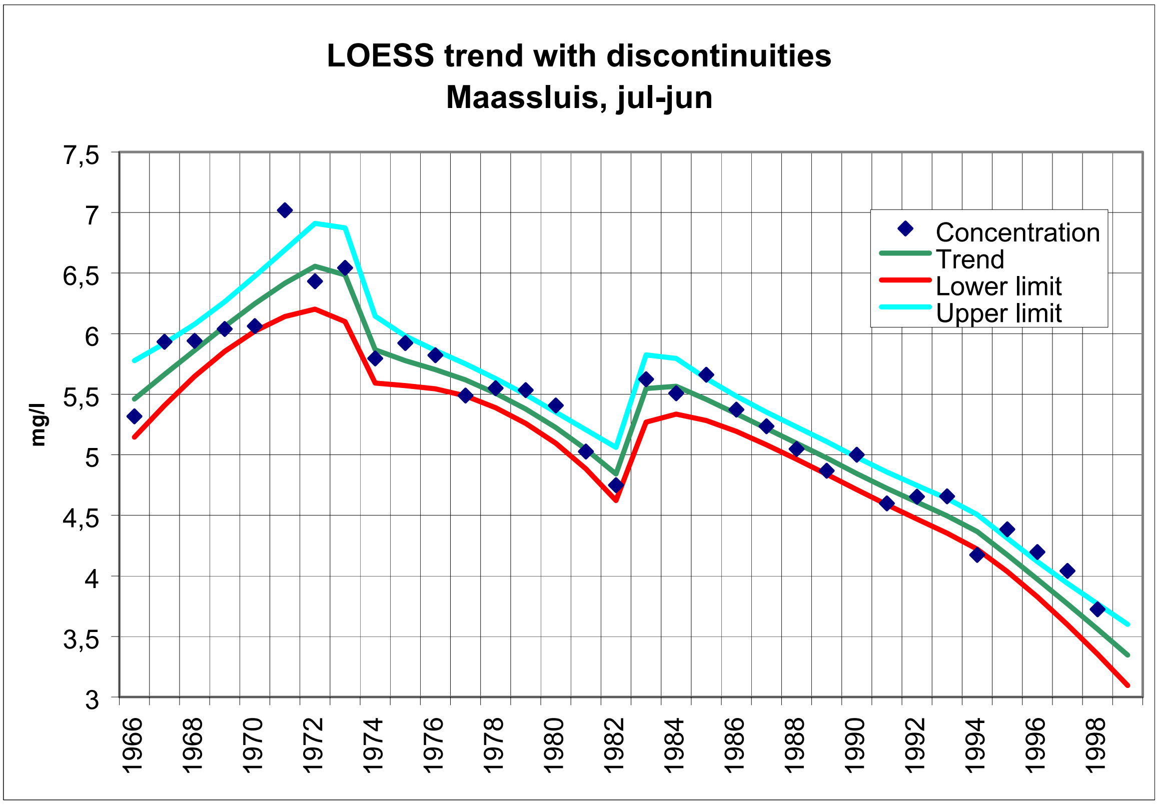
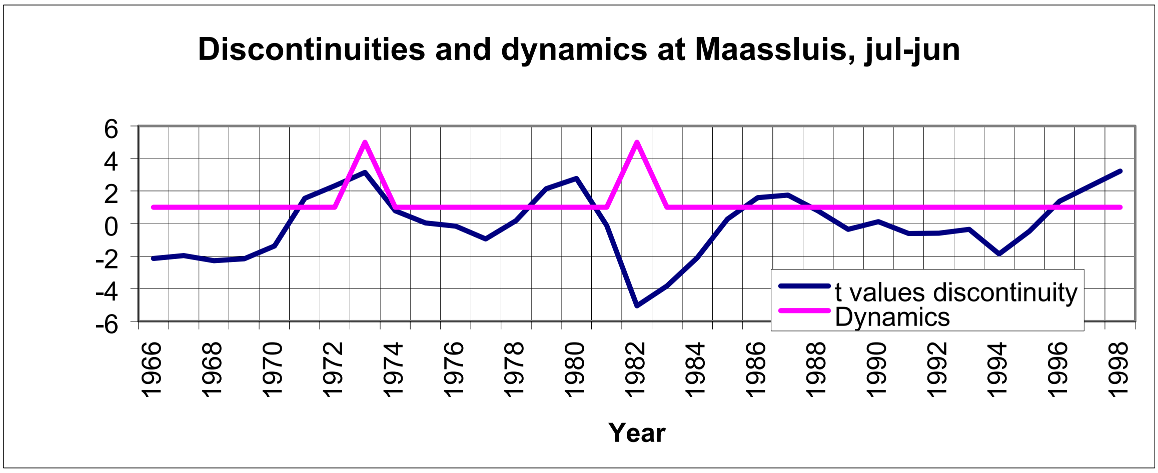


Figure A2.3.4.4. Discontinuities and dynamics for the mean nitrogen concentrations at Maassluis. The years represent the time interval *year*−1 to *year*, e.g., “1983” means “1982–1983”.



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ANNEX 3: COMPARING THE CHANCE TO DETECT HOTSPOTS FOR VARIOUS SAMPLING DESIGNS USING RANDOMIZATION TECHNIQUE

Introduction

The objective of the present study is to investigate how various sampling designs will influence the chance to locate a "hotspot", e.g., a highly contaminated spot, well delimited from the surroundings in the sampling area. Nicholson (2001) demonstrated the theoretical functions for missing a circular target of varying size using a random, square, and triangular lattice, respectively, of sampling points. He remarked that, of course, the shape of the target will also affect the result of such a survey. Different approaches to these problems are further discussed in, e.g., Berry and Baker (1968); McBratney *et al*. (1981); Gilbert (1987); and Nicholson (2001).

In a field situation, practical circumstances may lead to divergences from a desired ideal sampling design. In these cases, randomization techniques could help to estimate the power to detect a certain target size for the sampling design actually used. This method may also be more flexible to study various target shapes or *ad hoc* sampling designs.

In the present study, a "Monte Carlo" approach is checked against the theoretical functions presented by Nicholson (2001).

The merits of some additional sampling designs, "random with inhibition distance", "unaligned lattice", and the quasi-random "Sobol sequence" are also discussed. To investigate target shape, square and rectangular targets in a fixed orientation are contrasted against a circular shape.

Method

In this study, six different sampling designs are compared and for each design, a circular, a square, and two rectangular "hotspots" are tested. The lengths of the rectangles are two times and four times the width, respectively, the latter imitating string-like hotspots of contamination. The orientation of the rectangles is fixed in a vertical position to illustrate a "worst case" for regular sampling.

The plots show the sampling area (e.g., 1000 m × 1000 m) with the sampling spots laid out in the various sampling designs.

The chance to locate a hotspot of a certain area is simply determined by placing the hotspot randomly in various positions. In the examples below, a number of 1000 or 2000 randomizations has been used. This is repeated for 100 different hotspot sizes. A selection of target sizes is depicted in the figures. At least the centre of the hotspot is assumed to be inside the sampling area.

The sampling area is overlaid by a graph, showing the relation between the risk to miss a target and a standardized hotspot radius, R, defined by Nicholson (2001) as:

$$R = \frac{r}{\sqrt{\frac{A}{N}}}$$

, where r is the radius for a circular target, A is the sampling area, and N is the number of samples.

For a rectangular target, a corresponding R can be defined as:

$$R = \frac{\sqrt{\frac{h \cdot w}{\pi}}}{\sqrt{\frac{A}{N}}}$$

, where h is the height and w is the width of the target. For each of the 100 target sizes, R is calculated and the risk to miss the target (y-axis) at this standardized hotspot radius (x-axis) is depicted with a small cross.

The number of samples will not affect the graph if the standardized radius R is used. Nevertheless, in the examples below, 100 sample points are used.

In order to compare the effectiveness of various sampling strategies, a smoother is applied to fit a line through the estimated chance for each target size and the area above the smoother line (LOESS smoother, Cleveland, 1979) is calculated (in the plots, the scale factors for both x- and y-axes are equal, generating a quadratic graph). This area is tentatively called CCI (Cumulated Chance Index) and is used to compare the various sampling designs and target shapes.

Comparisons are also made with the theoretical probability functions for this risk for a random, a square lattice, and a triangular lattice sampling design, respectively, given by Nicholson (2001).

Probabilities of missing a target with the standardized radius, R, for a random, $\Pr_{ran}$, a square lattice, $\Pr_{sqr}$, and a triangular lattice design, $\Pr_{tri}$, as given by Nicholson (2001), are:

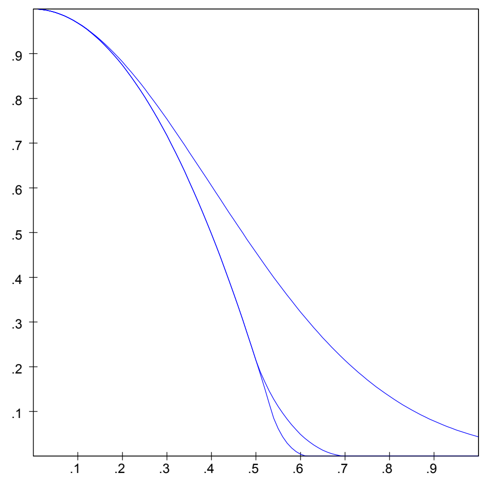
$$\Pr_{ran}(R) = (1 - \frac{\pi R^2 \, A/N}{A})^N$$

$$\Pr_{sqr}(R) = 1 - \pi R^2 \qquad 0 < R \le 0.5$$

$$\Pr_{sqr}(R) = 1 - R^2\{\pi - 4\cos^{-1}[(2R)^{-1}]\} - (4R^2 - 1)^{0.5}$$

$$0.5 < R \le 0.5^{0.5}$$

Figure A3.1. Theoretical functions for the risk of missing a target vs. standardized hotspot radius, *R*, for a random design, upper function; a square lattice design, middle function; and a triangular lattice design, lower function. The theoretical functions for a random and a square lattice design are plotted in several of the graphs below for comparison.



$\Pr_{sqr}(R) = 0 \qquad R > 0.5^{0.5}$

$\Pr_{tri}(R) = 1 - \pi R^2 \qquad 0 < R \le 2^{-0.5}3^{-0.25}$

$\Pr_{tri}(R) = 1 - \pi R^2 + 6R^2 Z - \left[3(2\sqrt{3}R^2 - 1)\right]^{0.5}$
$0.5 < R \le 0.5^{0.5}$

$\Pr_{tri}(R) = 0 \qquad R > 3^{-0.75}2^{0.5}$

where:

$Z = \cos^{-1}(2^{-0.5}3^{-0.25} / R)$

Random design

The sampling sites are randomly placed in the sampling area (Figures A3.2a and A3.2b), resulting in a Poisson distributed pattern. This means that neighbouring sampling sites can be very close or possibly even coincide. On the other hand, the target shape or regularities in the distribution of the hotspots do not lower the chance to locate the hotspot. The estimated risk from the "Monte Carlo" method is very close to the theoretical risk of missing target at various target sizes given by Nicholson (2001). Occasionally an individual random sampling scheme may deviate from the theoretical function since the sampling points can show strains of clusters by chance. For the random design, target shape does not influence the chance to detect the target.

Square lattice design

The risk of missing the circular hotspot, estimated from randomizations, shows an almost perfect fit to the theoretical function. For a circular target, the square lattice design (CCI ≈ 0.62) is far better than the random scheme (CCI ≈ 0.51). For a square target, it is even slightly better (CCI ≈ 0.63), but for a rectangular shape it might be far worse, especially when the hotspot becomes more string-like. This is illustrated in Figures A3.3a and A3.3b.

Triangular lattice design

The theoretical risk of missing a target at various target sizes for the triangular lattice design is slightly smaller compared to the square lattice design (Nicholson, 2001). Also, studies by McBratney *et al.* (1981) suggest that the triangular lattice is slightly superior to the square grid if the spatial correlation structure varies with direction. Opposite to the square lattice design, the triangular lattice design is less sensitive to shape but, as can be seen for rather extreme elongated rectangles (1:4), the chance to be detected is considerably lowered and becomes less than for the random design. This is illustrated in Figures A3.4a and A3.4b.

Figure A3.2a. Random sampling scheme. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). 100 sampling points. 2000 randomizations for each target size. Target size illustrated by open circles (left) or squares (right). The smooth lines show the functions for the theoretical risk at random sampling, and square and triangular lattices.

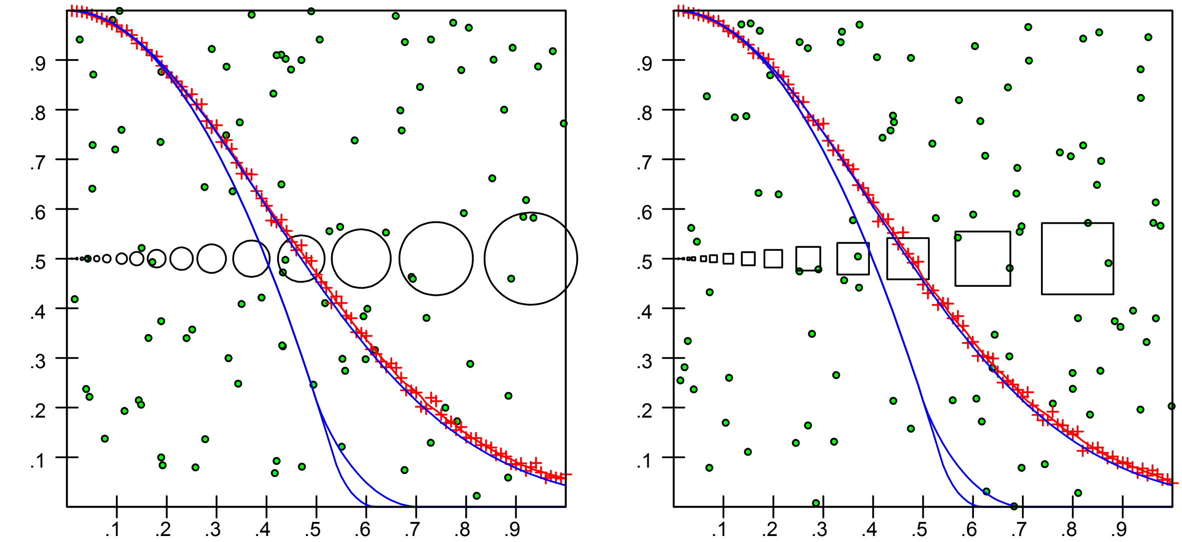


Figure A3.2b. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). Rectangular target of moderate elongation (1:2), left, and rectangular target of more extreme proportions (1:4), right; random sampling scheme. 1000 randomizations for each target size. Target size illustrated by open rectangles. Whereas a square lattice sampling design is far less effective for a rectangular target compared to a circular target, there is no difference for a random design.

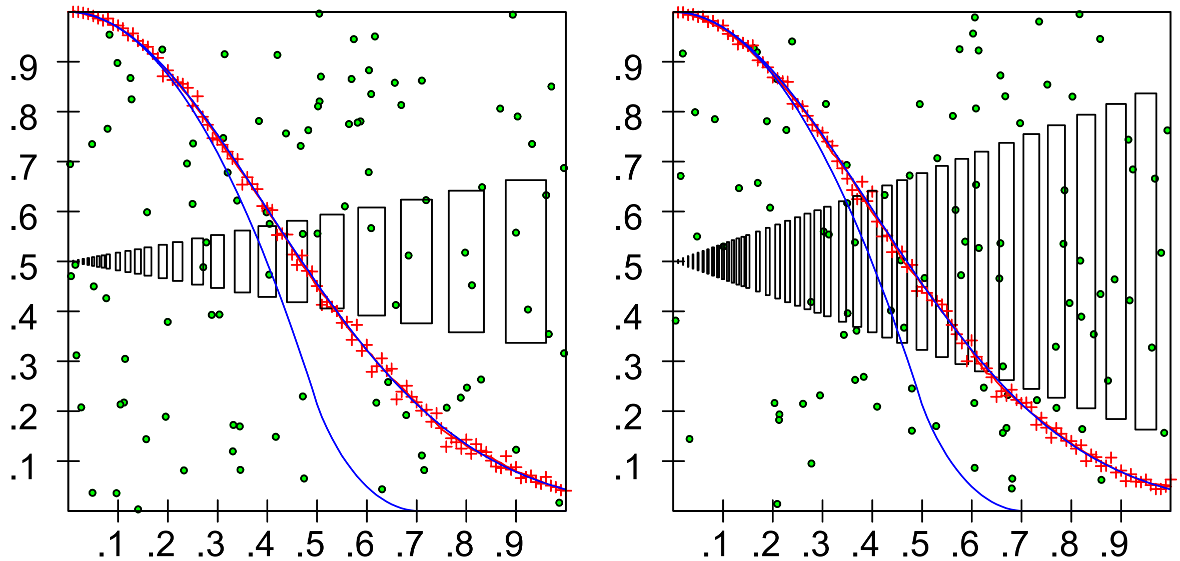


Figure A3.3a. Square lattice sampling design. Risk of missing target (y-axis) vs. standardized hotspot radius, R, of the target (x-axis). 500 randomizations for each target size. CCI ≈ 0.62.

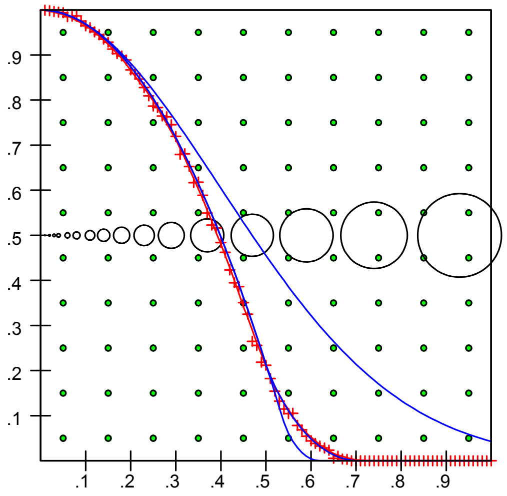


Figure A3.3b. Square lattice sampling design. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). 2000 randomizations for each target size. Rectangular target, fixed orientation. CCI ≈ 0.43 and 0.22, respectively.

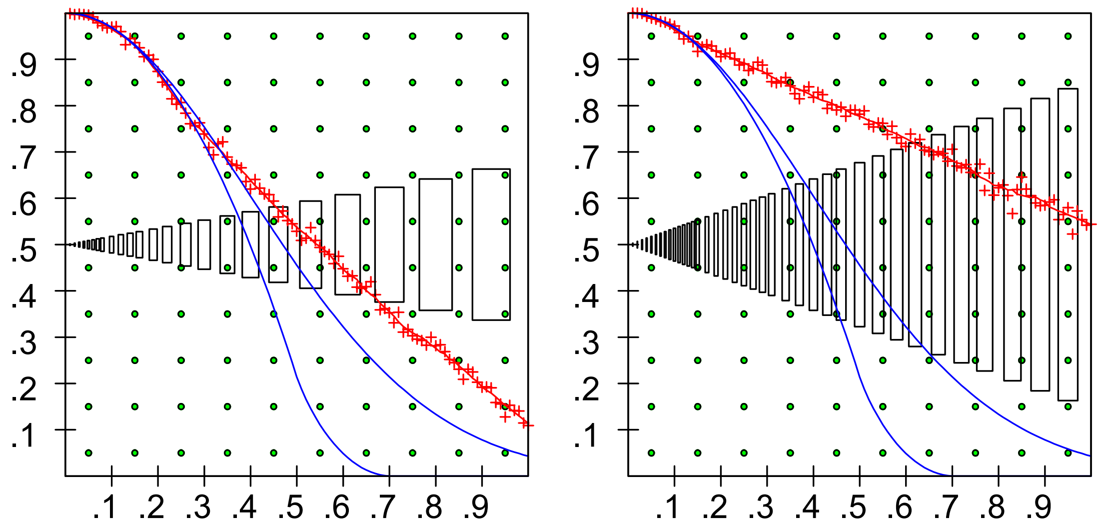


Figure A3.4a. Triangular lattice sampling design. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). 2000 randomizations for each target size. Circular target: CCI ≈ 0.621; square target: CCI ≈ 0.625.

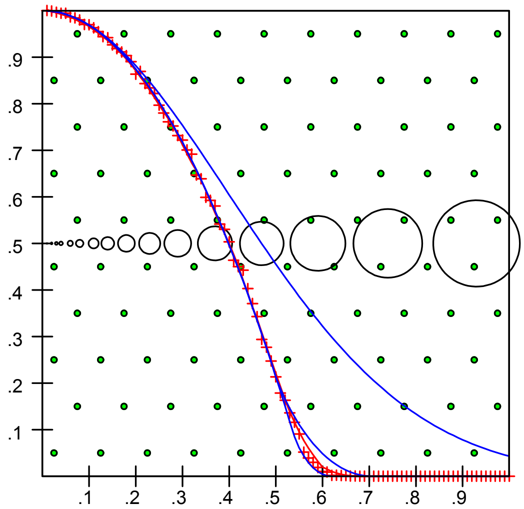


Figure A3.4b. Triangular lattice sampling design. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). 2000 randomizations for each target size. Rectangular target, fixed orientation. CCI ≈ 0.61and 0.44, respectively.

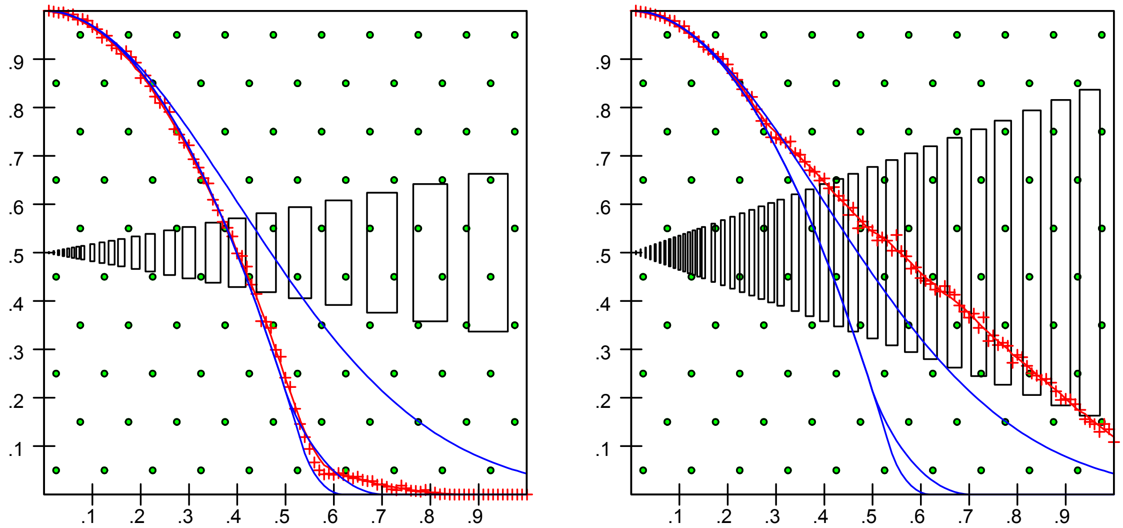


Figure A3.5a. Unaligned lattice design. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). 100 sampling points. 2000 randomizations for each target size. CCI ≈ 0.59.

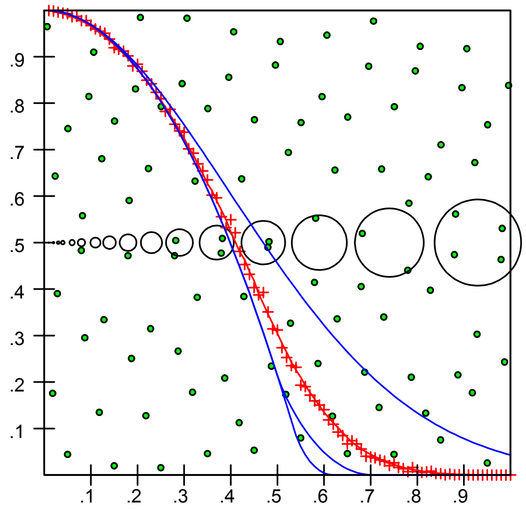
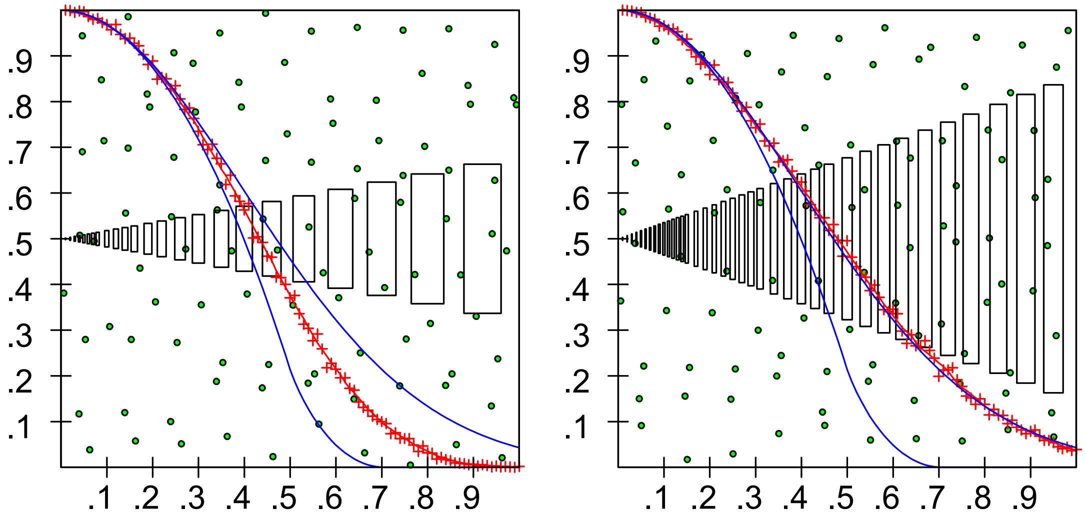


Figure A3.5b. Unaligned lattice design. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). Rectangular target 2:1 and 4:1; 2000 randomizations for each target size. The unaligned sampling strategy is more effective than random design for rectangles of moderate proportions. CCI ≈ 0.56 and 0.50, respectively.



Unaligned lattice design

The unaligned lattice is a combination of random design and systematic square lattice design. A random point is selected in the upper left square. In the square to the right, a new random north-coordinate is found, whereas the east-coordinate relative to the square corner is kept constant. The same procedure is repeated for the next row of squares. The technique is described in detail by Gilbert (1987). The random component will cause the effectiveness to vary somewhat between individual "layouts".

This method is superior to the ordinary, square lattice design if non-circular targets or several targets periodically distributed over the sampling area are to be detected. This method has been recommended as the generally best design by Berry and Baker (1968). However, for string-like hotspots, the design performs no better than the random design. The results of an application of this method are shown in Figures A3.5a and A3.5b.

Figure A3.6a. Random design with inhibition distance of 30 m. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). 2000 randomizations for each target size. CCI ≈ 0.57.

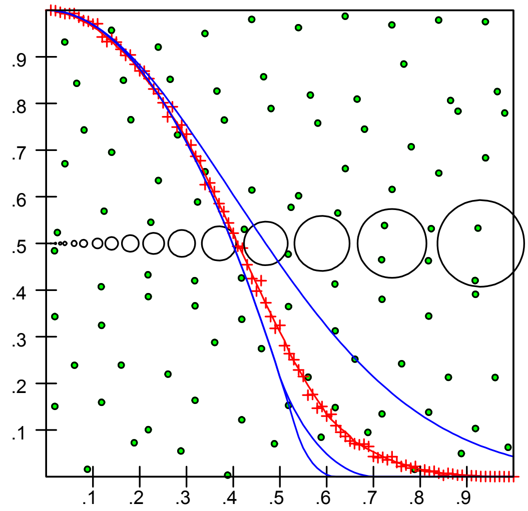
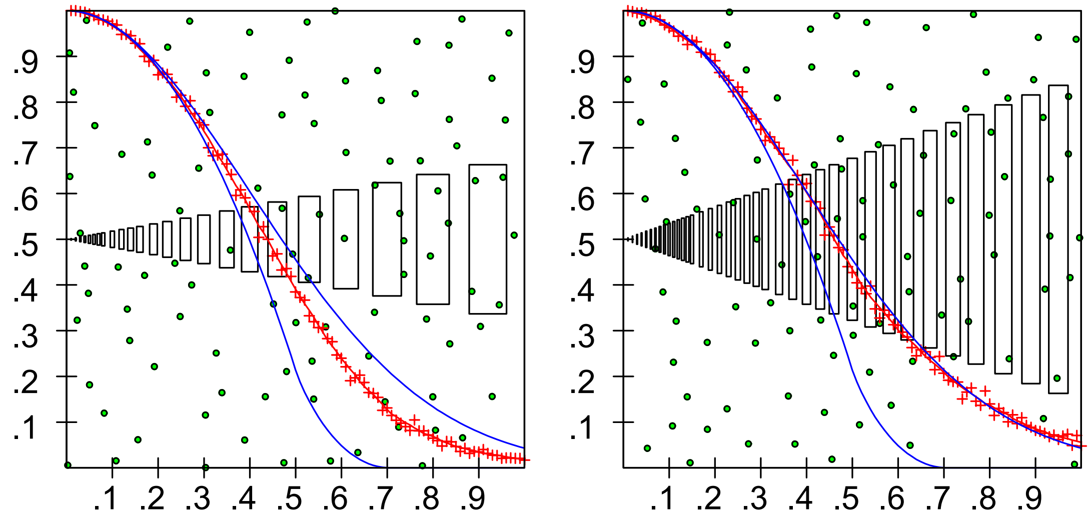


Figure A3.6b. Random design with inhibition distance of 30 m. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). Rectangular target 2:1 and 4:1; 2000 randomizations for each target size. Blue lines = theoretical risk to miss a circular target with random and square lattice design, respectively. CCI ≈ 0.55 and 0.51, respectively.



Random design with inhibition distance

Another approach to combine the advantages of a random and a regular design would be to start with a random design but not allow sampling points to coincide or to be too close, i.e., to set up a threshold distance between sampling points (inhibition distance in plant ecology literature) which must not be passed. This will lead to a more or less regular distribution with a random component depending on the length of the inhibition distance. The random component will lead to a somewhat varying performance of the sampling pattern achieved, but to a lesser extent than the pure random design. The results of an application of this method are shown in Figures A3.6a and A3.6b.

Figure A3.7a. Sobol sequence. Risk of missing target (y-axis) vs. standardized hotspot radius, R, of the target (x-axis). 2000 randomizations for each target size. CCI ≈ 0.57, 0.57.

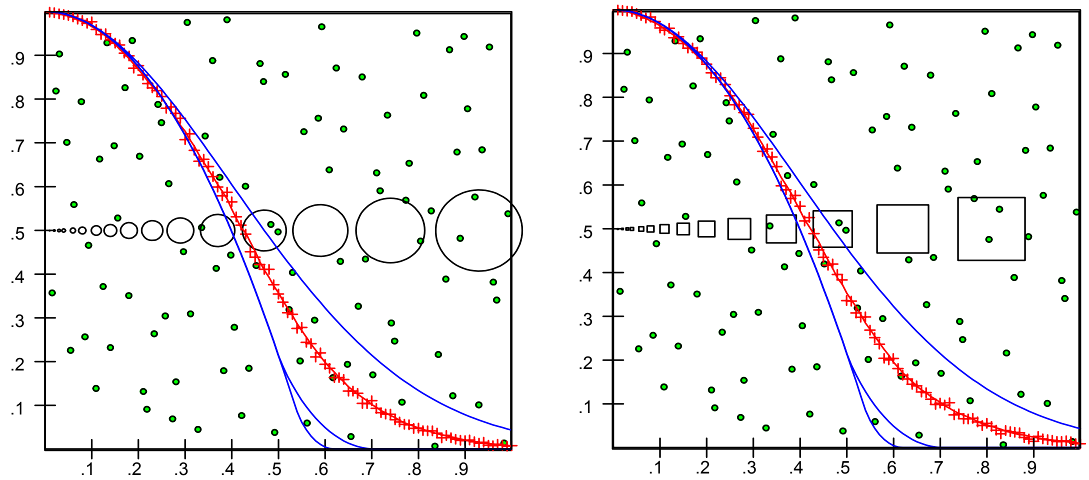
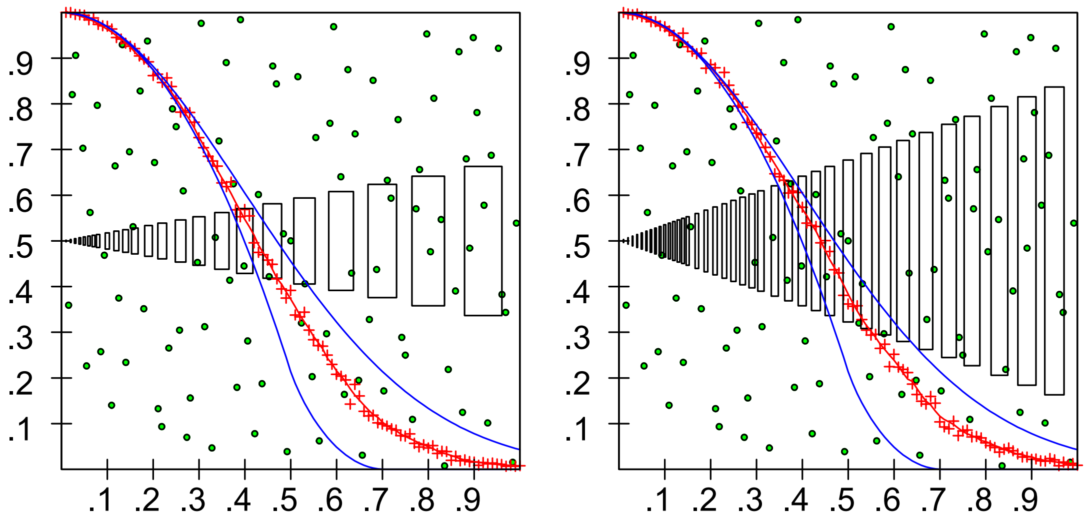


Figure A3.7b. Sobol sequence. Risk of missing target (y-axis) vs. standardized hotspot radius, *R*, of the target (x-axis). Rectangular target 2:1 and 4:1, respectively; 1000 randomizations for each target size. Whereas a square lattice sampling design is far less effective for a rectangular target compared to a circular target, there is no noticeable difference for a Sobol sequence. CCI ≈ 0.56 and 0.55, respectively.



Sobol sequence design

The Sobol sequence is called a quasi-random sequence and, though the visual appearance is similar to that of the random design with an inhibition distance (i.e., rather regular), the distribution is not random at all, but two consecutive sampling points in the sequence are "avoiding each other" and any new point will fill in a gap in the distribution but will never coincide with a previous sampling point. This seems to be a desirable property if dynamic sampling is applied and the sampling stops when the hotspot is found. The mathematical description of the method for generating the Sobol sequence is quite complicated, but a handy algorithm is provided by Press *et al.* (1992). As can be seen from the plot, this method is more effective than the random design. It is insensitive to target shape, even with extreme proportions. Since it is not random, the effectiveness will not vary between individual random "layouts" of the sampling points, but will still keep the beneficial properties of a random design in being insensitive to regularities in the target pattern or target shape. The results of an application of the Sobol sequence design are shown in Figures A3.7a and A3.7b.

Table A3.1. Proportion of the area above the estimated function in the figures of the total area and the percentage of success compared to the triangular lattice design for circular targets.

Design	Circular target shape, theoretical	Circular target shape	Square target	Rectangular 1:2	Rectangular 1:4
Random	0.506 (81 %)	0.508 (82 %)	0.500 (80 %)	0.507 (81 %)	0.508 (82 %)
Square lattice	0.617 (99 %)	0.616 (99 %)	0.627 (101 %)	0.441 (71 %)	0.225 (36 %)
Triangular lattice	0.623 (100 %)	0.621 (100 %)	0.625 (100 %)	0.613 (98 %)	0.435 (70 %)
Unaligned square lattice		0.586 (94 %)	0.592 (95 %)	0.562 (90 %)	0.504 (81 %)
Random inhibition dist.= 30 m		0.589 (94 %)	0.591 (95 %)	0.548 (88 %)	0.511 (82 %)
Sobol sequence		0.566 (91 %)	0.566 (91 %)	0.562 (90 %)	0.552 (89 %)

Summary

The overall results are shown in Table A3.1. The random design is superior to the square lattice design in detecting regular patterns or rectangular targets. On the other hand, its generally low performance makes it less valuable compared to methods combining both a random and a regular component. The square lattice performs very well for circular targets, but is much less sensitive for elongated objects. This fact makes the triangular lattice far superior to the square lattice. For string-like targets, however, the triangular lattice design may fail to be very effective.

The unaligned square lattice, the random with inhibition distance, and the Sobol sequence seem to be fairly robust for various target shapes, the Sobol sequence being the best for extreme proportions.

If no knowledge about the hotspot shape exists or if string-like shapes are suspected, the Sobol sequence may be an interesting alternative, taking also into account its qualities for dynamic sampling.

Acknowledgement

This report was prepared by A. Bignert, Swedish Museum of Natural History, Stockholm, Sweden.

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ANNEX 4: WEIGHTED SMOOTHERS FOR ASSESSING TREND DATA OF VARIABLE ANALYTICAL QUALITY

1 INTRODUCTION

In a paper presented to the 2001 meeting of the Marine Chemistry Working Group (MCWG), Nicholson *et al.* (2001) reviewed the implications for contaminant trend assessments of using data filters to remove data not supported by evidence of satisfactory analytical quality. They considered an alternative approach, where information about analytical performance is used to weight the trend data according to its accuracy.

Broadly, their conclusions were:

1) Although intuitive interpretation of *P* and *Z* scores relative to fixed values such as 2 provide a useful, informal guide to performance within a Quality Assurance (QA) exercise, a more formal approach should be used for filtering data from monitoring programmes. Reference values should reflect the numbers of observations used to calculate *P* and *Z* so that *p*-values for rejecting data remain constant between years and between laboratories.

2) In practice, given the levels of sampling and environmental variability observed for temporal monitoring data within the current OSPAR Joint Assessment and Monitoring Programme (JAMP), analytical variability tends to have only a small effect on the ability to detect trends.

3) Data-filtering criteria for the OSPAR JAMP programme could be less stringent, allowing more data to be assessed.

4) In terms of the ability to detect a linear trend, comparisons of four potential weighting strategies gave rankings: 1 *optimum*-; 2 *intuitive*-; 3 *equal*-; and 4 *zero-weighting* (i.e., deletion of *Poor* data). However, strategy 4 was by far the least efficient.

5) Since these different weighting strategies were demonstrated using synthetic data generated using defined levels of *Good* and *Poor* analytical performance, an example using real data should be presented.

Section 2 presents an example using QA and trend data for PCBs generated at the UK Burnham Laboratory. The example is very realistic, reflecting that historic information about analytical performance is often incomplete. Consequently, the QA weights in some years need to be estimated. For comparison, a simpler approach using intuitive weights is also applied.

Any practical solution to this problem will be a compromise between the need to develop and maintain good analytical practice, the needs of assessment groups to make the best use of submitted data, and for the correct application of statistical methods. In Section 3, a simple solution is proposed that attempts to satisfy all of these.

2 QA WEIGHTING APPLIED TO TRENDS IN PCBs IN COD FROM THE NORTH SEA

Table A4.2.1 summarizes the available ICES-7 PCB data for the period 1982–2000. As can be seen, the series of available QA data is very short relative to the trend series, with little overlap between them. Although it is statistically irresponsible, we will estimate values for the missing QA data, to show that it is possible and to demonstrate how this might be done.

Optimum-Weighted Analysis of Trend Data

The missing QA data can be estimated by assuming a simple model for between-year variation (bias) and within-year variation (precision). Bias is assumed to consist of both a systematic and a random component. Both of these may change with time. Precision is also allowed to change with time. A formal description of this model and the method of estimating its parameters are given in the Technical Annex, and in Nicholson and Fryer (2001).

The results for the data in Table A4.2.1 are summarized in Figures A4.2.1a and A4.2.1b. Figure A4.2.1a shows the QA annual means with their 95 % confidence intervals (vertical lines). Superimposed is the change in systematic bias (solid line) projected back to the start of the trend data (dashed line). For simplicity, the random bias component was assumed to be constant, and estimated to be 4 %. Similarly, Figure A4.2.1b shows the QA annual variances with their corresponding trend.

The results of the trend assessment are shown in Figure A4.2.2.

Intuitive-Weighted Analysis of Trend Data

For comparison, we consider a simpler analysis using intuitive down-weighting of data with poor performance or missing QA data and a different plotting symbol to signify the status of data in each year.

The following convention was adopted:

- satisfactory QA (closed circles): weight = 100 %;
- unsatisfactory QA (crossed open circles): weight = 50 %;
- missing QA (open circles): weight = 10 %.

Using simplistic targets for bias and precision of ±12.5 %, only the data for 1993 were considered to have unsatisfactory QA (Table A4.2.1). The resulting trend assessment is shown in Figure A4.2.3.

3 CONCLUSIONS AND RECOMMENDATIONS

The problem discussed here brings together three issues that are inextricably linked, but which are invariably treated separately. These are:

1) analytical performance, i.e., how well contaminants are measured;
2) monitoring performance, e.g., how well trends are detected; and
3) statistical assessment methodology, e.g., survey design and how trends are assessed.

Ideally, a monitoring programme would develop by first defining targets for, e.g., trend detection. For a particular survey design and method of trend assessment, this would imply a maximum level of variability in observed contaminant concentrations. In turn, this would identify a suitably small component of analytical variability, which laboratories would demonstrate in interlaboratory comparisons.

This tidy progression tends not to occur. Here, a statistical method is trying to accommodate data with unknown or variable analytical performance. Further, in the past these data have been filtered using criteria relevant to good laboratory practice independently of monitoring requirements.

The problem we must tackle is how to move closer to the ideal, making sensible analyses of the maximum amount of data.

It is demonstrated here how missing and variable analytical QA data could be incorporated into contaminant trend assessments. However, estimating the optimum weights cannot be recommended as a general procedure within a large assessment programme. The method may not be reliable when there are few QA data, and may give a spurious implication of statistical correctness. Also, from an analytical viewpoint, there is a point at which data stop being *variable* and become *meaningless*.

However, with sensible statistical guidance, a sub-optimal weighting system could be employed that:

- allows historic trend data (where QA data are missing) to be included in assessments;
- is statistically reliable; and
- responds to the need to maintain good analytical quality.

The following is proposed:

1) a simple four-tier system for analytical quality corresponding to, e.g., *Good*, *Poor*, *Unknown*, and *Unacceptable*. Within the trend assessment, corresponding data would be given weights w_{good}, w_{poor}, w_{unknown}, and zero (i.e., deleted);
2) that a procedure for identifying QA performance as *Good*, *Poor,* or *Unacceptable* should be a compromise between analytical, assessment, and statistical issues; and
3) similarly, that the values of w_{good}, w_{poor}, and w_{unknown} are determined taking account of the analytical, assessment, and statistical implications of this compromise.

4 ACKNOWLEDGEMENT

This paper was prepared by M. Nicholson, CEFAS, Lowestoft, UK, and R. Fryer, FRS Marine Laboratory, Aberdeen, UK. The authors express thanks to Colin Allchin at the CEFAS Burnham Laboratory for providing the PCB QA data.

5 REFERENCES

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Table A4.2.1. Environmental and QA data on PCBs from 1982–2000.

Year		QA data		Monitoring Data
	Replicates	Relative Mean %	Relative Standard Deviation %	Annual PCB Index mg kg^{-1}
1982	-	-	-	14.4
1983	-	-	-	12.6
1984	-	-	-	-
1985	-	-	-	6.67
1986	-	-	-	7.62
1987	-	-	-	5.26
1988	-	-	-	8.00
1989	-	-	-	7.94
1990	-	-	-	4.36
1991	-	-	-	5.09
1992	-	-	-	-
1993	3	73	16.3	2.73
1994	12	98	12.3	6.25
1995	21	96	8.4	-
1996	27	100	5.8	2.98
1997	35	100	7.8	-
1998	33	103	9.1	-
1999	26	103	6.0	-
2000	9	99	3.9	-

Figures A4.2.1. (a) QA annual means with their 95 % confidence intervals (vertical lines, with superimposed change in systematic bias (solid line)) projected back to the start of the trend data (dashed line). (b) QA annual variances with their corresponding trend.

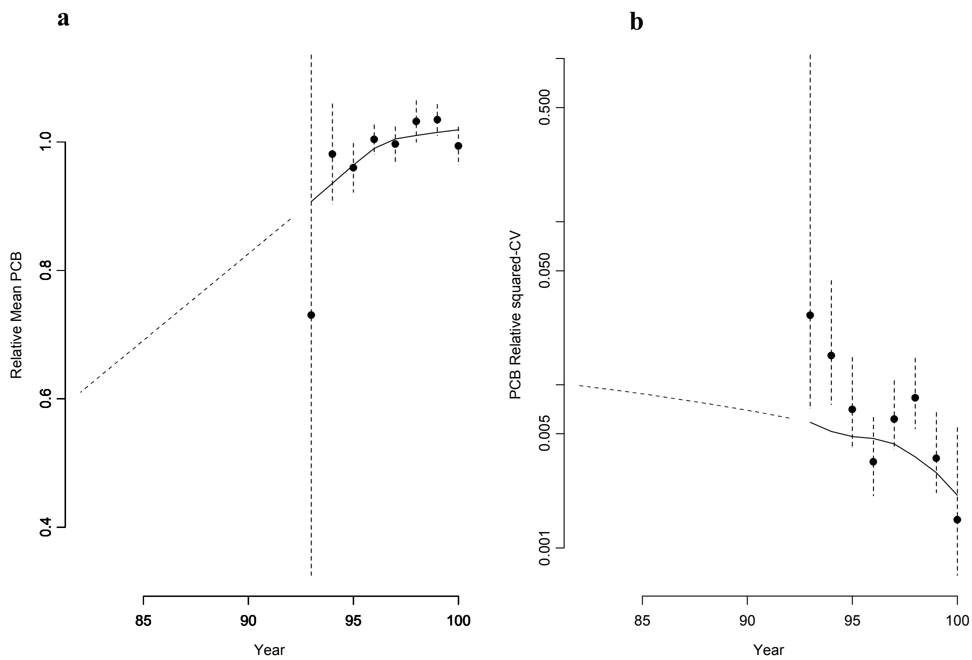


Figure A4.2.2. Weighted trend in PCBs using estimated optimum weights.

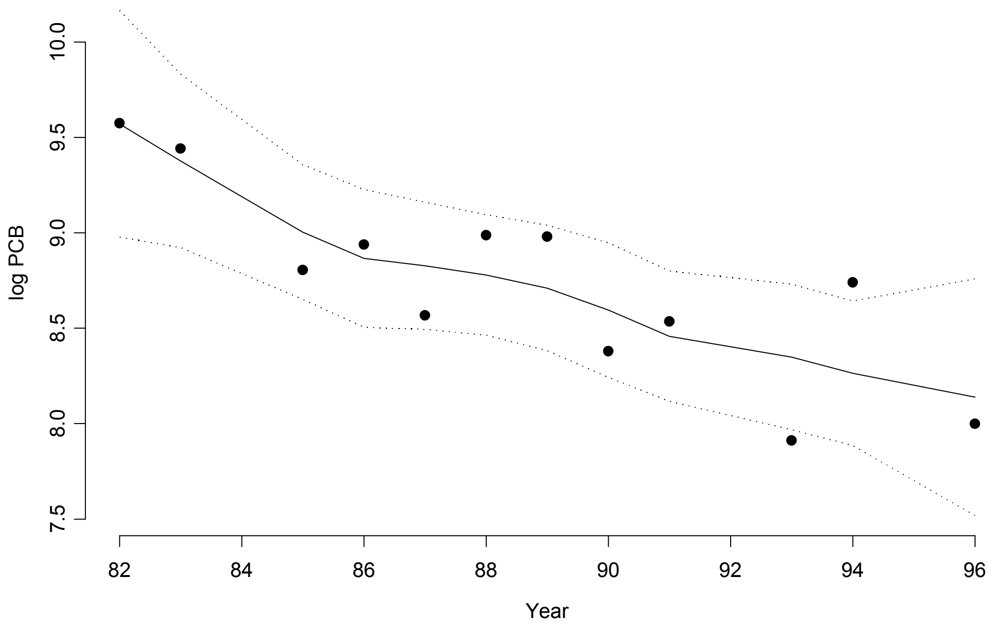
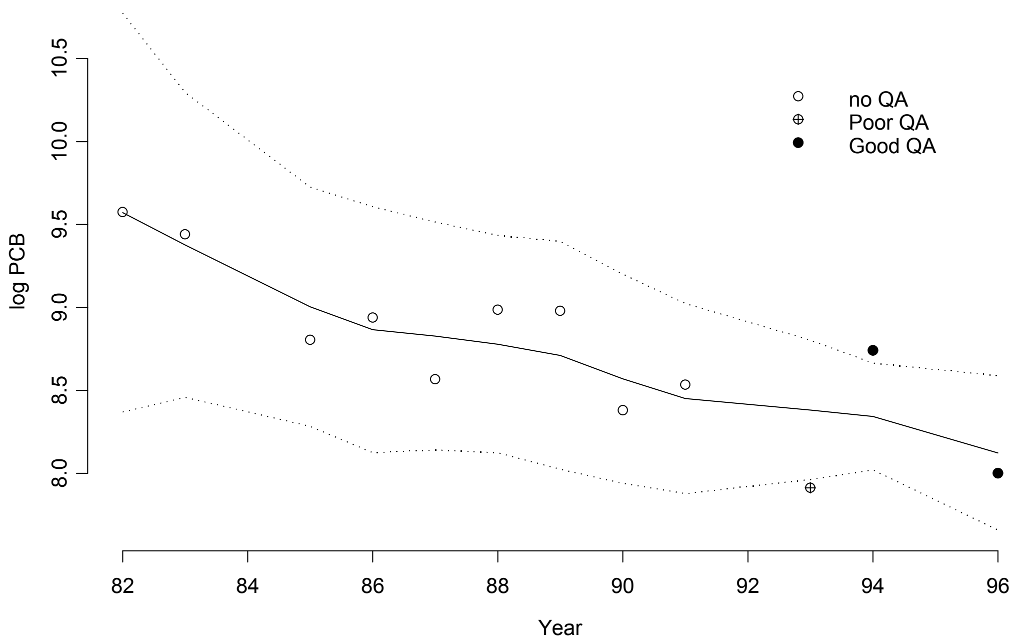


Figure A4.2.3. Weighted trend in PCBs using intuitive weights.



Technical Annex to Annex 4

Weighting Procedures for Assessing Trend Data of Variable Analytical Quality

Analysis of QA data

A simple model for the observed mean (m_y) and variance (v_y) estimated from n_y replicates in year y is

$$m_y = f(y) \times \mu + \varepsilon_y$$

where ε_y is a random component of bias in year y with zero mean and variance given by

$$V[\varepsilon_y] = g(y) \times {\sigma_b}^2 + h(y) \times \sigma_w^2 / n_y$$

where $g(y)$ represents the trend in the between-year variance ${\sigma_b}^2$. The mean for v_y is given by

$$E[v_y] = h(y) \times {\sigma_w}^2$$

where $h(y)$ represents the trend in the within-year variance ${\sigma_w}^2$.

For simplicity here, we will assume that $g(y) = 1$, i.e., there is no trend in ${\sigma_b}^2$.

The true mean μ is estimated by the overall mean. The trend in the bias, $f(y)$, and the between-year variance, ${\sigma_b}^2$, are estimated using the EM-algorithm described in Nicholson and Fryer (2001) for a weighted smoother of m_y on y with weights estimated by

$$w_y = \frac{1}{\sigma_b^2 + v_y / n_y}.$$

The trend in the within-year variance, $h(y)$, is estimated using a weighted smoother of v_y on y with weights estimated by

$$w_y = \frac{n_y - 1}{2{v_y}^2}.$$

Analysis of Trend Data

Having estimated the annual components of analytical variance, these were used to construct the component of analytical variance in the annual trend index (assuming individual analyses of an annual sample of 25 fish), i.e.,

$$\sigma_{ay}^2 = \hat{\sigma}_b^2 + \hat{h}(y)\hat{\sigma}_w^2 / 25$$

with total variance given by

$$\psi^2 v_t = \sigma_e^2 \;\; + \sigma_{at}^2$$

where σ_e^2 is the unknown and constant environmental variance (including sampling variability), and σ_{at}^2 is the (now assumed known) total analytical variance. Equating

$$\psi^2 = \sigma_e^2$$

and

$$v_t = 1 + \frac{\sigma_{at}^2}{\sigma_e^2}$$

the optimum weights are given by

$$w_t = v_t^{-1} = \frac{\sigma_e^2}{\sigma_e^2 + \sigma_{at}^2}.$$

The variance components are again estimated using the EM-algorithm.

ANNEX 5: NOTE ON THE IMPACT OF SYSTEMATIC BIAS TO THE WEIGHTED LOESS SMOOTHER

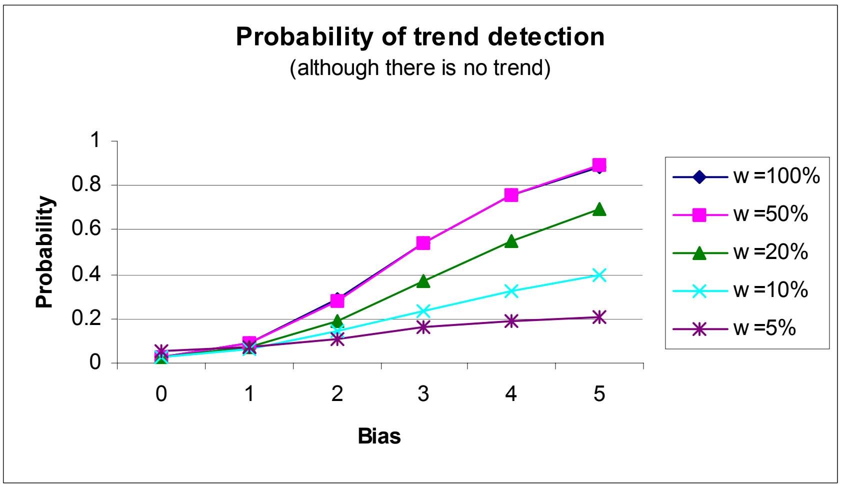
A weakness of any method for trend analysis is the assumption that all measurements are unbiased. If the lack of quality control corresponds to a period of constant bias, then including these points in the trend assessment will induce a spurious trend (see Nicholson and Fryer, 2001). This holds not only for unweighted, but also for weighted, trend analysis. In order to quantify this effect, a simulation study based on a series of 12 years is undertaken. The actual significance level is calculated for the linear trend test based on the weighted LOESS smoother using fixed (intuitive) weights.

The model applied is as follows: $Y_t = \mu_t + b_t + \varepsilon_t$, for t=1,…,12, with the true underlying trend μ_t, the analytical bias b_t, and the Normally distributed random error ε_t, with standard deviation σ_t.

The settings for the simulation study are described in the following table:

Year t	True trend μ_t	Analytical bias b_t	Standard deviation σ_t	Weight
1	10	b	2	w
2	10	b	2	w
3	10	b	2	w
4	10	b	2	w
5	10	b	2	w
6	10	b	2	w
7	10	0	1	100 %
8	10	0	1	100 %
9	10	0	1	100 %
10	10	0	1	100 %
11	10	0	1	100 %
12	10	0	1	100 %

Settings for bias b and weight w are b = 0,1,2,3,4,5 and weight w = 100 %, 50 %, 10 %, and 5 %. The actual significance level for each of these settings is presented in the following figure (formal significance level = 5 %).



Apparently even with very small weights of 5–20 % there is a high risk of obtaining significant spurious trends. It seems that weighting is not appropriate to deal with biased data, especially if the beginning or the end of the time series is biased. Therefore, it is recommended not to include data with unknown QA into the trend analysis, and a prerequisite for any trend analysis should be that data are not biased with regard to sampling or chemical analysis.

Acknowledgement

This paper was prepared by S. Uhlig, quodata, Dresden, Germany.

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ANNEX 6: STUDIES CARRIED OUT IN ICES MEMBER COUNTRIES ON THE RELATIONSHIP BETWEEN ENVIRONMENTAL CONTAMINANTS AND SHELLFISH PATHOLOGY

SUMMARY

Several shellfish diseases, with the potential to cause deleterious impacts on shellfish populations, have been associated with exposure to environmental contaminants. Most of these conditions have a multifactorial aetiology and may be triggered by a variety of natural and anthropogenic factors. New molecular biological tools are currently being used to investigate the effects of environmental contaminants on genes of the p53 family that may be involved in the pathogenesis of haemic and gonadal neoplasias in bivalve species. Stereological and histochemical techniques are used to explore the link between exposure to environmental contaminants and digestive atrophy in marine bivalves. Imposex in gastropods has been used successfully to monitor levels of tributyltin (TBT) in the marine environment. In some areas, parasitic infections or genetic adaptation may alter the prevalence of imposex. The potential of gastropods to be used to monitor the levels of endocrine-disrupting substances other than TBT is under investigation. Multivariate analyses of the relationship between the prevalence and intensity of parasite infections in oysters have revealed a strong influence of large-scale climatic changes on these infections but have failed to reveal a clear effect of environmental contaminants. Few examples of field studies exist to show which exposures to contaminants can be linked to increased incidence of diseases in invertebrate species. Field and laboratory studies on the effects of environmental contaminants on the immune system of invertebrates are under way.

1 HAEMIC NEOPLASIA

The cause of the disease is unknown; possibly it is due to a virus. Haemic neoplasia was transmitted to healthy clams by injection with whole neoplastic haemocytes but not with cell-free filtrates. Reverse transcriptase activity was demonstrated in haemolymph with high numbers of neoplastic haemocytes (House *et al*., 1998). It may cause heavy mortalities and the severity appears to increase with age. The disease may also be temperature related, with the highest prevalences being recorded in the autumn and winter.

High frequencies of haemic neoplasia are often found in association with high levels of environmental contaminants such as pesticides or PCBs. However, high prevalences have also been reported from sites with no evident industrial or agricultural contamination (McGladdery *et al*., in preparation). A parallel distribution of disseminated neoplasia and the presence of certain dinoflagellate biotoxins has also been reported (Landsberg, 1996).

1.1 Current Studies in *Mya arenaria* and Other Clams

In 1999, 95 % prevalence of advanced haemic neoplasia with mortalities was detected in softshell clam populations in Prince Edward Island, Canada (McGladdery *et al*., in preparation). Environmental factors at positive and negative sites are being studied at the Atlantic Veterinary College to see whether there are any common parameters. Preliminary transmission experiments in 2001 suggested an infectious agent; however, field-based proximity challenges and repeat experiments have been inconclusive. Significant levels of the disease were also found in clams from Sydney Mines, NS, and Kitimat Arm, BC, and at sites along the east coast of the U.S. with high levels of anthropogenic substances. Environmentally induced alterations in p53 may contribute to the pathogenesis of leukemia in *M. arenaria* in polluted environments. Analysis of the p53 gene obtained from PCB-exposed softshell clams revealed a mutation in exon 6 (Barker *et al*., 1997). Monoclonal antibodies belonging to the 1E10 series have been shown to react with neoplastic cells but not with healthy cells (Stephens *et al*., 2001). These proteins have possible linkages to the p53 gene family. The appearance of p73 and the disappearance of p97 coincided with leukemia-specific protein synthesis. In contrast, levels of p53 remain constant (Stephens *et al*., 2001; Kelley *et al*., 2001).

1.2 Current Studies in *Mytilus edulis*

Haemic neoplasia is endemic to mussel populations in Puget Sound, Washington. No relationship between the body burden of environmental contaminants and the prevalence of haemic neoplasia in mussels has been identified. To evaluate the short-term ability of chemical contaminants to induce haemic neoplasia, mussels were fed microencapsulated polycyclic aromatic hydrocarbons (PAHs) or polychlorinated biphenyls (PCBs) and the prevalence of neoplasia was assessed after 30 days or 180 days of exposure. No significant change in the prevalence of the disease was detected in treated mussels compared to controls. Thus, there is no experimental evidence that chemical contaminants induce or promote the development of haemic neoplasia in these mussels (Krishnakumar *et al*., 1999).

2 GONADAL NEOPLASIA

The cause of this condition in mussels is unknown and it is relatively rare compared with haemic neoplasia. The relationship between sex, size, season, reproductive cycle and with the occurrence of gonadal neoplasia has been described. Gonadal neoplasia has also been studied in relation to environmental contaminants, such as from oil spills and herbicides (Hillman *et al*., 1992; Hillman, 1993). Advanced stages of the disease in other bivalves (softshell clams, see below) limit gamete development, but this does not appear to be a significant factor for mussels due to the relative rarity of the condition. A parallel in the distribution and incidence of germinomas and blooms of toxin-producing dinoflagellates (*Alexandrium* sp.) has also been reported (Landsberg, 1996).

2.1 Current Studies in *Mytilus galloprovincialis*

Gonadal neoplasia was found in several specimens of *Mytilus galloprovincialis* collected from the Ria de Vigo (northwest Spain) (Alonso *et al*., 2001). The highest prevalence was found in the spring, coincidental with mussel raft cleaning and maintenance. More studies are needed to evaluate the potential carcinogenic effects of the chemical substances used in raft maintenance.

2.2 Current Studies in *Mya arenaria* and Other Clams

The relationship between gonadal neoplasia and exposure to environmental contaminants is under investigation at the University of Maine (Barber, 1996; Barber and Bacon, 1999), and the U.S. Environmental Protection Agency laboratory in Narragansett, RI. One epidemiological investigation identified the prevalence of gonadal cancers as high as 40 % in softshell clams (*Mya arenaria*) in Maine and 60 % in hardshell clams (*Mercenaria* spp.) from Florida. In the same geographical areas, human mortality rates with ovarian cancer were significantly higher than the national average. NIH3T/ transfection assays were used to examine DNA isolated from these molluscan tumours for the presence of activated oncogenes. DNAs isolated from advanced tumours in both species were able to transform NIH3T3 cells and induce tumours in athymic mice. Studies are under way to identify the gene identified in this assay (Van Beneden, 1994).

Clams were exposed to 2,4-D (2,4-dichlorophenoxy-acetic acid) and to TCDD (2,3,7,8-tetrachlorodibenzo-*p*-dioxin) with or without DEN and were sacrificed six months after exposure. Although histological analysis did not indicate tumour formation, both 2,4-D and TCDD inhibited gametogenesis to an extent that gender was indeterminate (Butler *et al*., 2001). The expression of Ahr, E3, p53, and p73 was analysed in normal and neoplastic gonadal tissue from an affected population of Maine. Preliminary results indicate that tumourous tissue expressed higher levels of E3, an ubiquitin-protein ligase that may potentially target p53 for degradation. There is an inverse relationship between E3 and p53 (Harring *et al*., 2001).

3 IMPOSEX AND INTERSEX

Imposex and intersex in gastropods has been successfully used as a biological-effect monitoring system to determine the degree of environmental tributyltin (TBT) pollution (Matthiessen and Gibbs, 1998). Continuing use of TBT on large vessels is causing problems despite the widespread ban on the use of TBT on smaller boats (for example, Bright *et al*., 2001, around Vancouver Island, Canada).

In some areas, parasitic infections or genetic disorders may interfere with the monitoring of TBT-related imposex in gastropods. In the northern Gulf of St. Lawrence, Canada, the castrating trematode, *Neophasis* sp., may cause atrophy of the penis in the male common whelk, *Buccinum undatum* (Tetreault *et al*., 2000). Elevated levels of imposex have also been found in dogwhelk (*Nucella lapillus*) collected in areas adjacent to a gull roost. Compounds in the birds' excreta and/or parasites may have caused the imposex (Evans *et al*., 2000). A genetic disorder, "Dumpton syndrome", was found in several populations of *N. lapillus* sampled at 56 stations along the coast of Galicia from 1996 to 1998 (Quintela *et al*., 2001; Barreiro *et al*., 1999). "Dumpton's syndrome" is the name given to a dogwhelk mutation found near to Dumpton, Ramsgate, UK, in the early 1990s (Gibbs, 1993). It causes a reduction in penis size in males. The population of dogwhelks almost disappeared from the area owing to TBT coming from nearby ships. This mutation appears to protect the females from imposex. This syndrome was also found in 1992 in *N. lapillus* populations in the vicinity of Brest, France (Huet *et al*., 1996).

The effects of various endocrine-disrupting chemicals on freshwater and marine pseudobranch species (*Nucella lapillus, Nassarius reticulatus*) were analysed in laboratory experiments. Xeno-estrogens (e.g., bisphenol A, octylphenol) primarily cause induction of superfemales, resulting in an increased female mortality by the enhancement of spawning mass and egg production. Male sex organs may be reduced. Xeno-androgens (triphenyltin, tributyltin) cause virilization of females (imposex) and a marked decrease in fecundity. Anti-androgens (cyproterone acetate, vinclozolin) have less effect, causing reduced male sexual organs and suppression of imposex development (Tillmann *et al*., 2001). Thus, morphological changes in the genital tract of gastropods may be used to monitor exposure to endocrine-disrupting compounds other than tributytin.

4 INTENSITY OF PARASITIC INFECTION AS AN INDICATOR OF ENVIRONMENTAL HEALTH

As part of the NOAA Mussel Watch Program, oysters and mussels are sampled yearly from the East, West, and Gulf Coasts of the United States and the Great Lakes. Biological responses are evaluated in parallel to the concentrations of metals, PAHs, and pesticides.

Scientists at the State University of New Jersey have examined the influence of climate change and contaminant body burden on the prevalence and intensity of infection of oysters by various parasites. Their studies reveal that the intensity of parasitic infections was strongly influenced by large-scale climatic changes. In the Gulf of Mexico, the health of each oyster population sampled was evaluated by measuring size, condition index, reproductive stage, and the prevalence and intensity of infection by the parasite responsible for "Dermo" disease, *Perkinsus marinus*. Length, condition index, reproductive stage, and *P. marinus* infection intensity were characterized by strong concordance in interannual variations between 1986 and 1990, when a strong El Niño/La Niña shift occurred, and a weak concordance in the period of 1990–1993, characterized by weak climatic shifts (Kim and Powell, 1998). The distribution of some contaminants, particularly metals, also appears to be markedly influenced by weather and less by watershed-dependent processes, such as land use and river flow. This may be correlated to food supply and feeding rates being influenced by climatic changes, thereby affecting the body burdens of contaminants (Kim *et al*., 2001).

Mussels are often exposed in their natural habitat to high hydrocarbon concentrations from petroleum seep and, thus, offer the opportunity to examine the relationship between parasitism, disease, and contaminant exposure. The parasitic fauna was highly variable between populations. Forty percent of the populations were severely reproductively compromised by a *Bucephalus* sp. digenean flatworm infection. Variation in two parasite infection levels: gill ciliates and *Bucephalus* sp., explained most of the variation in PAH body burden between mussel populations. PAHs are known to be sequestered preferentially in gametic tissue. *Bucephalus* sp. may reduce the PAH body burden by replacing gametic tissue (Powell *et al*., 1999).

5 DIGESTIVE GLAND ATROPHY

Digestive gland atrophy has been observed in bivalves exposed to a variety of contaminants. This condition has been correlated with contaminant burdens, disease, condition, and nutritional states. Cell-type replacement in the digestive gland of mussels in response to pollution is under investigation (Ferreira and Bebianno, 2000; Soto *et al*., 2001; Syasina *et al*., 1997). Both the severity of the atrophic changes observed and the type of cells that are affected may be typical of a pollutant-induced response, compared with physiological changes associated with nutrition (Winstead, 1995). Histochemical and stereological techniques are used to characterize the changes associated with exposure to environmental contaminants. For example, auto-metallography, stereology of the lysosomes, and morphometry of the digestive epithelia were used to demonstrate the effect of metal contamination in mussels (*Mytilus galloprovincialis*) transplanted from a relatively pristine site to a polluted one in the Lagoon of Venice (Italy) (Da Ros *et al*., 2000).

The seasonal and the site-specific variations in the structure of peroxisomes and in the activity of the peroxisomal marker enzyme catalase in digestive epithelial cells of mussels were studied in mussels sampled monthly for fourteen months in two Basque estuaries with different degrees of pollution. Stereological procedures were applied to detect changes in peroxisome structure in response to organic pollution. Further studies are needed before changes in peroxisomal structure can be used as a biomarker to assess environmental quality (Orbea *et al*., 1999).

6 EFFECT OF CONTAMINANTS ON THE FUNCTION OF THE IMMUNE SYSTEM

Few examples of field studies exist for which exposure to contaminants can be linked to increased incidence of diseases in invertebrate species. More research is needed on the effects of natural factors (gonad maturation, temperature, nutrition, and stress) on the immune function of invertebrates and on the relationship between observed changes in immunological responses and incidence of diseases in natural populations. The relative simplicity of invertebrate immune functions offers a good model to study the complex interactions between exposure to environmental contaminants and immune dysfunction (Galloway and Depledge, 2001). Investigations are under way. For example, in France, a scientist at IFREMER is studying the correlation of summer mortalities of *Crassostrea gigas* with environmental contaminants and immunotoxicity. Preliminary studies carried out after the "Erika" wreck indicate that ciliates are more abundant in mussels, and fungal infections increased in the cockle, *Cerastoderma edule,* after the oil spill. In Canada, a scientist is studying the immune responses of bivalves exposed *in situ* to pulp mill and municipal effluents.

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ANNEX 7: ICES GUIDELINES FOR THE MANAGEMENT OF MARINE SEDIMENT EXTRACTION[1]

Introduction

In many countries, sand and gravel[2] dredged from the seabed makes an important contribution to the national demand for aggregates, directly replacing materials extracted from land-based sources. This reduces the pressure to work land of agricultural importance or environmental and hydrological value, and where materials can be landed close to the point of use, there can be additional benefits of avoiding long-distance over-land transport. Marine dredged sand and gravel is also increasingly used in flood and coastal defence, and land reclamation schemes. For beach replenishment, marine materials are usually preferred from an amenity point of view, and are generally considered to be the most appropriate economically, technically, and environmentally.

However, these benefits need to be balanced against the potential negative impacts of aggregate dredging. Aggregate dredging activity, if not carefully controlled, can cause significant damage to the seabed and its associated biota, to commercial fisheries and to the adjacent coastlines, as well as creating conflict with other users of the sea. In addition, current knowledge of the resource indicates that while there are extensive supplies of some types of marine sand, there appear to be more limited resources of gravel suitable, for example, to meet current concrete specifications and for beach nourishment.

Against the background of utilizing a finite resource, with the associated environmental impacts, it is recommended that regulators develop and work within a strategic framework which provides a system for examining and reconciling the conflicting claims on land and at sea. Decisions on individual applications can then be made within the context of the strategic framework.

General principles for the sustainable management of all mineral resources overall include:

- conserving minerals as far as possible, whilst ensuring that there are adequate supplies to meet the demands of society;
- encouraging their efficient use (and, where appropriate, re-use), minimizing wastage, and avoiding the use of higher quality materials where lower grade materials would suffice;
- ensuring that methods of extraction minimize the adverse effects on the environment, and preserve the overall quality of the environment once extraction has ceased;
- protecting sensitive areas and industries, including fisheries, important habitats (such as marine conservation areas), and the interests of other legitimate users of the sea; and
- preventing unnecessary sterilization of mineral resources by other forms of development.

The implementation of these principles requires a knowledge of the resource, and an understanding of the potential impacts of its extraction and of the extent to which rehabilitation of the seabed is likely to take place. The production of an Environmental Statement, developed along the lines suggested below, should provide a basis for determining the potential effects and identifying possible mitigating measures. There will be cases where the environment is too sensitive to disturbance to justify the extraction of aggregate, and unless the environmental and coastal issues can be satisfactorily resolved, extraction should not normally be allowed.

It should also be recognized that improvements in technology may enable exploitation of marine resources from areas of the seabed which are not currently considered as reserves, while development of technical specifications for concrete, etc., may in the future enable lower quality materials to be used for a wider range of applications. In the shorter term, continuation of programmes of resource mapping may also identify additional sources of coarser aggregates.

Scope

It is recognized that sand and gravel extraction, if undertaken in an inappropriate way, may cause significant harm to the marine and coastal environment. There are a number of international and regional initiatives that should be taken into account when developing national frameworks and guidelines. These include the Convention on Biological Diversity (CBD), EU Directives (particularly those on birds, EIA, and habitats) and other regional conventions/agreements, in particular, the OSPAR and Helsinki Conventions, and initiatives pursued under them. This subject, for example, has recently been included in the Action Plan for Annex V to the 1992 OSPAR Convention on the "Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area" as a human activity requiring assessment.

Administrative framework

It is recommended that countries have an appropriate framework for the management of sand and gravel

[1] These guidelines do not relate to navigational dredging (i.e., maintenance or capital dredging).

[2] It is recognized that other materials are also extracted from the seabed, such as stone, shell and maerl, and similar considerations should apply to them.

extraction and that they define and implement their own administrative framework with due regard to these guidelines. There should be a designated regulatory authority to:

- issue authorization, having fully considered the potential environmental effects;
- be responsible for compliance monitoring;
- develop the framework for monitoring;
- enforce conditions.

Environmental impact assessment

The extraction of sand and gravel from the seabed can have significant physical and biological effects on the marine and coastal environment. The significance and extent of the environmental effects will depend upon a range of factors including the location of the extraction area, the nature of the surface and underlying sediment, coastal processes, the design, method, rate, amount and intensity of extraction, and the sensitivity of habitats, fisheries, and other uses in the locality. These factors are considered in more detail below. Particular consideration should be given to sites designated under international, European, national, and local legislation, in order to avoid unacceptable disturbance or deterioration of these areas for the habitats, species, and other designated features.

To enable the organization(s) responsible for authorizing extraction to evaluate the nature and scale of the effects and to decide whether a proposal can proceed, it is necessary that an adequate assessment of the environmental effects be carried out. It is important, for example, to determine whether the application is likely to have an effect on the coastline, or have potential impact on fisheries and the marine environment.

The Baltic Marine Environment Protection Commission (Helsinki Commission) adopted HELCOM Recommendation 19/1 on 26 March 1998. This recommends to the Governments of Contracting Parties that an environmental impact assessment (EIA) should be undertaken in all cases before an extraction is authorized. For EU Member States, the extraction of minerals from the seabed falls within Annex II of the "Directive on the Assessment of the Effects of Certain Public and Private Projects on the Environment" (85/337/EEC)[3]. As an Annex II activity, an EIA is required if the Member State takes the view that one is necessary. It is at the discretion of the individual Member States to define the criteria and/or threshold values that need to be met to require an EIA. The Directive was amended in March 1997 by Directive 97/11/EC. Member States are obliged to transpose the requirements of the Directive into national legislation by March 1999.

It is recommended that the approach adopted within the EU be followed. Member States should therefore set their own thresholds for deciding whether and when an EIA is required.

Where an EIA is considered appropriate, the level of detail required to identify the potential impacts on the environment should be carefully considered and identified on a site-specific basis. An EIA should normally be prepared for each extraction area, but in cases where multiple operations in the same area are proposed, a single impact assessment for the whole area may be more appropriate, which takes account of the potential for any cumulative impacts. In such cases, consideration should be given to the need for a strategic environmental assessment.

Consultation is central to the EIA process. The framework for the content of the EIA should be established by early consultation with the regulatory authority, statutory consultees, and other interested parties. Where there are potential transboundary issues, it will be important to undertake consultation with the other countries likely to be affected, and the relevant Competent Authorities are encouraged to establish procedures for effective communication.

As a general guide, it is likely that the topics considered below will need to be addressed.

Description of the physical setting

The proposed extraction area should be identified by geographical location, and described in terms of:

- the bathymetry and topography of the general area;
- the distance from the nearest coastlines;
- the geological history of the deposit;
- the source of the material;
- type of material;
- sediment particle size distribution;
- extent and volume of the deposit;
- the stability and/or natural mobility of the deposit;
- thickness of the deposit and evenness over the proposed extraction area;
- the nature of the underlying deposit, and any overburden;
- local hydrography including tidal and residual water movements;
- wind and wave characteristics;

[3] EIA Directive

- average number of storm days per year;
- estimate of bed-load sediment transport (quantity, grain size, direction);
- topography of the seabed, including occurrence of bedforms;
- existence of contaminated sediments and their chemical characteristics;
- natural (background) suspended sediment load under both tidal currents and wave action.

Description of the biological setting

The biological setting of the proposed extraction site and adjacent areas should be described in terms of:

- the flora and fauna within the area likely to be affected by aggregate dredging (e.g., pelagic and benthic community structure), taking into account temporal and spatial variability;
- information on the fishery and shellfishery resources including spawning areas with particular regard to benthic spawning fish, nursery areas, over-wintering grounds for ovigerous crustaceans, and known routes of migration;
- trophic relationships (e.g., between the benthos and demersal fish populations by stomach content investigations);
- the presence of any areas of special scientific or biological interest in or adjacent to the proposed extraction area, such as sites designated under local, national, or international regulations (e.g., Ramsar sites, the UNEP "Man and the Biosphere" Reserves, World Heritage sites, Marine Protected Areas (MPAs), Marine Nature Reserves, Special Protection Areas (EU Birds Directive), or the Special Areas of Conservation (EU Habitats Directive)).

Description of the proposed aggregate dredging activity

The assessment should include, where appropriate, information on:

- the total volume to be extracted;
- proposed maximum annual extraction rates and dredging intensity;
- the expected lifetime of the resource and proposed duration of aggregate dredging;
- the aggregate dredging equipment to be used;
- the spatial design and configuration of aggregate dredging (i.e., the maximum depth of deposit removal, the shape and area of resulting depression);
- substrate composition on cessation of aggregate dredging;
- proposals to phase (zone) operations;
- whether on-board screening (i.e., rejection of fine or coarse fractions) will be carried out;
- the number of dredgers operating at a time;
- the routes to be taken by aggregate dredgers to and from the proposed extraction area;
- the time required for aggregate dredgers to complete loading;
- the number of days per year on which aggregate dredging will occur;
- whether aggregate dredging will be restricted to particular times of the year or parts of the tidal cycle;
- the direction of aggregate dredging (e.g., with or across tide).

It may be appropriate, when known, also to include details of the following:

- energy consumption and gaseous emissions;
- ports for landing materials;
- servicing ports;
- on-shore processing and onward movement;
- project-related employment.

Information required for physical impact assessment

To assess the physical impacts, the following should be considered:

- implications of extraction for coastal and offshore processes, including possible effects on beach draw down, changes to sediment supply and transport pathways, changes to wave and tidal climate;
- changes to the seabed topography and sediment type;
- exposure of different substrates;
- changes to the behaviour of bedforms within the extraction and adjacent areas;
- potential risk of release of contaminants by aggregate dredging, and exposure of potentially toxic natural substances;
- transport and settlement of fine sediment disturbed by the aggregate dredging equipment on the seabed, and from hopper overflow or on-board processing and its impact on normal and maximum suspended load;
- the effects on water quality mainly through increases in the amount of fine material in suspension;
- implications for local water circulation resulting from removal or creation of topographic features on the seabed;

- the time scale for potential physical "recovery" of the seabed.

Information required for biological impact assessment

To assess the biological impact, the following information should be considered:

- changes to the benthic community structure;
- effects of aggregate dredging on pelagic biota;
- effects on the fishery and shellfishery resources including spawning areas with particular regard to benthic spawning fish, nursery areas, over-wintering grounds for ovigerous crustaceans, and known routes of migration;
- effects on trophic relationships (e.g., between the benthos and demersal fish populations);
- effects on sites designated under local, national, or international regulations (see above);
- predicted rate and mode of recolonization, taking into account initial community structure, natural temporal changes, local hydrodynamics, and any predicted change of sediment type;
- effects on marine flora and fauna including seabirds and mammals;
- effects on the ecology of boulder fields/stone reefs.

Interference with other legitimate uses of the sea

The assessment should consider the following in relation to the proposed programme of extraction:

- commercial fisheries;
- shipping and navigation lanes;
- military exclusion zones;
- offshore oil and gas activities;
- engineering uses of the seabed (e.g., adjacent extraction activities, undersea cables and pipelines including associated safety and exclusion zones);
- areas designated for the disposal of dredged or other materials;
- location in relation to existing or proposed aggregate extraction areas;
- location of wrecks and war-graves in the area and general vicinity;
- wind farms;
- areas of heritage, nature conservation, archaeological and geological importance;
- recreational uses;
- general planning policies for the area (international, national, and local);
- any other legitimate use of the sea.

Evaluation of impacts

When evaluating the overall impact, it is necessary to identify and quantify the marine and coastal environmental consequences of the proposal. The EIA should evaluate the extent to which the proposed extraction operation is likely to affect other interests of acknowledged importance. Consideration should also be given to the assessment of the potential for cumulative impacts on the marine environment. In this context, cumulative impacts might occur as a result of aggregate dredging at a single site over time, or from multiple sites in close proximity or in combination with effects from other human activities (e.g., fishing and disposal of harbour dredgings).

It is recommended that a risk assessment be undertaken. This should include consideration of worst-case scenarios, and indicate uncertainties and the assumptions used in their evaluation.

The environmental consequences should be summarized as an impact hypothesis. The assessment of some of the potential impacts requires predictive techniques, and it will be necessary to use appropriate mathematical models. Where such models are used, there should be sufficient explanation of the nature of the model, including its data requirements, its limitations and any assumptions made in the calculations, to enable assessment of its suitability for the particular modelling exercise.

Mitigation measures

The impact hypothesis should include consideration of the steps that might be taken to mitigate the effects of extraction activities. These may include:

- the selection of aggregate dredging equipment and timing of aggregate dredging operations to limit impact upon the biota (such as birds, benthic communities, and fish resources);
- modification of the depth and design of aggregate dredging operations to limit changes to hydrodynamics and sediment transport and to minimize the effects on fishing;
- spatial and temporal zoning of the area to be authorized for extraction or scheduling extraction to protect sensitive fisheries or to respect access to traditional fisheries;
- preventing on-board screening or minimizing material passing through spillways when outside the dredging area to reduce the spread of the sediment plume;

- agreeing exclusion areas to provide refuges for important habitats or species, or other sensitive areas.

Evaluation of the potential impacts of the aggregate dredging proposal, taking into account any mitigating measures, should enable a decision to be taken on whether or not the application should proceed. In some cases, it will be appropriate to monitor certain effects as the aggregate dredging proceeds. The EIA should form the basis for the monitoring plan.

Authorization issue

When an aggregate extraction operation is approved, then an authorization should be issued in advance (which may take the form of a permit, license, or other form of regulatory approval). In granting an authorization, the immediate impact of aggregate extraction occurring within the boundaries of the extraction site, such as alterations to the local physical and biological environment, is accepted by the regulatory authority. Notwithstanding these consequences, the conditions under which an authorization for aggregate extraction is issued should be such that environmental changes beyond the boundaries of the extraction site are as far below the limits of allowable environmental change as practicable. The operation should be authorized subject to conditions which further ensure that environmental disturbance and detriment are minimized.

The authorization is an important tool for managing aggregate extraction and will contain the terms and conditions under which aggregate extraction may take place, as well as provide a framework for assessing and ensuring compliance.

Authorization conditions should be drafted in plain and unambiguous language and will be designed to ensure that:

a) the material is only extracted from within the selected extraction site;

b) any mitigation requirements are complied with; and

c) any monitoring requirements are fulfilled and the results reported to the permitting authority.

Monitoring compliance with conditions attached to the authorization

An essential requirement for the effective control of marine aggregate extraction is monitoring on a continuous basis of all aggregate dredging activity to provide a permanent record. This has been achieved in several ways, e.g., an Electronic Monitoring System or Black Box. The information provided will allow the regulatory authority to monitor the activities of aggregate dredging vessels to ensure compliance with particular conditions in the authorization.

The information collected and stored will depend on the requirements of the individual authorities and the regulatory regime under which the permission is granted, e.g., EIA, Habitats, Birds Directives of the EU.

The minimum requirements for the monitoring system should include:

- an automatic record of the date, time, and position of all aggregate dredging activity;
- position to be recorded to within a minimum of 100 metres, in latitude and longitude or other agreed coordinates using a satellite-based navigation system;
- there should be an appropriate level of security;
- the frequency of recording of position should be appropriate to the status of the vessel, i.e., less frequent records when the vessel is in harbour or in transit to the aggregate dredging area, e.g., every 30 minutes, and more frequently when dredging, e.g., every 30 seconds.

The above are considered to be reasonable minimum requirements to enable the regulatory authority to monitor the operation of the authorization in accordance with any conditions attached thereto. Individual countries may require additional information for compliance monitoring at their own discretion.

The records can also be used by the aggregate dredging company to improve utilization of the resources. The information is also an essential input into the design and development of appropriate environmental monitoring programmes and research into the physical and biological effects of aggregate dredging, including combined or cumulative impacts (see section above).

Environmental monitoring

Sand and gravel extraction inevitably disturbs the marine environment. The extent of the disturbance and its environmental significance will depend on a number of factors. In many cases, it will not be possible to predict, in full, the environmental effects at the outset, and a programme of monitoring may be needed to demonstrate the validity of the EIA's predictions, the effectiveness of any conditions imposed on the authorization, and therefore the absence of unacceptable impacts on the marine environment.

The level of monitoring should depend on the relative importance and sensitivity of the surrounding area. Monitoring requirements should be site-specific, and should be based, wherever possible, on the findings of the EIA. To be cost effective, monitoring programmes should have clearly defined objectives derived from the impact hypothesis developed during the EIA process. The results should be reviewed at regular intervals against the stated objectives, and the monitoring exercise should then be continued, revised, or even terminated.

It is also important that the baseline and subsequent monitoring surveys take account of natural variability. This can be achieved by comparing the physical and biological status of the areas of interest with suitable reference sites located away from the influence of the aggregate dredging effects and of other anthropogenic disturbance. Suitable locations should be identified as part of the EIA's impact hypothesis.

A monitoring programme may include assessment of a number of effects. When developing the programme, a number of questions should be addressed, including:

- what are the environmental concerns that the monitoring programme seeks to address;
- what measurements are necessary to identify the significance of a particular effect;
- what are the most appropriate locations at which to take samples or observations for assessment;
- how many measurements are required to produce a statistically sound programme;
- what is the appropriate frequency and duration of monitoring.

The regulatory authority is encouraged to take account of relevant research information in the design and modification of monitoring programmes.

The spatial extent of sampling should take account of the area designated for extraction and areas outside which may be affected. In some cases, it may be appropriate to monitor more distant locations where there is some question about a predicted nil effect. The frequency and duration of monitoring may depend upon the scale of the extraction activities and the anticipated period of consequential environmental changes, which may extend beyond the cessation of extraction activities.

Information gained from field monitoring (or related research studies) should be used to amend or revoke the authorization, or refine the basis on which the aggregate extraction operation is assessed and managed. As information on the effects of marine aggregate dredging becomes more available and a better understanding of the impacts is gained, it may be possible to revise the monitoring necessary. It is therefore in the interest of all concerned that monitoring data are made widely available. Reports should detail the measurements made, results obtained, their interpretation, and how these data relate to the monitoring objectives.

Reporting Framework

It is recommended that the national statistics on aggregate dredging activity continue to be collated annually by the ICES Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT).

Definitions

In these Guidelines, "marine sediment extraction" is intended to refer to the extraction of marine sands and gravels (or "aggregates") from the seabed for use in the construction industry (where they often directly replace materials extracted from land-based sources), and for use in flood and coastal defense, beach replenishment, and land reclamation projects. It is recognized that other materials are also extracted from the seabed, such as stone, shell materials, and maerl, and similar considerations to those set out in the Guidelines should also apply to them. The Guidelines do not apply to navigational dredging (e.g., maintenance or capital dredging operations).

In these Guidelines, the term "authorization" is used in preference to "permit" or "license" and is intended to replace both terms. The legal regime under which marine extraction operations are authorized and regulated differs from country to country, and the terms permit and license may have a specific connotation within national legal regimes, and also under rules of international law. The term "authorization" is thus used to mean any use of permits, licenses, or other forms of regulatory approval.

ANNEX 8: ACME/ACMP ADVICE BY TOPIC FOR THE YEARS 1991–2002

Numbers in the table refer to sections of the present report and of the ACMP or ACME reports from 1991 to 2002, in reverse chronological order. From 2001, relevant sections from the report of the Advisory Committee on Ecosystems (ACE) are also listed.
*Signifies major advice on that topic.

Topic	Sub-topic	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
Monitoring	Strategy								5.1	*4; *Ann. 1	5	5.1	
	Programme evaluation			6.7						4.2			
	Statistical methods for design	4.3.3; Ann. 3	4.6.2; 4.6.3; 4.6.4	6.6.2	5.6								
	Benthos			6.8.1				6.1.2; 11.1; *Ann. 8				8; *Ann. 6	8.1
	NSTF/MMP										5.2		
	Sediments/guidelines	4.2.1	4.5.1; *Ann. 2			4.6; *Ann. 2	4.5; *Ann. 1	5.5; *Ann. 4		5.5	6.1; *Ann. 1		
	Sediment data normalization		4.5.1; *Ann. 2	6.5.1; Ann. 1	5.5		4.5.2	5.5.1		5.5			
	Sediment sensitivity, variance factors								5.6				
	Metals/sediments	4.2.1						9.5	5.6	5.5			
	Substances that can be monitored												
	▪ organic				5.4	4.5		5.4	6.6	6.8			
	▪ inorganic			6.4	5.4	4.5	4.2						
	Use of seaweeds									5.1			
	Use of seabird eggs				13.2; Ann. 7	4.7.5							
	Spatial monitoring	4.3.3; Ann. 3	4.6.2; 4.6.4	6.6.3			*4.7.2		5.3	5.1			
	JAMP/JMP guidelines						4.1	5.2; 5.4	5.4			13.3	
	BMP guidelines							5.1.2	5.4		5.3		
	AMAP		4.4	6.3	5.2	4.4		5.1.3		5.4			
	Effects of nutrient enrichment	10.6			12.1			9.1	5.8				
	Monitoring PAHs					4.2; *Ann. 1	4.4.1; 4.5; *Ann. 1						

Topic	Sub-topic	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
Assessment	Statistical methods	4.3; Ann. 1,2	4.6.1; Ann. 3,10			4.7.1							
	Combined effects of contaminants				5.1.5	11.2							
	Biological community data		9.4										
	Data screening prior to assessment	5.5; 5.6; Ann. 4,5	10.2; Ann. 8,9										
	Inputs and environmental concentrations	6.2											
Temporal trend monitoring	Strategy/objectives							*4; Ann. 1		*4; *Ann. 1			
	Guidelines							4.4		4; 5.2			
	Data analysis					4.7.4	15.2			5.2	6.2	5.2	
	Nutrients							5.7			6.3		
	Fish/JMP/JAMP		4.6.5		5.6.4			5.6					5.1
	Fish/CMP							5.6					5.1
	Biota/BMP								7.3				
	Biological effects					4.1							
	Mussels												5.1
	Precision			6.6.5						5.2		*Ann. 1	
	Sediments	4.2.3						4.3; 5.5.3					
	Statistical requirements					4.7			4.3				
Integration of biological/ chemical measurements	Sediment quality	4.2.2	6.3; 6.4					5.2.2	4.2; Ann. 2	5.4	6.4; *Ann. 2		
Biological effects monitoring	Monitoring strategy							*5.3	4.1; *Ann. 1				
	Statistical design					4.1*	4.31						
	Methods	4.1	4.1	6.1.2	5.1.1		4.3.2	5.3.2	Ann. 1			6.2	7.2
	Molecular techniques	4.1.2							*5.2				
	Pathology						4.3.3	5.3.3	8.4	9.4			
	Workshop results	4.1.1	4.1.1	6.1.4				5.3.2				6.1	7.1
	Source of variability			6.1.1; 6.6.4	5.1.2								
	Data analysis ▪ general											6.3	
	▪ EROD											*Ann. 2	
	▪ oyster bioassay											*Ann. 2	
	Endocrine disruption			9.6									

Topic	Sub-topic	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
Baseline studies	ICES Baseline TM/SW												6
	Contaminants in ▪ Baltic sediments				5.2	4.3	6.1	7.1	7.1	7.1	8.1	13.2	14.1
	▪ North Sea sediments											13.1	
	HCH in sea water											14	
Regional assessments	Preparation plans/reviews		10.5	18.4; Ann. 9									
	North Sea QSR										4.1	4	4
	Baltic Sea							7.2	7.2	7.3			
	Baltic fish			18.2				7.3	7.2	7.3			
	Canadian waters												16
	AMAP	6.1											
Quality assurance	Philosophy												13.6
	Reference materials		5.6; Ann. 4	7.5; Ann. 4		5.6	4.2			*6.9	7.11		
	Oxygen in sea water						*Ann. 3						
	Nutrients						5.7						
	Quality/comparability ▪ organic contaminants				5.4	4.5			*6.6	*6.8			
	Lipids								6.4	6.5			
	Biological effects techniques	5.3	5.3	7.3	7.4	5.4	5.3	*6.2; *Ann. 5	6.2		7.1		7.3
	QA of sampling			7.7	7.6	5.7	5.10					*12.8	
	QA info. In data bank		5.5				16.1.1			6.10			
	Chemical measurements– Baltic Sea	5.4	5.4	7.4	7.5	5.5	5.4	6.3	6.3	6.2	7.4		
	Biological measurements	5.1; 5.2	5.1; 5.2	7.1; 7.2	7.1; 7.2	5.1; 5.2	5.1; 5.2	6.1	6.1	6.1	7.3		
	Fish disease monitoring		5.3			8.2	5.3.2	*Ann. 6					
	Use of QA data	5.5; 5.6 Ann. 4,5	10.2										
Intercomparison exercises	Status				Ann. 8		Ann. 10	Ann. 10	Ann. 7	Ann. 6	Ann. 5	Ann. 8	Ann. 3
	Nutrients/sea water							6.4	6.5	6.6	7.8	12.4	
	Hydrocarbons in biota								6.7				
	PAHs/standards											12.2	13.1
	PCBs/CBs in biota								6.6; 6.7	6.3;6.4	7.5	12.1	13.2
	Organochlorines in biota								6.6; 6.7				
	CBs in sediments								6.6	6.3	7.5		13.2
	Metals in ▪ sea water						5.5	6.5					
	▪ SPM									6.7	7.9	12.3	13.3

Topic	Sub-topic	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
Intercomparison exercises (cont.	Dissolved oxygen in sea water											12.5	13.4
	Oyster embryo bioassay											Ann. 4	
	EROD											12.6; *Ann. 3	
Methods	DO in sea water						*Ann. 3						
	Sediment normalization		4.5.1; *Ann. 2	6.5.1; Ann. 1						5.5			14.2; 14.3
	Organic carbon measurements						4.6; Ann. 2						
	Zooplankton studies	10.5; 10.6		6.8.3									
Phytoplankton and algal blooms	Primary production methods	10.6									6.5	11	11.1
	Initiating factors of blooms												*11.3
	Dynamics of blooms					10.2	9.2			8	10		
	Exceptional blooms	10.4	9.3	6.8.2; Ann. 3	12.2; Ann. 2	Ann. 3	Ann. 8						11.2
	Phycotoxins/ measurements												11.4
	Eutrophication effects on phytoplanktion	10.3											
Nutrients and eutrophication	Nutrients in the Baltic Sea	14.4											
	Nutrient trends/eutrophication in OSPAR area	14.3	11				Ann. 9						
	Nutrients and eutrophication					10.1	9.1	9.1	5.8		6.3	10	*11.3
Fish diseases and related issues	Relation to pollution					8.2	8.3	5.3.3	8.4	9.4			9.1
	Survey methods						7.2						9.2
	Diseases in fish/shellfish	8.1	7.1	9.1	10.1								
	Baltic fish			9.4; *Ann. 6			7.2		8.1; 8.2; 8.3	9.3			
	Data analysis		7.2	9.2	10.2; Ann. 5	8.1; *Ann. 8	7.1	8.2		9.5	9.4	7	
	M74 in Baltic salmon	8.2	7.1	9.3	10.3	8.3	6.2	7.4	7.4	9.1			
	Contaminants and shellfish pathology	8.5; Ann. 6											
	Diseases in farmed fish	8.3; 8.4											
Mariculture	Interactions	11.1; 11.3	12	14.1	15.2			15.1	14	13		9.1	
	Guidelines for EIA	11.2.1											
	Monitoring	11.2.2											
	Escape of fish—effects			15.1		14.2	14.1						
	Nutrient inputs/Baltic			14.2								*9.2	
	Use of chemicals	11.4		14.1.2	15.2		14.2						

Topic	Sub-topic	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
Introductions and Transfers	Code of Practice	9.2						14.2	13.1	14.1	12.1		
	Accidental transfers, including via ships	9.3; 9.4	8.1.2; 8.3	10.1.2; 10.2	11.1	9.1; 9.2	13.2	14.4; *Ann. 9	13	14.2	12.3		
	Genetically modified organisms				15.1	9.3		14.5			12.2		
	On-going introductions	9.1	8.1.1	10.1.1			13.1	14.1					
	Baltic Sea				11.1	9.3		14.3					
Marine mammals	Contaminants/effects			13.2	14.1	12.2; *Ann. 10	11.4	5.4.2; 13.3; 13.4					
	Baltic marine mammal stocks			*13.1	14.2		11.1	13.1		10.2		*18	
	Populations/N. Atlantic		ACE 4.6							10.1	11.1	*18	18
	Pathogens										11.2; Ann. 3		
	Impact of fisheries	ACE 2	ACE 3			12.1; *Ann. 9	11.2; 11.3	13.2					
Seabirds	Diet, food consumption				13.1; *Ann. 6								
	Use in contaminant monitoring		ACE 4.9		13.2; *Ann. 7				5.3				
	Effects of contaminants			12.1									
	Populations		ACE 4.8										
Overviews	Mercury					7.1; *Ann. 4							
	Hormone disruptors		6.2			7.4; Ann. 6		Ann. 2					
	Tris(4-chlorophenyl) methanol/methane	7.2.2	6.1.1	8.1				10; *Ann. 7					
	Benzene/ alkylated benzenes								10.2; *Ann. 5				
	Chlorinated alkanes			8.1					10.1; Ann. 4				
	PBBs and PBDEs	7.2.3	6.1.2		9.2; *Ann. 4								
	PCDDs and PCDFs	7.2.1	6.1.5; *Ann. 7										
	PCDEs						8.1; *Ann. 6						
	TBT				9.2; *Ann. 3								
	Octachlorostyrene												20.1

Topic	Sub-topic	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
Overviews (cont.)	Toxaphene	7.2.4					8.1; *Ann. 5			12.3			
	Atrazine									12.1			
	Irgarol 1051		6.1.3; *Ann. 5				8.1; *Ann. 4						
	Antifouling booster biocides		6.1.3 *Ann. 5										
	Volatile organic contaminants		6.1.4; Ann. 6										
Classification/ assessment tools	Hazardous substances	7.1				11.1			12.3			*15	
	Background concentrations	6.4		6.2			15.1		12.1				
	Ecological Quality Objectives—North Sea	6.5; ACE 10	ACE 4	18.6	17.2								
	Ecotoxicolgical reference values								12.2				
	Environmental indicators	6.6; 6.7	10.4		17.1								
Sand/gravel extraction	Code of Practice/Guidelines	12.1											
	Effects	12.2	13	16	8.1	6.1	*6.3						15
	Environmental impact assessment	12.1; 12.3	13		8.1				*15	*15	13		
Modelling	Radioactive contaminants/Baltic Sea											*17.1	
	Use in monitoring and assessment									16		17.2	
Data banks and management	Nutrients	14.2	15.2	20.2	19.2	15.2	17.2	16.1.2					
	Contaminants	14.1	15.1	20.1	19.1	15.1	17.1	16.1.1; 16.3	17	2.2	2.2		
	NSTF											20	*21
	ICES format	14.1; 14.6	15.1	20.1.10; 20.5	19.1			16.6					
	ICES databases	14	15.1	20.1	19.1						14		
	Biological database	14.5	15.3	20.3	19.3	15.1.3	17.3; 17.4			11.2; Ann. 4			
	AMAP		15.1	20.1.3	19.1.3		17.1.1	16.2					
Ecosystem effects of fishing	General			18.1			*12	12		18		*19	19
	Effects of disturbance on benthos, seabed habitats	ACE 4		5		10.4	9.3	11.2	9; Ann. 3	11.1		8.3	8.2
	Seabird/fish interactions			12.2	4		10			19			
	Impact on non-target fish species	ACE 7				*13.3							
	Models and metrics			18.5		13.4.1							

Topic	Sub-topic	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	1992	1991
Ecosystem effects of fishing (cont.)	Effects on level of predation on benthos by fish					13.4.2							
	Impact on size/age and spatial distributions of target fish					13.1							
	Discards			*11		13.2							
Inputs of contaminants and nutrients	Riverine inputs (gross)					4.7.2; 4.7.3	*4.7.1						
	Trend detection methods	4.3.1: Ann. 1,2	4.6.1; Ann. 3	*6.6.1; *Ann. 2	*6; *Ann. 1								
	Atmospheric inputs						4.7.1						
ICES Environmental Report	Oceanographic conditions	6.8.1	10.6.1	18.3.1	8.4.1	6.2.1							
	Zooplankton	6.8.2	10.6.2			6.2.2							
	Harmful algal blooms	6.8.3	10.6.3	18.3.2	8.4.2; Ann. 2	6.2.3; Ann. 3							
	Fish disease prevalence	6.8.4	10.6.4	18.3.3; Ann. 8									
Special topics	Sediments—Baltic				5.2	4.3	6.1	7.1	7.1	7.1			14.1
	Sediments (bioavailability)							9.3	4.2; Ann. 2	5.4	6.4; Ann. 2		7.4
	Bioaccumulation of contaminants						8.2; *Ann. 7						
	Oil spill studies		Ann. 1										
	Coastal zone fluxes										8.2		
	Influence of biological factors on contaminant concentrations					7.2; Ann. 5							
	Discharge of produced water by offshore platforms					7.6; Ann. 7							
	North Sea Benthos Survey	10.1	9.1						9			*Ann. 5	
	GLOBEC		14.1	19.1	18.1	16.2							
	GOOS	13.1	14.2	19.2	18.2	16.1	16						
	GIWA		14.3										
	Marine habitat classification/ mapping	ACE 5	ACE 5	17	16								
	Toxicity of dredged material			8.4									

ACRONYMS

ACE	Advisory Committee on Ecosystems
ACFM	Advisory Committee on Fishery Management
AChE	acetylcholinesterase
ACME	Advisory Committee on the Marine Environment
ALA-D	δ-aminolevulinic acid dehydratase
AMAP	Arctic Monitoring and Assessment Programme
AQC	analytical quality control
ASC	Annual Science Conference (ICES)
ASMO	Environmental Assessment and Monitoring Committee (OSPAR)
BDE	bromodiphenylether
BECPELAG	ICES/IOC Sea-going Workshop on Biological Effects of Contaminants in Pelagic Eosystems
BEEP	Biological Effects of Environmental Pollution in Marine Coastal Ecosystems
BEQUALM	Biological Effects Quality Assurance in Monitoring Programmes
BEWG	Benthos Ecology Working Group
BOD	biological oxygen demand
CBs	chlorobiphenyls
CD-ROM	compact disc: read-only memory
CEFAS	Centre for Environment, Fisheries and Aquaculture Science (UK)
CEMP	Coordinated Environmental Monitoring Programme (OSPAR)
COMBINE	Cooperative Monitoring in the Baltic Marine Environment (HELCOM)
CRMs	certified reference materials
2,4-D	2,4-dichlorophenoxyacetic acid
DDT	dichlorodiphenyltrichloroethane
DGTs	diffusive gradients in thin films
DIAC	Dioxin Analysis by Comprehensive multi-dimensional gas chromatogaphy
DIFFCHEM	OSPAR Working Group on Diffuse Sources
DIFFERENCE	Dioxins in Food and Feed
DIN	dissolved inorganic nitrogen
DIP	dissolved inorganic phosphate
DNA	deoxyribonucleic acid
DYNAMEC	Ad Hoc Working Group on the Development of a Dynamic Selection and Prioritisation Mechanism for Hazardous Substances (OSPAR)
EAC	ecotoxicological assessment criteria
EC	European Commission
EcoQO	ecological quality objective
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EI	electron impact ionization
EIA	environmental impact assessment
EQS	environmental quality standard
EROD	ethoxyresorufin-*O*-deethylase
EU	European Union
EUC	Eutrophication Committee (OSPAR)
EUNIS	European Nature Information System
FAO	Food and Agriculture Organization
GC	gas chromatography
GCOS	Global Climate Observing System
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GEOHAB	Global Ecology and Oceanography of Harmful Algal Blooms (IOC-SCOR)
GIS	Geographical Information System
GIWA	Global International Waters Assessment
GLOBEC	Global Ocean Ecosystem Dynamics Programme
GOOS	Global Ocean Observing System
HAB	harmful algal bloom
HAE	harmful algal event
HAEDAT	Harmful Algal Event Database
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission)
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
ICZM	Integrated Coastal Zone Management
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IMO	International Maritime Organization

IOC	Intergovernmental Oceanographic Commission
ISO	International Organization for Standardization
IWC	International Whaling Commission
JAMP	OSPAR Joint Assessment and Monitoring Programme
LOESS	statistical smoother
LOICZ	Land-Ocean Interactions in the Coastal Zone
MAFF	Ministry of Agriculture, Fisheries and Food (UK)
MCWG	Marine Chemistry Working Group
MON	Working Group on Monitoring (OSPAR)
MONAS	Monitoring and Assessment Group (HELCOM)
mRNA	messenger ribonucleic acid
NSBP	North Sea Benthos Project
OCs	organochlorines
OSPAR	OSPAR Commission
PAHs	polycyclic aromatic hydrocarbons
PBBs	polybrominated biphenyls
PBDEs	polybrominated diphenylethers
PBTs	persistent, bioaccumulative, toxic compounds
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzo-*p*-dioxins
PCDEs	polychlorinated diphenylethers
PCDFs	polychlorinated dibenzofurans
PCP	pentachlorophenol
PCR	polymerized chain reaction
PEG	Phytoplankton Expert Group
PGNSP	ICES-EuroGOOS Planning Group on the North Sea Pilot Project
PICES	North Pacific Marine Science Organization
PLC	Pollution Load Compilation
POPs	persistent organic pollutants
QA	quality assurance
QC	quality control
QUASH	Quality Assurance of Sampling and Sample Handling (EC)
QUASIMEME	Quality Assurance of Information for Marine Environmental Monitoring in Europe
RIKZ	Rijksinstituut voor Kust en Zee [National Institute for Coastal and Marine Management]
SACs	special areas of conservation
SCF	EC Scientific Committee on Food
SEPA	Scottish Environment Protection Agency
SG	Study Group
SGBOSV	ICES/IOC/IMO Study Group on Ballast and Other Ship Vectors
SGEAM	Study Group on Ecosystem Assessment and Monitoring
SGGOOS	Steering Group on GOOS
SGPOP	ICES/AMAP Study Group for the Assessment of AMAP POPs and Heavy Metals Data
SGSEA	Steering Group for a Sea-going Workshop on Pelagic Biological Effects Methods
SGQAB	ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea
SGQAC	ICES/HELCOM Steering Group on Quality Assurance of Chemical Measurements in the Baltic Sea
SGQAE	Steering Group on Quality Assurance of Biological Measurements in the Northeast Atlantic
SIME	Working Group on Concentrations, Trends and Effects of Substances in the Marine Environment (OSPAR)
SOPs	Standard Operating Procedures
SPMDs	semi-permeable membrane devices
SPME	solid-phase micro-extraction
SQL	structured query language
SSH	selective subtractive hybridization
TBT	tributyltin
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TCPM	*tris*(4-chlorophenyl)methanol
TCPMe	*tris*(4-chlorophenyl)methane
TDI	tolerable daily intake
TEQ	toxic equivalent
TIMES	*ICES Techniques in Marine Environmental Sciences*

TOC	total organic carbon
TWI	tolerable weekly intake
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
U.S.	United States
USA	United States of America
VHSV	viral hæmorrhagic septicæmia virus
VIC	Voluntary International Contaminant Monitoring in Temporal Trends (OSPAR)
VTG	vitellogenin
WFD	Water Framework Directive
WGAGFM	Working Group on the Application of Genetics in Fisheries and Mariculture
WGBEC	Working Group on Biological Effects of Contaminants
WGECO	Working Group on Ecosystem Effects of Fishing Activities
WGEIM	Working Group on Environmental Interactions of Mariculture
WGEXT	Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem
WGHABD	ICES/IOC Working Group on Harmful Algal Bloom Dynamics
WGITMO	Working Group on Introductions and Transfers of Marine Organisms
WGMS	Working Group on Marine Sediments in Relation to Pollution
WGOH	Working Group on Oceanic Hydrography
WGPDMO	Working Group on Pathology and Diseases of Marine Organisms
WGPE	Working Group on Phytoplankton Ecology
WGSAEM	Working Group on the Statistical Aspects of Environmental Monitoring
WGSE	Working Group on Seabird Ecology
WGZE	Working Group on Zooplankton Ecology
WHO	World Health Organization
YTX	Yessotoxin

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