
Book 1
Introduction, Overviews and Special Requests

Books 1 - 10
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Preface

This report contains the 2008 ICES advice to Clients regarding marine management issues. The report is produced by the advisory committee providing advice on behalf of the Council. This advisory committee replaced the three former advisory committees: the Advisory Committee on Fishery Management (ACFM), the Advisory Committee on Ecosystems (ACE), and the Advisory Committee on the Marine Environment (ACME).

The members of the advisory committee include one designated scientist from each of the ICES member countries and the committee has an independently elected chair and three vice-chairs. The chair of the Consultative Committee is member ex-officio. ACOM works through a set of guidelines adopted at meetings in February and in December but the advisory texts are adopted in web conferences. ICES has invited Client Commissions and stakeholder groups to be present at advisory committee meetings (whether physical or virtual) in observer capacity.

The basis for the advice is reports of expert working groups. These reports are peer reviewed by designated groups. The review groups are composed of scientists who are not members of the assessment working group under review and who normally do not originate from countries with a strong interest in the stocks concerned. A few review groups include invited reviewers not involved in the ICES assessment in some cases recruited from institutions not normally involved with ICES advisory work. The Expert Working Group chairs assist the review groups.

The advisory text is developed in advice drafting groups guided by a chair appointed by ACOM. ICES Delegates and ACOM members appoint participants in the advice drafting groups. These groups normally meet physically.

As mentioned above ACOM approves the advice through web conferencing.

Structure of the report

Book 1 explains the conceptual and institutional framework for the assessments and advice. It contains a general introduction to the ICES advice, and includes general and non-regional advice.

Books 2-8 are regional reports.

- Book 2: Iceland and East Greenland
- Book 3: The Barents Sea and the Norwegian Sea
- Book 4: The Faroe Plateau Ecosystem
- Book 5: Celtic Sea and West of Scotland
- Book 6: North Sea
- Book 7: Bay of Biscay and Iberian Seas
- Book 8: The Baltic Sea

Book 9 is a separate chapter for widely distributed and migratory stocks and Book 10 provides information on the North Atlantic salmon.

Each of these regional ecosystem-volumes includes an ecosystem overview, a description of the human impact on the ecosystem, answers to specific requests, a description of the fisheries in the region and the operational conclusions based on the stock assessments. Finally the report presents a series of stock summary sheets.

The fisheries advice includes reflection on mixed fisheries issues in fisheries management. For those fisheries for which mixed fisheries issues are known to be minor the advice is given on a stock basis. This applies mainly to pelagic stocks. For most demersal stocks or stocks where mixed fisheries are known to be important the advice is based on an identification of the critical stocks and the overall advice is based on the requirements for those stocks. As a consequence of taking a fisheries perspective the advice for all stocks is now given in the area overview section.
Corrections after release of the Extract Report

The Advisory report is issued as extracts during the year. Some minor and a few major errors were discovered in the ICES advice after it was released and these were corrected. This report only contains the final version and where appropriate corrected versions of these sections. The following sections were corrected:

5.4.5 Whiting in Division VIIa (Irish Sea)
5.4.19 Megrim (*Lepidorhombus whiffiagonis*) in Divisions VIIb-k and VIIa,b,d
5.4.25 Whiting in Division Vla (West of Scotland)
5.4.30 Herring in Division Vla North
6.3.3.7 EC Request on Cod Recovery Management Plans (corrected in section 6.3.3.8)
6.4.2 Cod in Subarea IV (North Sea), Division VIIId (Eastern English Channel) and Division IIIa (Skagerrak)
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<td>Representative: Jakúp Reinert</td>
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<td>Greenland</td>
<td>Representative: Jesper Boje</td>
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1 Introduction, overview and special requests

1.1 About ICES

ICES was established in 1902 as an intergovernmental organisation. The ICES Convention from 1964 outlines the fundamental purposes of ICES, which are:

- to promote and encourage research and investigations for the study of the sea particularly related to the living resources thereof;
- to draw up programmes required for this purpose and to organise, in agreement with the Contracting Parties, such research and investigations as may appear necessary;
- to publish or otherwise disseminate the results of research and investigations carried out under its auspices or to encourage the publication thereof.

Under the Convention, ICES is concerned with the Atlantic Ocean and adjacent seas, primarily the North Atlantic. For decades, ICES has led the way in the design and coordination of international marine research, and it has provided scientific advice. Its programmes have been carried out mainly at national expense. Throughout ICES’ long history, its members have unselfishly supported the research programmes designed through ICES, because in reality, the members are ICES and the programmes of ICES are theirs. The past success of ICES has benefited very much from the ownership Member Countries feel for ICES and its programmes, which will also be critically important in the future. ICES has increasingly provided scientific advice based on its research programme. Today, ICES provides the scientific underpinning for most of the regulatory commissions concerned with fisheries and the environment in the Northeast Atlantic and the Baltic Sea.

ICES has grown from a small body of like-minded researchers to a complex organisation involving about 1600 scientists, with 20 Member Countries as well as several Observer Countries and non-governmental organisations. ICES fulfils its functions through an Annual Science Conference, about a dozen committees, more than 100 working and study groups, several symposia annually, and a wide range of publications. There is a Secretariat located in Copenhagen, which currently has 44 full-time professional and support staff.

It is the scientists who participate in ICES activities who generate ICES products. The main products are scientific information based on research conducted in the Member Countries and scientific advice containing information provided in a format that can be used by policy-makers. The responsibility for overseeing the production of scientific advice rests with the Management Committee for the Advisory Process. It assigns advisory tasks to the Advisory Committee on Ecosystems (ACE), the Advisory Committee on Fishery Management (ACFM), or the Advisory Committee on the Marine Environment (ACME). The membership of the advisory committees consists of one member per country.

ICES is requested to provide advice on a range of issues relating to marine policies and management. The clients for such requests are:

- Governments of ICES’ member countries,
- European Commission (EC)
- Helsinki Commission (HELCOM),
- North Atlantic Salmon Commission (NASCO),
- North East Atlantic Fisheries Commission (NEAFC)
- OSPAR Commission (OSPAR)

ICES may also on its own initiative draw the attention of clients to marine matters which may require policy and management attention. The present report is the ICES advice produced in 2008.

There is growing awareness of the impact that human activities, other than fishing have on the marine environment. ICES responded to the needs of international intergovernmental organisations for advice on how to measure these impacts and how to determine their significance. Many expert groups were formed to study the techniques for measuring chemical and biological variables in marine ecosystems and for determining the effects of human activities on marine biota. Starting in the 1990s, ICES has been asked to provide advice on how to integrate scientific knowledge of ecosystem components to provide the underpinning for an ecosystem approach to managing human activities in marine waters.
ICES works with its clients to find the most effective way of delivering integrated advice. The immediate delivery of advice is through the ICES internet site and the annual summary of advice is provided in this document that includes all aspects of ICES’ advice.

Also ICES has had to consider carefully the effectiveness of its organisation in meeting not only the types of requests for advice but also the timeliness in the delivery of that advice and the robustness of its peer review process. As a result of this review ICES expects to move towards a revised advisory process in 2008 that will provide all advice through one single advisory committee.

This has meant challenging many expert working groups to undertake new research or to reconsider existing information in order to provide the scientific basis for this integrated advice.

1.2 General guidelines for the ICES advice

ICES provides advice in relation to policies and objectives identified by governments and international client commissions. ICES provides that advice with reference to a number of international agreements and codes of practice:

- “Precautionary principle”: chapter 17 of Agenda 21 of the UN Conference on Environment and Development (UNCED 1992),
- “Precautionary approach”: the United Nations Straddling Fish Stocks agreement (UN 1995) and the FAO Code of Conduct for Responsible Fisheries (FAO 1995)
- Convention on Biological Diversity (UN 1992),
- “Ecosystem approach” and “Maximum Sustainable Yield”: the Johannesburg Declaration of the World Summit of Sustainable Development (UN 2002)

1.2.1 Precautionary approach

The Precautionary Approach was summarised in the UN Straddling Fish Stocks Agreement (UN 1995) as follows:

“States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures.”

In 1997, ICES was asked by its clients to suggest an approach for implementing the precautionary approach into fisheries management in the North East Atlantic. The precautionary approach suggested by ICES consists of a dual system of conservation limits (limit reference points) and a buffer to account for the uncertainty of the knowledge about the present and future states relative to the conservation limit (precautionary approach reference points). The reference points are expressed in terms of single-stock exploitation boundaries (limits on fishing mortality) and biomass boundaries (minimum biomass requirements).

In practice the precautionary approach suggested by ICES (ICES 1997; ICES 1998; ICES 1999) is based on the following reference points:

<table>
<thead>
<tr>
<th>Reference Point</th>
<th>Spawning stock biomass (SSB)</th>
<th>Fishing mortality (F)</th>
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</thead>
<tbody>
<tr>
<td>Limit reference point</td>
<td>(B_{\text{lim}}): minimum biomass. Below this value recruitment is expected to be ‘impaired’ or the stock dynamics are unknown.</td>
<td>(F_{\text{lim}}): exploitation rate that is expected to be associated with stock ‘collapse’ if maintained over a longer time.</td>
</tr>
<tr>
<td>Precautionary reference point</td>
<td>(B_{\text{pre}}): precautionary buffer to avoid that true SSB is at (B_{\text{lim}}) when the perceived SSB is at (B_{\text{pre}}).</td>
<td>(F_{\text{pre}}): precautionary buffer to avoid that true fishing mortality is at (F_{\text{lim}}) when the perceived fishing mortality is at (F_{\text{pre}}).</td>
</tr>
</tbody>
</table>

The buffer safeguards against natural variability and uncertainty in the assessment. The size of the buffer depends upon the accuracy of the projections (of SSB and F) and the risk society accepts that the true SSB is below \(B_{\text{lim}}\) and the true F is above \(F_{\text{lim}}\). The accuracy of the projections depends on the magnitude of the variability in the natural system and of the accuracy of the population estimates.
Limit reference points

The minimum spawning stock reference point is described by the symbol $B_{\text{lim}}$ (the biomass limit reference point). $B_{\text{lim}}$ is set on the basis of historical data so that when a stock would be below $B_{\text{lim}}$, there is a high risk that recruitment will ‘be impaired’ (i.e. substantially lower than when the stock size is higher). Below $B_{\text{lim}}$ there is a higher risk that the stock could “collapse”. The meaning of “collapse” is that the stock has reached a level where it suffers from severely reduced productivity. “Collapse” does not mean that a stock is at high risk of biological extinction. However, recovery of the stock to an improved status is likely to be slow and will depend on effective conservation measures.

When information about the relationship between recruitment and SSB is absent or inconclusive, ICES has used the lowest observed biomass $B_{\text{obs}}$ as a proxy for $B_{\text{lim}}$. This interpretation of $B_{\text{lim}}$ is as a boundary under which the stock would enter an area where the stock dynamics are unknown.

The limit reference point for fishing mortality $F_{\text{lim}}$ is the fishing mortality that is expected to drive the stock to the biomass limit when it is maintained over time.

Precautionary reference points

Spawning stock biomass and fishing mortality can only be estimated with uncertainty. As long as the estimate of spawning biomass is at or above $B_{\text{pa}}$, the probability of actually being at or below $B_{\text{lim}}$ should be small. Similarly for fishing mortality: when the estimate of fishing mortality is at or below $F_{\text{pa}}$, there should be a low probability of actually fishing at or above $F_{\text{lim}}$.

The precautionary reference points are a mechanism for managing the risk of the stock falling below $B_{\text{lim}}$ or the fishing mortality exceeding $F_{\text{lim}}$. This buffer safeguards against natural variability and uncertainty in the assessment. The size of the buffer depends upon the accuracy of the projections (of SSB and F) and the risk society accepts that the true SSB is below $B_{\text{lim}}$ and the true F is above $F_{\text{lim}}$. The accuracy of the projections depends on the magnitude of the variability in the natural system and of the accuracy of the population estimates. E.g. if the quality of catch data were to decline, for example, a higher $B_{\text{pa}}$ would be needed for the same $B_{\text{lim}}$. The same applies when society would want to accept a lower risk that the true biomass was below $B_{\text{lim}}$.

**How have reference points been estimated?**

Most reference points that are currently used were estimated in a process whose results were endorsed by the Advisory Committee on Fishery Management in 1998 (ICES 1999).

The estimation process consisted of the identification of limit reference points based on risk of reduced reproductive capacity and fishing mortality which is expected to drive stocks to reduced reproductive capacity. Precautionary reference points reflect the combined effects of the uncertainties in the assessments and the level of risk society is willing to take. In practice neither of these two effects could be directly quantified. Uncertainties in the assessments were approximated with rules-of-thumb estimates of coefficients of variation in the order of 20%. The level of risk that measures the distance between the limit and precautionary reference points was set at 5-10%. If, for example, the quality of catch data were to decline or multi-year forecasts were required for catch advice, a higher $B_{\text{pa}}$, would be needed for the same $B_{\text{lim}}$. The same is true if society will only accept a very low risk that the true biomass is below $B_{\text{lim}}$.

Fisheries managers and stakeholders shall define the level of risk they were willing to accept this is not a science question. Therefore, the limit reference points have been presented as considerations from ICES and the precautionary reference points as proposals.
Precautionary and limit reference points are used in two ways in the fisheries advice: (1) to classify the state of the stocks (see text box) and (2) to bind the advice for short term exploitation boundaries.

When the spawning biomass is estimated to be below $B_{pa}$, ICES advises that management action should be taken to increase the stock to above $B_{pa}$. Similarly, to be certain that fishing mortality is below $F_{lim}$, fishing mortality should in practice be kept below a lower level $F_{pa}$. When fishing mortality is estimated to be above $F_{pa}$, ICES advises management action to reduce it to $F_{pa}$. Such advice is given even if the spawning biomass is above $B_{pa}$, because fishing mortalities above $F_{pa}$ are considered unsustainable. If a management plan exists which ensures that the SSB will be kept above $B_{pa}$, $F_{pa}$ may temporarily be above $F_{pa}$ as long as there are mechanisms ensuring a downward adjustment before SSB approaches $B_{pa}$.

ICES stresses that these precautionary reference points should not be treated as management targets, but as lower bounds on spawning biomass and upper bounds on fishing mortality. Good management should strive to keep SSB well above $B_{pa}$ and fishing mortality well below $F_{pa}$. If stocks are managed close to their precautionary reference points, then annual scientific advice will be altering conclusions on stock status and necessary management actions on the basis of assessment uncertainty as much as on the basis of true changes in stock status. Managing stocks to achieve targets well removed from the risk-based reference points would result in more stable scientific advice, as well as healthier stocks and more sustainable fisheries.

**State of the stock in relation to the precautionary approach**

The framework used to phrase the advice in relation to the precautionary approach relies on the assessment of the status of the stock relative to precautionary reference points.

When an assessment indicates that the spawning biomass is below $B_{pa}$ ICES classifies the stock as being "outside safe biological limits", regardless of the fishing mortality rate.

**Specific terminology concerning SSB:**

If SSB is above $B_{pa}$: “having full reproduction capacity.”
If SSB is below $B_{pa}$ but above $B_{lim}$: “being at risk of reduced reproductive capacity.”
If SSB is below $B_{lim}$: “suffering reduced reproductive capacity.” or “at a level where the stock dynamics is unknown and therefore risking reduced reproductive capacity”.

**Specific terminology with regards to fishing mortality:**

If $F$ is below $F_{pa}$: “harvested sustainably.”
If $F$ is above $F_{pa}$ but below $B_{lim}$: “at risk of being harvested unsustainably.”

**What happens when if reference points cannot be estimated?**

When reference points cannot be established or present knowledge does not enable an assessment of the state relative to reference points, ICES may advise on basis of past pressure which was found to be sustainable. Using fisheries as an example this may be fishing effort or catches from a period where the stock was known to maintain productivity with that pressure. If there are indications that the present state is critical and there is insufficient information to demonstrate that the present pressure is compatible with a reversal of the situation ICES advises considerable reduction in pressure.

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1 Referring to “safe biological limits” has in some cases mislead clients and other stakeholders to consider stocks described as being “outside safe biological limits” to be biologically threatened (i.e. close to extinction). The term “outside safe biological limits” is used in international agreements and has been used by ICES in the past to classify stocks for which the spawning biomass is below Bpa. While ICES considers this language to be perfectly justified and in accordance with international practices, the attention of ICES has also been drawn to instances of confusion in the public debate where “outside biological limits” has been equated to biological extinction. ICES has therefore from 2004 used a phrasing which more specifically refers to the concept on which this classification is based by referring to the reproduction capacity of the stock in relation to spawning stock biomass, and sustainable harvest in relation to fishing mortality. It should be emphasised that the expressions “outside safe biological limits” and “being at risk of reduced reproductive capacity” or “suffering reduced reproductive capacity” are considered entirely equivalent by ICES and that the change in language does not imply any change in judgement of the seriousness of the situation when a stock is outside safe biological limits and thereby outside precautionary limits.

The following text-table maps the new ICES terminology into the old terminology:

<table>
<thead>
<tr>
<th>New terminology</th>
<th>Old terminology</th>
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<tr>
<td>Biomass</td>
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<tr>
<td>“having full reproductive capacity”</td>
<td>“inside safe biological limits”</td>
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<tr>
<td>“being at risk of reduced reproductive capacity”</td>
<td>“outside safe biological limits”</td>
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<tr>
<td>or &quot;suffering reduced reproductive capacity&quot;</td>
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<tr>
<td>Fishing mortality</td>
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<tr>
<td>“harvested sustainably”</td>
<td>“harvested inside safe biological limits”</td>
</tr>
<tr>
<td>“at risk of being harvested unsustainably” or “harvested unsustainably”</td>
<td>“harvested outside safe biological limits”</td>
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1.2.2 Maximum sustainable yield

The World Summit on Sustainable Development (WSSD, 2002) has reinstated the concept of maximum sustainable yield (MSY) on the political agenda with regards to fisheries management. WSSD (2002, issue 30) states that:

“30. To achieve sustainable fisheries, the following actions are required at all levels: (a) Maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015;”

ICES’ clients are in the process of translating this requirement into operational management policies and ICES will modify its advice accordingly when policy decisions have been made. ICES contributes to this process by developing options for management strategies that aim to produce high long term yields while ensuring that there is little risk that the reproductive capacity of fish stocks will be impaired.

1.2.3 Ecosystem approach

The adoption of the Ecosystem Approach is intended to contribute to sustainable development. Sustainable development was originally defined in the Brundtland Report as development that “meets the needs of the present without compromising the ability of future generations to meet their own needs.” (WCED, 1987)

The Ecosystem Approach has been variously defined, but principally puts emphasis on a management regime that maintains the health of the ecosystem alongside appropriate human use of the environment, for the benefit of current and future generations. For example, the 1992 UN Convention on Biological Diversity (CBD) defines the Ecosystem Approach as:

“ecosystem and natural habitats management” to “meet human requirements to use natural resources, whilst maintaining the biological richness and ecological processes necessary to sustain the composition, structure and function of the habitats or ecosystems concerned.”

The Reykjavik declaration forms the basis for using the Ecosystem Approach to the management of the marine environment:

“in an effort to reinforce responsible and sustainable fisheries in the marine ecosystem, we will individually and collectively work on incorporating ecosystem considerations into that management to that aim.” (FAO 2001)

and the World Summit on Sustainable Development:

“(30.d) Encourage the application by 2010 of the ecosystem approach, noting the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystem 15 and decision V/6 of the Conference of Parties to the Convention on Biological Diversity” (UN 2002)

An ecosystem approach is expected to contribute to achieving long-term sustainability for the use of marine resources, including the fisheries sector. An ecosystem approach serves multiple objectives and should emphasise strong stakeholder participation and focus on human behaviour as the central management dimension.

There appears to be a general consensus as to the intent of the expression ‘Ecosystem Approach’. However, the actual definitions of the expression vary and already in the Reykjavik declaration there was a plea to for best practices with regard to “introducing ecosystem considerations into fisheries management”. Several large national and international research programmes attempt to develop an ecosystem approach (see ICES 2002)

How does the “Ecosystem Approach” affect ICES advice?

At the 13th Dialogue Meeting between ICES and the Clients (ICES 2004a), the ICES plans for the introduction an ecosystem approach into the advice were discussed. The implementation of the ecosystem approach into the advice will include stakeholder interaction and will be incremental. ICES has opened its advisory committees to stakeholder observers who will get better insight into the advisory process. Our understanding of the functioning of the ecosystems is confined to certain ecosystem components. Work is ongoing to expand the number of ecosystem components that are included in the analyses. Our understanding is not uniform among the ecosystems; there are ecosystems for which more data and better understanding of the critical processes exist compared to other systems. Therefore, implementation of
the Ecosystem Approach and ICES ability to satisfy information requirements from clients varies among ecosystems and will develop through time as knowledge is gained.

The organisation of the advisory report in Ecoregions facilitates the ecosystem approach to fisheries management (see section 1.3.1).

Achieving “Ecosystem objectives”

The most effective short-term progress towards meeting ecosystem objectives is likely to be made by implementing the advice for single- and mixed stock fisheries. The advice is mainly to substantially reduce the exploitation of fish stocks. Fishing fleet capacity often exceeds the long-term sustainable use of the ecosystems. There is increasing evidence that fisheries and other human activities are having a serious impact on marine ecosystems. An overall reduction in the exploitation rates for target stocks will reduce the pressures on biota and habitats and will contribute to restoring stocks to full reproductive capacity. This provides the basis for higher long-term yields at lower fishing effort.

1.2.4 European Marine Strategy

Management of all human activities in the sea shall be based on three central features: an Ecosystem Approach, Integrated Management, and a Regional Focus for the coordination and delivery of management programmes. ICES notes that these central features correspond closely to developments intended by its clients. Fisheries management authorities are planning to adopt an Ecosystem Approach to Fisheries Management and Regional Advisory Committees (RACs) have been established as a key component of regionally-based management of fisheries. Hence the new science necessary to support the implementation of the European Marine Strategy will also be necessary to support the major current clients of ICES fishery advice in their traditional and future roles.

The incremental demands on a scientific advisory body to support Integrated Management and an Ecosystem Approach on a regional basis are much more numerous, onerous, and complex than scientific advice on single-sector, single-factor management. ICES has a unique and central role to play in the implementation of the European Marine Strategy. Although ICES capacity and practices will both be challenged to support the Strategy, no other organisation or group of experts in Europe or internationally is nearly as ready to overcome these challenges. ICES can maintain the scientific quality, impartiality, and breadth of expertise that must be contained in the scientific basis for implementation of the European Marine Strategy. In particular, ICES has an established track record for provision of scientific advice on ecosystem management issues.

1.3 Structure of the report

1.3.1 A regional orientation

The ICES advisory report is based on a regional orientation in so-called “Ecoregions” that allows the further development of an ecosystem approach in European waters. A review of existing biogeographical and management regions against a series of evaluation criteria has demonstrated that no existing regions could be adopted as ecoregions (ICES 2004b, p. 115-131). The proposed ecoregions (figure 1) are based on biogeographic and oceanographic features and existing political, social, economic and management divisions:

- Greenland and Iceland Seas (A)
- Barents Sea (B)
- Faroes (C)
- Norwegian Sea (D)
- Celtic Seas (E)
- North Sea (F)
- South European Atlantic Shelf (G)
- Mediterranean Ecoregions:
  - Western Mediterranean Sea (H)
  - Adriatic-Ionian Seas (I)
  - Aegean-Levantine Seas (J)
- Oceanic northeast Atlantic (K)
- Baltic Sea (not numbered)
- Black Sea (not numbered)

The ecoregions Norwegian Sea (D) and Barents Sea (B) are presented in one single volume (3).
The widely distributed and migratory species (ecoregion K) and the deepwater species for which stock identity have not been established, are addressed in volume 9.

The North Atlantic salmon stocks that are of interest to the North Atlantic Salmon Commission (NASCO) are treated in a volume 10.

Figure 1. Proposed ecoregions for the implementation of the ecosystem approach in European waters. The ecoregions are Greenland and Iceland Seas (A), Barents Sea (B), Faroes (C), Norwegian Sea (D), Celtic Seas (E), North Sea (F), South European Atlantic Shelf (G), Western Mediterranean Sea (H), Adriatic-Ionian Seas (I), Aegean-Levantine Seas (J) and Oceanic northeast Atlantic (K). The question mark denotes the western Channel (ICES Area VIIe), which could be placed in either the Celtic Sea or North Sea ecoregion. Equidistant azimuthal projection.

1.3.2 Ecosystem overviews

Each of the regional ecosystem-volumes includes an ecosystem overview that provides a description of the ecosystem components and of the major ecological events and trends.
1.3.3 Human impacts on the ecosystem

Description human impact on the ecosystem (if available)
- Fishery effects on benthos and fish communities
- Other extractive uses (e.g. description of gravel, oil etc extractions]
- Pollution (brief description of trends in pollution)

1.3.4 Assessment and advice (e.g. mixed fisheries overviews)

The sections on assessment and advice contains (if available)
- Assessments and advice regarding protection of biota and habitats
- Assessments and advice regarding fisheries. The fisheries advice includes some reflection on mixed fisheries issues in fisheries management. For those stocks for which mixed fisheries issues are known to be minor the advice is given on a stock basis. This applies mainly to pelagic stocks. For most demersal stocks or stocks where mixed fisheries are known to be important the advice is based on an identification of the critical stocks and the overall advice is based on the requirements for those stocks. As a consequence of the need to take a fisheries perspective the advice for all stocks is now given in the area overview section.
- Special requests that are applicable to the area or stocks within the area.

1.3.5 Single stock summaries

The single stock summaries contain information on the individual stocks and the basis for the advice. These sections present descriptions of stock trends, short term outlook and main factors to be considered in managing these stocks.

1.4 Basis for the advice

1.4.1 Data used and data quality

*Catch and effort data*

The quality of the fish stock assessments is closely linked to the quality of the fisheries data, and ICES has expressed the greatest concern over the quality of catch and effort data for some of the important fisheries in the ICES area.

The stock assessments presented in this report are carried out using the best possible estimates of the total catch. These estimates are not necessarily identical with the official landings statistics because they may include estimates of unreported landings and corrections for misallocation of catches by area and species. In the past there have been problems associated with discrepancies between the official landing figures reported to ICES by member countries and the corresponding catch data used by ICES. ICES recognises the need for a clear identification of the categories of the catch data. ICES attempts to identify factors contributing to the total removals from the various stocks through:

- recorded landings,
- discards at sea,
- slipping of unwanted catches,
- losses due to burst nets, etc.,
- unreported landings,
- catch reported as other species,
- catch reported as taken in other areas,
- catch taken as bycatch in other (e.g. industrial) fisheries.

The discards, slipped fish, unreported landings and industrial bycatches may vary considerably between different stocks and fisheries. It may not always be possible to reveal the sources of the estimated removals because of restrictions on how the data has been made available to ICES (e.g. confidentiality clauses). As a minimum, ICES describes the origin of the data (sampling programmes, field observations, interviews, etc.) so that interested parties can evaluate the quality of the information. Estimates of by-catches from the industrial fisheries are included in the assessments wherever the data is available. In recent years more information on discards has been collected through observer programmes and this information is increasingly made available to ICES for assessment purposes. The catch data used in the stock assessments are presented in the “summary table” in each of the stock summaries (sections x.4 in each Ecoregion).

The catch data used by ICES are collated on a stock basis and not on an area basis so that direct comparisons between these figures and the official statistics are not always appropriate.
ICES attempts to correct the shortcomings in the catch data. For non-reported landings such corrections, by their very nature, are difficult to document and are obviously open to debate. The stock assessments that are based on these data are of poor quality but they are still expected to be the best possible assessment of the state of the stocks. The fishing industry has on various occasions strongly disagreed with ICES’ estimates and has blamed ICES for not performing well. ICES does not accept the responsibility for quantifying non-reporting fisheries or ensuring access to proper discard data. The responsibility for discards and non-reporting and the uncertainty regarding the extent of these phenomena rests with the national authorities and the industry.

When catch data could not be estimated, the trends in the stocks have sometimes been evaluated using research vessel data. This will only allow relative trends to be estimated and cannot be translated into a numerical advice on removals or effort.

**Research vessel data**

Research vessel surveys are an essential fishery-independent source of information for scientists and a vital cross-check to the figures gathered from the international landings and from sampling onboard fishing boats. On research vessel surveys, scientists sample demersal fish such as cod, haddock, hake and plaice or pelagic fish such as mackerel and herring.

To sample fish on or near the seabed scientists use bottom trawls in the same way that fishers do. But whereas fishers target hotspot areas and continually try to upgrade their fishing gear to maximise their catch, fisheries scientists don’t want to maximise their catch but instead collect a representative sample. They also have to compare their results with previous years to follow trends, so it is vital that they use the same standard fishing gear each year rather than continually improving it.

Research vessel surveys are carried out by national research institutes. ICES has an important role in internationally coordinating and analysing the surveys.

**Information from the fishing industry**

There is an increasing interaction between scientists and fishers during the collection of data in harbours and through observer programmes onboard fishing vessels. There have been a number of joint research projects between the fishing industry and scientists that have aimed to collect additional information on e.g. catch rates or catch compositions. In recent years, fishers in the North Sea have also been filling in questionnaires recording their perception of the state of key fish stock. This information is considered during the process of deriving ICES advice.

Commercial Catch per Unit Effort (CPUE) series have been used in several stocks assessment as an indicator of stock abundance. In most cases the catch is then disaggregated by age through a market sampling process. A major difficulty in the use of CPUE series in stock assessment is the standardisation of fishing effort. The increasing efficiency of fishing vessels (e.g. through technical developments, GPS devices, new gear materials etc.) needs to be taken into account in an estimate of effective fishing effort. This is not always possible due to lack of the relevant data for standardisation.

The collaborations between the fishing industry and scientists has provided information which has been included as part of the assessment process. Such information has contributed to the understanding of the fisheries, and is increasingly provided in a form which enables direct inclusion in quantitative assessments.

**1.4.2 Assessing the status of fish stocks**

Stock sizes and fishing mortalities are estimated in a stock assessment model. Most stock assessment models use catch at age information from the commercial fisheries and use additional information to “calibrate” the assessment. The additional information is mostly research survey indicators or catch rates in the commercial fishery (CPUE information). The estimated catches can be subject to serious bias if there are significant amounts of unreported landings or when information on discards at sea is not available. Catch information tends to become most unreliable when management measures are most restrictive (if they were implemented). In recent years several stocks have been at a low level and catch information has deteriorated for many fisheries. The consequence is that the ability to provide reliable, quantitative catch forecasts has decreased.

Most management strategies in the ICES area rely on some forecast of the outcome of fisheries management in the management year. Under these conditions the Management Option table is an important part of the ICES advice. The catch options rely on estimates of recent stock size and fishing mortality and requires an assumption about the total catch in the current or “assessment” year, because the fishery is rarely open when the assessment is carried out. In many cases, ICES considers two alternatives: 1) to assume that the catch will be equal to the TAC (a TAC constraint), or 2) to assume that the fishing mortality will continue to be equal to that of the previous year(s) (a status quo constraint). ICES
attempts to evaluates the weight of the evidence for a TAC constraint vs. a $F_{status quo}$ constraint and selects the more appropriate assumption.

1.4.3 Evaluations of management plans

When fisheries management plans have been agreed or proposed, ICES will evaluate the consistency of the management plan with international agreements and commitments. The main comparison will be in relation to the consistency with the precautionary approach.

The methods for evaluating management plans differ by area, species and type of plan, but the general characteristics are that both fish populations and the management measures are simulated in a computer simulation process. The results of the simulations are scored in relation to the probability with which the stocks would be expected to be below Blim in near to medium term future.

If the evaluation of a management plans indicates that a stock has a low probability (e.g. less that 5%) of being below Blim in the medium term, ICES considers the plan in accordance with the precautionary approach even when the stock is below the precautionary biomass level (Bpa) or above the precautionary fishing mortality (Fpa).

1.4.4 Three layers in providing fisheries advice (“form of the advice”)

The fisheries advice is the result of a three-step process:

- Single-stock exploitation boundaries are identified first,
- Consideration of mixed fisheries aspects,
- Consideration of ecosystem aspects.

1.4.4.1 Single stock exploitation boundaries

Single-stock exploitation boundaries are identified first. These are the boundaries for the exploitation of the individual fish stock and are identified on the basis of the status of stock in relation to the Precautionary Approach reference points, the (agreed) target reference points and/or the agreed management plan. The single-stock boundaries also include considerations of the ecosystem implications of the harvesting of that specific species in the ecosystem whenever such implications are known to exist. These single-stock exploitation boundaries are presented in the stock summaries (sections x.4 in each Ecoregion) and summarized in a table for each Ecoregion in Section x.3. The single-stock boundaries would apply directly as advice in the absence of mixed fisheries issues and ecosystem concerns beyond the impact of fishing on that stock.

The ICES advice will always be consistent with the Precautionary Approach. Within these constraints ICES does recommend any particular option and the ICES advice is therefore formulated as an upper bound on catch or exploitation. Where management bodies have agreed to a management plan or recovery plan, ICES will evaluate whether this plan is in accordance with the precautionary approach. If the plan is precautionary, the ICES advice will be based on the management plan. There are cases of non-precautionary management plans typically because the plan is inadequate in situations when the stock is depleted. However, when the stock is not in a precarious situation these management plan may still produce precautionary options and ICES will advise on these options. Obviously, ICES will not advise measures which are not consistent with the precautionary approach. In those cases, ICES will not be based on the management plan but on the strict interpretation of the precautionary approach. In these situations, ICES will calculate the management measures consistent with the management plan but states explicitly that these calculations do not constitute advice unless this is explicitly stated.

1.4.4.2 Mixed fisheries advice

For stocks harvested in mixed fisheries, the single-stock exploitation boundaries will apply to all stocks taken together simultaneously. The major constraints within which mixed fisheries should operate may be those stocks in the fish assemblage which are outside precautionary boundaries and which should therefore become the limiting factor for all fisheries exploiting those stocks. This implies that the stocks which are considered to be in the most critical state may determine the advice on those stocks which are taken together with critical stocks. ICES identifies which species within mixed fisheries have the most management advice and how these should limit the fishing possibilities on the mixed fish assemblage (section x.3 for each Ecoregion).

ICES has worked on these issues together with scientific groups under EC STECF to develop the necessary framework and to build the required databases. Much of this work has initially concentrated on the North Sea demersal fisheries but has been extended to other areas. Many fisheries harvest several quota species simultaneously and this poses at least two management problems:
• maintain catches of all species within their TACs while trying not to forego catches of species whose TACs are taken up more slowly.
• allocate the safe harvest of the shared species among fisheries in ways that allow the fisheries to take their allowable harvest of their various target species, without exceeding the total allowable catch of the shared species.

Experience from fisheries-based management in other parts of the world indicates that the provision of fishery-based advice is possible, but that it requires well-defined fisheries that are based on complete and reliable catch data. In the ICES area, model development has outpaced the compilation of appropriate data, both for defining fisheries and for providing mixed fishery advice. Specifically, the lack of complete catch data (including discards) and the problem of sampling all fisheries are major concerns.

Any approach to managing mixed fisheries that assumes a constant species composition over time implicitly discourages adaptive fishing behaviour. In many jurisdictions fishermen have demonstrated the ability to reduce bycatch of critical species, through season, area, or gear modifications, or through changes in their short-term fishing patterns. There is a danger that the allocation of fishing opportunities for different species based on past catch compositions will lock fisheries into their historical context, and provide no incentive for the industry to find ways to fish without catching species that are restrictive on fleet activities. Such adaptive changes in fishing behaviour are difficult to predict and they will limit the realism of mixed fishery forecasts.

In the absence of an analytical approach to mixed fisheries scenario evaluations, ICES is basing its advice on mixed fisheries on information available on the catch composition in these fisheries and the knowledge about the main interactions between fisheries and species. This means that the single-stock boundaries are supplemented with qualifiers about which targeted and mixed fisheries are known to harvest the critical species as target or incidental bycatch and to which extent different stocks should be seen as linked by being taken in the same fisheries.

1.4.4.3 Ecosystem aspects

Some ecosystem concerns are not related to one specific stock but rather to mixed fisheries or to groups of stocks. Such concerns may for instance include habitat and biota impacts of dragged gear, incidental by-catches of non-commercial species or food chain effects of fishing. Ecosystem concerns may represent further boundaries to fisheries beyond those implied by single-stock concerns and mixed fisheries issues and are presented (if available) in section x.3 for each Ecoregion.

The impact of fisheries on the ecosystem can at present rarely be quantified or predicted in quantitative terms. The incorporation of such considerations in the advice will therefore mainly be through qualifying statements regarding the quality and direction of expected impacts.

Present knowledge about ecosystem impacts is built on studies in specific ecosystems, but may not represent the overall ecosystem and can only be extended to other ecosystems in a general way. Many important ecosystem considerations regarding the impacts of fisheries will therefore be of a general, not area-specific nature.

1.4.5 Quality of the advice

ICES is dedicated to being transparent on the quality of the advice. Since 2004 a number of stakeholder organization are invited as observers to the advisory committee meetings. The quality of the advice can further be assessed through two sources of information in the stock summaries:

• the Advice table contains information on the basis for the advice in the subsequent years
• for stocks where analytical assessments could be carried out, a comparison (graph) is presented between the most recent assessment and the previous assessments
1.5 Answers to non-Ecoregion specific Special Requests

1.5.1 EC DG Fish

1.5.1.1 Indicator: status of fish stocks managed by the Community in the North-East Atlantic

The indicator chosen is the quantity of fish caught in 2006 that was taken from stocks grouped according to whether they were within or outside safe biological limits at the end of the year, i.e. 2007. In general terms, it is considered that a stock is within safe biological limits if its spawning stock biomass is above the value corresponding to a precautionary approach (Bpa) advocated by ICES. Further details on the way ICES formulates advice in precautionary terms can be obtained from the ICES website http://www.ices.dk.

1. Basis for the calculation:

1) **Source of data:** 2007 ICES Advice report.

2) **Selection of stocks:** all those for which ICES gives management advice and that are managed by the Community, autonomously or jointly with other partners. This excludes, for example, Arctic stocks managed by Norway or by Russia and Norway.

3) **Catch data:** taken as the total catch as estimated by ICES for assessment purposes. Sometimes this includes catch taken by third countries.

4) **Criteria to judge stock status:** If data exist, then a stock is considered within safe biological limits if its spawning stock biomass (SSB) estimated at the end of the year is higher than the SSB corresponding to the precautionary approach level, as recommended by ICES (Bpa). Sometimes these estimates are missing, but ICES gives other types of indication:

   - Estimates of fishing mortality (F) in the terminal year and F levels corresponding to the precautionary approach or (Fpa) or other desired levels of F serving as a guide for management. If F is higher than Fpa, then the stock is considered outside safe biological limits.\(^1\)

   - Estimates of catch per unit effort (U) and some desired level of U (Upa). For redfish this has been taken as half the maximum observed value. The reasoning goes on as for SSB.\(^2\)

   - If no warning signals are given by ICES in its advice, then it is assumed that the stock is within safe biological limits.

   - If ICES states, with no precise reference values, that the stock is outside safe biological limits, this is taken as a fact.

5) **Type of fish:** this is a classification intended to reflect both the biology of the species and the type of fishery realised. To some extent, this breakdown serves also purposes of economic analysis, since it brings together types of fish of comparable commercial value, although important differences still occur within each type. The possibility was examined to use prices per kg by species, but this part of the work is still going on. The difficulty is to obtain uniform price indices by stock.

   - **Benthic:** Nephrops, prawns, flatfish, anglerfish

   - **Demersal:** roundfish as cod, haddock, whiting, hake, etc

   - **Diadromous:** salmon, sea trout (eel is classified in other category)

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\(^1\) It should be noted that F values do not reflect the size of the stock in the precautionary context, but rather whether the stock is being exploited at precautionary levels. However, one may presume that in the long term, exploiting beyond precautionary levels will lead stocks outside biological limits.

\(^2\) In this case, U does reflect the size of the stock and may be used as a proxy for SSB.
- **Pelagic**: herring, anchovy, sardine, horse mackerel (North Sea and southern stocks), redfish
- **Industrial**: sprat, sandeel, Norway pout
- **Widely distributed**: blue whiting, western mackerel, western horse mackerel, eel, deepwater fish.

6) **Region**: The NEAFC regions, also defined in our technical measures legislation (Regulation 850/98). Essentially, Region 1 is ICES Subareas I, II, V, XII and XIV, Region 2 is the Baltic, North Sea and western approaches (ICES Subareas III, IV, VI and VII) and Region 3 is the Bay of Biscay and the Iberian peninsula (ICES Subareas VIII, IX and X).

2. **Results and discussion**

The table below shows the values found for the whole set of stocks examined, broken down by region, type of fish and year. It should be noted that the precautionary reference points chosen (Bpa and Fpa) are not management targets; they rather reflect a stock status that should trigger management action. In other words, maintaining a stock at Bpa values is not necessarily desirable or advisable.

Moreover, it should be noted that stock status as indicated by the relative values of SSB and Bpa cannot always be used to judge whether the stock is being exploited at a sustainable level. As an example, SSB2006 for blue whiting is above Bpa, but the levels of exploitation in recent years are well above sustainable levels and will lead the stock to unsafe levels if no drastic management action is taken.
Table showing catch of stocks (managed by the Community) within and outside safe biological limits (SBL).

<table>
<thead>
<tr>
<th>REGION</th>
<th>FISH TYPE</th>
<th>2007 Catches</th>
<th>2006 Catches</th>
<th>Within SBL</th>
<th>Outside SBL</th>
<th>TOTAL</th>
<th>% within SBL(catch)</th>
<th>% outside SBL(catch)</th>
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</thead>
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<td>Catch, '000 t</td>
<td>Catch, '000 t</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Catch, '000 t</td>
<td>Catch, '000 t</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Herring Plaice Anglerfish</td>
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<td>Dominant species</td>
<td>Catch, '000 t</td>
<td>Catch, '000 t</td>
<td>Catch, '000 t</td>
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<tr>
<td></td>
<td>Diadromous</td>
<td></td>
<td></td>
<td>Haddock Cod Whiting Hake</td>
<td>287,90</td>
<td>66,83</td>
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<tr>
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<td></td>
<td>Sprat Sandeel Norway Pout</td>
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<td>Catch, '000 t</td>
<td>Catch, '000 t</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Herring (North Sea and Baltic) Horse mackerel</td>
<td>540,75</td>
<td>40,30</td>
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<td>All</td>
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<td></td>
<td>Horse mackerel Blue whiting</td>
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<td>141,16</td>
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<td></td>
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<td>94,91</td>
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<td>2,72</td>
<td>2,72</td>
<td>0,00</td>
<td>100,00</td>
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<tr>
<td></td>
<td>Industrial</td>
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<td>287,90</td>
<td>868,08</td>
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<td>33,17</td>
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<tr>
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<td>All</td>
<td>All</td>
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<td></td>
<td>1321,89</td>
<td>6416,70</td>
<td>79,40</td>
<td>20,60</td>
</tr>
</tbody>
</table>

*ICES Advice 2008, Book 1*
1.5.1.2 Status of small cetaceans and bycatch in European waters

Request

Provide new information on small cetacean and other marine mammal population sizes, bycatches or mitigation measures. This advice should include information provided in national reporting under article 6 in Regulation 812/2004. This advice is in response to the European Commission standing request regarding fisheries that have a significant impact on small cetaceans and other marine mammals.

ICES response

1. New information on population sizes

Small cetaceans

Information on population sizes of some small cetacean species derived from SCANS (Small Cetaceans in the European Atlantic and North Sea) II surveys conducted in July 2005 was included in the advice ICES provided last year. More detailed information on the abundance and summer distribution of five cetacean species encountered during the SCANS II surveys is presented in Table 1 of the Technical Annex.

The abundance of common dolphin in ICES Areas VI, VII, and VIII is estimated to be about 250,000 animals (see details in the Technical Annex). However, this estimate does not cover the full range of the species in the Northeast Atlantic. This estimate should therefore be used only for these three ICES Areas, instead of the abundance estimate of 500,000 common dolphins for the entire Northeast Atlantic provided by ICES in 2005.

In July 2007, areas to the west of the European continental shelf edge were surveyed as part of the CODA (Cetacean Offshore Distribution and Abundance) and TNASS (Trans North Atlantic Sightings Survey) projects. Results from these surveys are expected to be available at the end of 2008 and will provide updated abundance estimates for common dolphins inhabiting offshore waters during summer. Together, the estimates from both the shelf (SCANS II) and offshore waters (CODA and TNASS) will provide a synoptic evaluation of the abundance of the common dolphin population in the Northeast Atlantic.

Ringed seals

In 2002, the stock of Baltic ringed seals, *Phoca hispida botnica*, was estimated at 4498 hauled-out animals. The stock has since been increasing about 5% per year. The total number of counted ringed seals in the Baltic in 2007 was 6670 (5020 in the Bay of Bothnia, 250 in the Gulf of Finland, and 1400 (2006 survey) in the Gulf of Riga and the Estonian coastal waters). This represents about 60% of the total population.

The minimum and maximum observed population sizes of Saimaa ringed seal, *Phoca hispida saimensis*, were 190 animals in 1990, and 280 animals in 2005. During the next two years, abundance declined by about 4% per year. The present population size is around 260 seals.

Abundance of the Lake Ladoga ringed seal population, *Phoca hispida ladogensis*, was determined from an aerial survey conducted in 2001, and estimated to be between 3000 and 5000 animals.

Grey seals in the Baltic

The total number of grey seals counted in 2007 was approximately 22,000 individuals. This figure comprises the following rounded counts by sea area: Bay of Bothnia and North Quark: 1050, Sea of Bothnia: 1830, waters around SW Finnish archipelago including Åland: 8520, Swedish Baltic proper between Gulf of Bothnia and 58°N (northern tip of Gotland): 6350, Finnish part of Gulf of Finland: 800, Estonia (Gulf of Finland, Gulf of Riga, and West Estonian archipelago): 2900, and Swedish Baltic proper south of 58°N: 550.

Harbour seals in the Baltic

Baltic harbour seal counts for the year 2007 are 527 for the Southern Baltic and 637 for Kalmarsund (Sweden).

2. New information about bycatch of small cetaceans and other mammals

Few recent estimates of total bycatch of small cetaceans in individual fisheries are available from European waters. Those estimates that are available are primarily based on National Reports submitted under Council Regulation 812/2004.

The Commission provided ICES with copies of National Reports from the following countries: Belgium, Bulgaria, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, the Netherlands, Poland, Portugal, Romania, Slovenia, Spain, Sweden, and the UK. The only extrapolated estimates of total annual bycatch in individual fisheries were those provided by the UK and France.

Recent estimates of bycatch in individual fisheries in European waters:

<table>
<thead>
<tr>
<th>Species</th>
<th>Area</th>
<th>Nation</th>
<th>Gear Type</th>
<th>Year</th>
<th>Estimated bycatch (number of animals)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour porpoise</td>
<td>Celtic Sea</td>
<td>UK</td>
<td>Gill- and tanglenets</td>
<td>2005</td>
<td>464</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2006</td>
<td>730</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ireland*</td>
<td>355</td>
</tr>
<tr>
<td>Common dolphin</td>
<td>Celtic Sea</td>
<td>UK</td>
<td>Gill- and tanglenets</td>
<td>2005</td>
<td>253</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2006</td>
<td>554</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pair trawl bass</td>
<td>2005</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pair trawl bass</td>
<td>2006</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pair trawl albacore</td>
<td>2006</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>VII</td>
<td>France</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* additional estimate for porpoise bycatch for Irish fisheries (not from 812/2004 National Reports).

ICES recommends the European Commission to establish schemes that meet Articles 9 (2b) and 15 (1biv) of the Data Collection Regulation (EC 199/2008) record and report bycatch of all vertebrates.

The observer programmes conducted by the Baltic countries under Regulation 812/2004 in 2006 covered 0.1% to 9% of the national fleets concerned, but no harbour porpoise bycatch was recorded. Bycatch of harbour porpoise is still an important issue in the Baltic, but the introduction of Regulation 812/2004 has caused resentment within the fishing industry and has not addressed the principal fisheries where porpoise bycatch is a problem. The best conservation efforts are likely to include stakeholder involvement. ICES advises that porpoise bycatches in small vessel fisheries in the Baltic need to be assessed, with observer coverage needed most in Danish, Swedish, Polish, and German waters.

New information regarding mitigation measures

**General issues**

ICES recognises that the introduction of bycatch reduction technologies has not always been successful. For example, persistent problems have occurred with the introduction of acoustic deterrent devices under Regulation 812/2004. In many cases, there has been a failure to effectively address most, if not all, of the following issues:

- Control and enforcement;
- Ecological impacts;
- Economic impacts;
- Technical issues;
- Biological impacts;
- Monitoring;
- Acceptance/Incentives; and
- Legislative issues.

ICES recommends that any further mitigation plans for minimising cetacean (or other protected species) bycatches should be introduced only after careful consideration of all of the above-mentioned factors.

**Specific issues**

ICES recognises that implementation of Article 2 of Regulation 812/2004 has been problematic. The fishing industry has been reluctant to adopt a technology widely considered to be expensive and unreliable. Research efforts have focused on the possibility of using fewer pingers and/or louder pingers, which may reduce the financial burden on the
industry. However, ICES is not aware of any technological developments that might make existing pingers any more reliable or any less expensive.

Different types of pingers have been evaluated in a number of European pelagic trawl fisheries to assess their effectiveness in reducing small cetacean bycatch, primarily common dolphins. Bycatch is a rare event in these fisheries and statistically significant results have been difficult to obtain. Nonetheless, experimental results from both the UK and the French sea bass fisheries suggest that some types of pingers can reduce bycatch of common dolphins in pelagic trawl fisheries.

Exclusion devices – rigid grids and rope barriers – have also been evaluated in a number of European pelagic trawl fisheries to assess their effectiveness in reducing bycatch, again primarily of common dolphins. However, none of the configurations tested so far have proven particularly effective.

Sources of information

## Technical Annex

### Table 1  Abundance estimates for small cetaceans from the SCANS II survey.

<table>
<thead>
<tr>
<th>Species</th>
<th>Geographical Area</th>
<th>SCANS-II Blocks (see Figure 1)</th>
<th>Abundance Estimate</th>
<th>CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour porpoise</td>
<td>Inner Danish waters, Kattegat, and Skagerrak</td>
<td>S</td>
<td>23 227</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Northern North Sea</td>
<td>J,M,T</td>
<td>37 968</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Central North Sea</td>
<td>L,V</td>
<td>58 706</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Southern North Sea and Channel</td>
<td>B,H,U,Y</td>
<td>134 434</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td>Western shelf waters</td>
<td>N,O,P,Q,R</td>
<td>128 637</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>France, Spain, Portugal shelf waters</td>
<td>W</td>
<td>2 646</td>
<td>0.8</td>
</tr>
<tr>
<td>Common dolphin</td>
<td>Western shelf waters</td>
<td>N,O,P,Q,R,W</td>
<td>63 400</td>
<td>0.46</td>
</tr>
<tr>
<td>White-beaked dolphin</td>
<td>Northern and central North Sea</td>
<td>J,T,U,V</td>
<td>10 562</td>
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<td>Western shelf waters</td>
<td>N,O,Q,R</td>
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<td>Bottlenose dolphin</td>
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<td></td>
<td>France, Spain, and Portugal shelf waters</td>
<td>W,Z</td>
<td>4 304</td>
<td>0.35</td>
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<tr>
<td>Minke whale</td>
<td>Northern and central North Sea</td>
<td>J,T,U,V</td>
<td>10 541</td>
<td>0.32</td>
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<tr>
<td></td>
<td>Western shelf waters and Channel</td>
<td>B,O,P,Q,R</td>
<td>8 072</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Figure 1  Survey blocks defined for the SCANS-II surveys. Those surveyed by ship were S, T, V, U, Q, P, and W. The remaining strata were surveyed from aircraft.
Abundance estimate of common dolphins in the ICES Areas VI, VII, and VIII

As part of the EU-funded NECESSITY (Nephrops and Cetacean Species Selection Information and Technology) project, common dolphin abundance estimates were obtained and combined from various shipboard and aerial surveys. Abundance in summer was estimated using density surface models fitted as a function of covariates, such as longitude, slope, depth, and distance from the coast. This method allows a higher resolution of estimates of density and abundance. However, various assumptions had to be made that may not be fully supportable. Survey results were corrected for animals missed on the trackline, \( g(0) \), and for responsive movement using factors derived from the SCANS II survey. It was also assumed that the density and distribution of common dolphins did not change over the 13-year survey period.

Abundance was obtained by integrating under the estimated density surfaces in the region of interest. The size of this prediction region was 1 871 600 km\(^2\). The estimated number of common dolphin schools was 28 791 (CV=0.24; 95% CI 15 370–42 210) and the estimated number of animals was 248 962 (CV=0.18; 95% CI 161 920–336 000).

### Table 2
Summary of survey data. In the columns headed ‘Number of sightings’, observer 1 and observer 2 refer to the sightings seen by the two teams of observers for surveys using the trial configuration mode. For single platform surveys, sightings are listed under observer 1. The numbers of sightings and search effort have not been truncated by perpendicular distance or Beaufort sea state, respectively.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Type</th>
<th>Date of survey</th>
<th>Block</th>
<th>Size (km(^2))</th>
<th>Effort (km)</th>
<th>Number of sightings</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Start</td>
<td>End</td>
<td>( g(0) )</td>
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<tr>
<td>MICA</td>
<td>Ship</td>
<td>03/07/1993</td>
<td>20/08/1993</td>
<td>709 161</td>
<td>6 736</td>
<td>55</td>
</tr>
<tr>
<td>SCANS-94</td>
<td>Ship</td>
<td>29/06/1994</td>
<td>24/07/1994</td>
<td>201 490</td>
<td>1 604</td>
<td>29(^1)</td>
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<tr>
<td>NASS-95</td>
<td>Ship</td>
<td>08/07/1995</td>
<td>06/08/1995</td>
<td>774 376</td>
<td>2 468</td>
<td>27</td>
</tr>
<tr>
<td>SIAR</td>
<td>Ship</td>
<td>31/07/2000</td>
<td>21/08/2000</td>
<td>120 000</td>
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<tr>
<td>ATLANCET</td>
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<td>14/08/2002</td>
<td>140 730</td>
<td>4 077</td>
<td>40</td>
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<tr>
<td>PELGAS</td>
<td>Ship</td>
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<td>24/06/2003</td>
<td>82 660</td>
<td>3 550</td>
<td>10</td>
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<tr>
<td></td>
<td></td>
<td>28/04/2004</td>
<td>23/05/2004</td>
<td></td>
<td>3 186</td>
<td>4</td>
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<td></td>
<td>05/05/2005</td>
<td>25/05/2005</td>
<td></td>
<td>2 843</td>
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<td>30/05/2006</td>
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<td>3 642</td>
<td>13</td>
</tr>
<tr>
<td>SCANS-II</td>
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<td>27/07/2005</td>
<td>Q 149 637</td>
<td>3 702</td>
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</tr>
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<td></td>
<td></td>
<td>W 138 639</td>
<td>4 238</td>
<td>36</td>
<td>34</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P 197 400</td>
<td>3 489</td>
<td>66</td>
<td>61</td>
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<tr>
<td>Aerial</td>
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<td>26/07/2005</td>
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<td>O 45 417</td>
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<td>Z 31 919</td>
<td>1 522</td>
<td>4</td>
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</tr>
</tbody>
</table>

\(^1\) Although SCANS-94 was conducted in trial configuration mode, it was analysed using conventional LT methods.
Figure 2  Plot of the region of interest (solid black line) and the regions covered by the surveys (dashed lines). The surveys are MICA (pink), SCANS-94 (black), NASS-95 (red), SIAR (cyan), ATLANCET (yellow), PELGAS (red in Bay of Biscay), and SCANS-II (green).
1.5.1.3 Interactions between fisheries and seabirds in EU waters

Request

ICES was requested by the European Commission (EC) to provide an initial assessment and advice on interactions between fisheries and seabirds in European Union (EU) waters with a view towards developing a National Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (NPOA–Seabirds) for European waters. The development of such a plan would be done in fulfilment of the FAO International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (IPOA–Seabirds). The EC requested that the ICES advice cover the interactions between all fisheries and seabirds in all EU waters, consistent with the ongoing development of FAO best practice guidelines for the development of an NPOA–Seabirds.

ICES advice is to be based upon collection and analysis of information, as recommended by IPOA–Seabirds:

- criteria used to evaluate the need for a NPOA–Seabirds;
- fisheries information pertinent to fisheries-seabird interaction, *inter alia*
  - fishing fleet data (number of vessels by size),
  - fishing techniques data (demersal, pelagic, methods),
  - description of fishing areas,
  - fishing effort by fishery (seasons, species, catch, number of hooks/year/fishery);
- status of seabird populations in the fishing areas, if known;
- total annual catch of seabirds (numbers per 1000 hooks set/species/ fishery);
- existing mitigation measures in use and their effectiveness in reducing incidental catch of seabirds; and
- systems for monitoring incidental catch of seabirds (observer programmes, etc.).

ICES response

ICES advises that the EC should develop an NPOA–Seabirds for EU waters, based on available evidence of seabird–fisheries interactions. ICES further recommends that that an EC-wide Plan of Action (EC–POA) be developed to ensure cohesiveness and regulatory coordination among fishing fleets operating in EC waters. ICES advises that this plan of action should cover all fisheries (not just longline) where there is some indication of seabird bycatch. ICES notes that an assessment of seabird bycatch by the International Commission for the Conservation of Atlantic Tunas (ICCAT) is in progress. ICES advises that the development and implementation of an EC–POA is coordinated with any related ICCAT activities that apply to EU waters.

ICES advises that there is an immediate and critical need for more systematic data collection of seabird bycatch data throughout EU waters and for a standard protocol and format for recording these data. It is impossible to accurately assess the extent of seabird bycatch within EU waters without these developments. These deficiencies can cause gross underestimation of the actual amounts of seabird bycatch. Nonetheless, the presently available data are sufficient to indicate that seabird mortality is substantial in the Northeast Atlantic and Mediterranean longline fisheries. There are also too few available data to accurately estimate population trends for all of the seabird species of concern in any of the fishing areas considered. Nevertheless, available information indicates a persistent and possibly severe problem in some waters, especially in the Mediterranean.

To facilitate the development and implementation of appropriate regional mitigation measures, ICES advises that a geographic substructure be adopted for the EC–POA. It is important that this sub-structure can form the basis for an assessment of the total EU impact by seabird species. ICES advises that the following geographic sub-structure be adopted:

- Baltic Sea (ICES Areas IIIb, c, d)
- North Sea (ICES Areas IV and IIIa)
- Northwest waters (ICES Area VI)
- Celtic and Irish Seas (ICES Area VII)
- Bay of Biscay (ICES Area VIII)
- Iberian Seas (ICES Area IX)
- Azorean waters (ICES Area X)
- Western Mediterranean, including Tyrrhenian Sea (FAO subarea 37.1)
- Central Mediterranean, including Adriatic and Ionian Seas (FAO subarea 37.2)
- Eastern Mediterranean, including Aegean Sea (FAO subarea 37.3)
- Black Sea
Next steps

ICES notes the European Commission’s commitment to establish an EC–POA by 2009 (COM (2008) 187 final). ICES understands that the EC–POA is meant to be synoptic, covering all EU waters and including all seabird species and all fisheries where seabird bycatch occurs. To ensure that this commitment is met, ICES proposes a 3-step approach (see below) to developing the EC–POA.

The EC–POA should be based on as much information as is available on the extent of the seabird bycatch problem. As noted above, ICES has assessed this with regard to some longlining fisheries but there remain gaps in the initial assessment, both in regard to longlining and to other fishing gears. Fishing effort data are required to scale-up observed bycatch to estimate the total bycatch. Without these data, it will not be possible to develop an adequate and effective EC–POA.

Step 1. Accessing fishing effort data

ICES does not have ready access to fishing effort data. As such, ICES recommends that the following information be provided by the EC for each of the following sea regions: ICES Areas IIIb, c, d; IV and IIIa; VI; VII; VIII; IX; X; the western Mediterranean; the central Mediterranean; the eastern Mediterranean; and the Black Sea:

- the average number of hooks set annually per longline fishery from 2002 to 2007;
- the average soak time (km.hours) during which gillnets and/or tangle nets were deployed during 2002–2007.

ICES is aware that the data available to the EC on fishing effort in some of these fisheries are incomplete due to insufficient submission of these data by relevant EU member states. ICES emphasises that it will not be possible to draft an effective EC–POA lacking such data. In addition, if data were made available at a greater spatial definition (e.g. by ICES Subareas) it would be possible to produce a more precise EC–POA in some areas. This would be particularly useful in examining the interaction between coastal fisheries and seabirds.

Step 2. Special ICES meeting in autumn 2008 (late October/early November)

ICES recommends that an extra meeting of the ICES Working Group on Seabird Ecology (WGSE) be convened in autumn 2008 to more fully assess the extent of seabird bycatch in all fishing gears. This meeting should strive to:

- Complete the collation of information on EU seabird populations
- Assess the extent of seabird bycatch in fishing regions within EU waters in fishing gears other than longlines (particularly in bottom-set nets) and make recommendations for mitigating seabird bycatch for inclusion within the EC–POA; and
- Where appropriate and possible, update earlier reports by ICES with respect to longline fishing effort.

ICES experts will ensure that various data on seabird populations and their distribution, including the European Seabirds at Sea Database, are made available for this WG meeting. ICES experts can access these data for the ICES area, but further expertise will be needed from other areas, especially parts of the Mediterranean and Black Seas.

Information on seabird bycatch in bottom-set net fisheries for each of the following sea regions: ICES Areas IIIb, c, d; IV and IIIa; VI; VII; VIII; IX; X; the western Mediterranean; the central Mediterranean; the eastern Mediterranean; and the Black Sea is required for this meeting. This information will be obtained from both published and unpublished literature (and various other sources), but again, additional expertise may be needed to obtain seabird bycatch data for fisheries in portions of the Mediterranean and Black Seas.

Participation at this meeting would include relevant seabird experts and representatives of organisations with expertise in the subject. Expertise would be invited from:

- all Regional Advisory Councils;
- the General Fisheries Commission for the Mediterranean;
- the Secretariat of the Convention for the Protection of the Marine Environment and Coastal Region of the Mediterranean (Barcelona Convention) (including the Regional Activity Centre for Specially Protected Areas);
- the Secretariat of the Commission on the Protection of the Black Sea against Pollution (Bucharest Convention);
- the Commission of the Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM);
- the Secretariat of the OSPAR Convention;
- BirdLife International.

ICES Advice 2008, Book 1
ICES notes that special arrangements may be required to ensure that effort data are available from the EC’s Joint Research Centre. ICES is willing to host the special WGSE meeting at ICES HQ.

**Step 3. Drafting meeting for Plan of Action**

ICES recommends that the first draft of the EC–POA be developed by a group of national and invited experts at a workshop to be convened by ICES in March/April 2009 at ICES HQ. This workshop would include seabird experts from within and outside the ICES community, and would be informed by the Report of the Special WGSE meeting in autumn 2008. Fisheries experts will also be invited to the 2009 Workshop to offer further interpretation of fisheries data and advice on protocols for EC–POA data collection.

**Components of the EC Plan of Action**

ICES recommends that the EC–POA follow best practice with respect to data collection and mitigation of seabird bycatch as provided in the Commission for the Conservation of Antarctic Living Marine Resources (CCAMLR) model. ICES further recommends that the EC–POA be composed of three broad components (see Technical annex for further details):

- ongoing assessment of the extent of the problem,
- prescription of mitigation measures, and
- education and ensuring compliance.

**Source of information**

Technical annex

Evaluating the Need for an EC–POA

In assessing the informational needs for an EC–POA, ICES followed the guidance provided for National Plans of Action–Seabirds contained within the FAO International Plan of Action (IPOA-Seabirds), adopted by the 23rd Session of the FAO Committee on Fisheries in February 1999 and endorsed by the FAO Council in June 1999. ICES notes that these data requirements are consistent with those required to conduct an assessment of seabird–fisheries interactions. Indeed, the EC specifically requested advice on collecting and analyzing such information with a view toward developing an EC–POA. Although other data may be considered, ICES found the stated list to be sufficient for the initial assessment requested by the EC.

ICES considered all available information to determine whether a seabird bycatch problem exists in EU waters. ICES also considered the FAO Code of Conduct for Responsible Fisheries (FAO 1995, Art 6.6), which calls for best practice to avoid unnecessary mortality of non-target species, irrespective of whether this mortality threatens the overall status of the impacted species. Therefore, the bycatch of seabirds within EU waters need not be proven significant nor affect threatened or endangered populations to warrant the use of mitigation measures.

The IPOA-Seabirds does not explicitly recommend that Plans of Action be based on the absolute number of seabirds taken as incidental bycatch or on the conservation status of the affected seabird species. Nevertheless, it calls for the collection and analysis of the total annual catch of seabirds and the status of seabird populations in the fishing areas. Of course, the need for an EC–POA and any potential remedial actions prescribed within such a Plan would be greater if the seabird mortality is potentially significant. This would be particularly true where any of the affected seabird species is listed as threatened, or is in need of protection according to internationally recognised criteria (e.g. IUCN, the EC Birds Directive).

ICES notes that there are significant gaps in the data required for a more thorough analysis. In particular, ICES views three data categories as particularly relevant in evaluating the need for an EC–POA: Total annual catch of seabirds, Systems for monitoring seabird bycatch and Use/effectiveness of mitigating measures. Data are severely lacking in all three information categories, but are critical to fully assessing and mitigating seabird bycatch. The Total annual catch of seabirds cannot be adequately assessed without adequate monitoring systems (especially on-board observer programmes). Likewise, bycatch cannot usually be reduced or eliminated without routine application of effective mitigation measures. As there are a priori reasons to consider that neither monitoring nor mitigation are adequately developed in fisheries in EU waters, the acquisition of adequate information is vitally important in the development (and successful implementation) of an EC–POA.

Even with sparse information, ICES finds that 20 species of seabirds interact with EC longline fisheries. Six of these species are notable for their high conservation concern, and their moderate to high frequency of capture (sooty shearwater, Balearic shearwater, Yelkouan shearwater, Cory’s shearwater, Audouin’s gull, and black-legged kittiwake). Two species have high reported numbers of mortalities (northern fulmar and great shearwater). This information signals a potentially large impact of fishing on some or all of the seabird populations in EU waters, whether seasonally or throughout the year. Based on these data, substantial seabird bycatch may be occurring in EC longline fisheries in the western Mediterranean, in ICES Area VII (Gran Sol grounds), and in Azorean waters.

Gillnet fisheries have large seabird bycatches in Polish and Lithuanian waters, off northwestern Spain, and in the western Mediterranean. Unfortunately, even less information is available to make a comprehensive estimation of overall mortality in these and other gillnet fisheries.

Based on an initial assessment, ICES concludes that there is a seabird bycatch problem in EU waters and that an EC–POA should be developed.

Seabirds in EU waters

ICES has compiled data on breeding seabird numbers and trends in seabird abundance for all EU coastlines except the Baltic, Mediterranean, and Black Seas. Information from these latter areas is believed to exist and to be easily available. EU waters are also visited by birds that breed elsewhere, some which breed in the Arctic and some in northern Europe/Asia. Great and sooty shearwaters travel from their southern hemisphere breeding grounds to feed in EU waters. The population size of some of these species is poorly known. Trends in abundance of most species are not well known except around the North Sea, NW waters, Irish Sea, Celtic Sea, and in the Bay of Biscay. Balearic, Cory’s and Yelkouan shearwaters are better understood with documentation of Mediterranean breeding grounds being a primary focus of research. All three of these species (or one or more of their subspecies) are endemic to EU waters and are experiencing population declines. These species face significant threats on their breeding colonies and, where data are
available, appear vulnerable to further mortality from bycatch in longline fisheries. Likewise, the black-legged kittiwake is experiencing severe population declines in ICES Areas IV, VI, and in Norway and are also vulnerable to bycatch mortality in longline or other fisheries.

In general, the ICES review revealed a paucity of data for many species, including information on distribution, threat vulnerability, and overall conservation status. Furthermore, the quality of information among seabird species in EU waters is variable and presents a challenge for fully assessing the impact of fisheries on these species.

Bycatch of seabirds in EU waters

ICES conducted a complete search for information on bycatch of seabirds in longline fisheries, including data contained in the published literature, in reports of observer programmes, and in other sources. ICES concludes that insufficient data exist to document seabird bycatch in the northeast Atlantic, making it impossible to fully understand the extent of seabird–fisheries interactions. For example, in ICES Areas III, IV, and VI–X, the only data available on seabird bycatch in longline fisheries were derived from:

1) three trips (2006–2007) on Spanish hake longliners (a fleet of c. 20 vessels) fishing the Gran Sol in ICES Area VII;
2) questionnaire returns from NW Iberia (ICES Area VIII);
3) limited observations from vessels fishing near the Azores (ICES Area X) in 2000–2005; and
4) occasional events reported elsewhere.

Within the Mediterranean area, some longline bycatch data exist (including a compilation of seabird bycatch data in 2003). However, only half of the Mediterranean countries with longline fleets reported information on seabird bycatch and mortality. Therefore, additional seabird bycatch is likely in the longline fisheries of the non-reporting Mediterranean countries, as well as in the longline fisheries of countries such as Japan, Korea, and Taiwan, fisheries which are also conducted in the Mediterranean Sea. The most extensive information on longline bycatch is for Spain. These data were sufficient to enable identification of the main species taken by longlines, as well as to derive qualitative estimates of seabird mortality. Bycatch occurs in both pelagic and demersal longline fisheries, with the latter appearing to be the main threat to seabirds. The Spanish longline fleet accounts for only a small proportion of the total fishing fleet in the Mediterranean. Balearic, Yelkouan, and Cory’s shearwaters are prominent in the recorded seabird bycatch of the Spanish longline fleet.

Although observer programmes exist in Azorean waters to document both target and non-target catch in longline fisheries, there is only one record of seabird bycatch in either demersal or pelagic longline fisheries. However, the proportion of the fleet observed is low. Expanding the observer programme to cover a larger proportion of the Portuguese national fleet, as well as other national fleets present in the Azorean EEZ, would provide a greater understanding of seabird–fisheries interactions in this region.

Most records of bycatch are associated with larger fishing vessels; it is likely, however, that seabird bycatch is substantial in the small-vessel fleets. Observing and documenting bycatch in these fleets has been particularly challenging.

Seabird bycatch data from a single vessel fishing in the vicinity of Iceland and the Faroes during 1996–1998 (ICES Areas V and II) are also available, being perhaps also representative of the bycatch of vessels fishing in the northern part of ICES Area VI. These data are supplemented by some bird ring recoveries. Observations have also been made off western Norway which may be applicable to the extreme northern part of the North Sea (ICES Area VI).

ICES concludes that there is an immediate and critical need for more systematic data collection of seabird bycatch data throughout EU waters and for a standard protocol and format for recording these data. It is impossible to accurately assess the extent of seabird bycatch within EU waters without these developments. These deficiencies can cause gross underestimation of the actual amounts of seabird bycatch. Nonetheless, the presently available data are sufficient to indicate that seabird mortality is substantial in the Northeast Atlantic and Mediterranean longline fisheries.

Existing mitigation methods

ICES reviewed seabird bycatch mitigation methods used throughout the world’s oceans, many of which have potential applicability in EU waters. Seabird bycatch on longlines seems particularly amenable to mitigation; many effective methods have been developed and are currently in use around the world. Development of these mitigation methods has relied heavily on the assistance and expertise of fishers, which has helped to ensure that these methods are safe, cost-effective, and practicable.
The effectiveness of each method (and combination of methods) varies due to their nature and usage as determined by various factors. These factors include: the nature of the target fishery, gear used, location and suite of seabird species encountered, and sea conditions. Options for mitigation include: offal and discard management, area/seasonal closures, underwater setting devices, bait casting/throwing machines, blue-dyed bait, side-setting, night-setting, bird-scaring lines, bird curtains, fish oil, integrated and external weight lines, line shooter, and bait condition and species.

ICES has compiled information on each of these methods, including data on their efficacy and safety. Some practices such as offal and discard management and area/seasonal closures are already in place in some fisheries for reasons other than reduction of seabird bycatch. Other mitigation methods have been specifically designed and tested to reduce seabird bycatch.

ICES has also reviewed and compiled descriptions of regulations to reduce longline seabird bycatch that have been implemented in many longline fisheries around the world. Some of the measures have been in place for several years and have been modified in light of actual experience and subsequent research findings. Area/seasonal closures can probably be fine-tuned to avoid or minimize seabird bycatch. Regulatory experience indicates that most fisheries require a combination of mitigation methods to achieve significant reductions in seabird bycatch. The efficacy of some measures (i.e., the use of thawed bait) is not supported by empirical evidence.

As a model of best practice, the Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR) has required seabird bycatch mitigation measures for demersal longline fisheries since 1992. CCAMLR uses risk assessment to determine how and where to apply such measures based on: (a) assessing the relative risk of seabird bycatch within subareas of their Convention Area, and (b) specific information regarding the seabird species themselves and their relationship to CCAMLR fisheries. Seabird bycatch in the CCAMLR area is now very low.

There is little information on EU countries implementing seabird bycatch mitigation methods, through either mandatory or voluntary means. Some fishers voluntarily use bycatch mitigation measures to reduce bait loss to seabirds. However, there is insufficient information to determine whether any of these initiatives have been effective.

**Suggested contents list of EC Plan of Action**

ICES has initiated the process of assembling the information needed to develop an EC–POA. This has been done on the basis of geographic sub-regions of the EU waters:

- Baltic Sea (ICES Areas IIIb, c, d)
- North Sea (ICES Areas IV and IIIa)
- Northwest waters (ICES Area VI)
- Celtic and Irish Seas (ICES Area VII)
- Bay of Biscay (ICES Area VIII)
- Iberian Seas (ICES Area IX)
- Azorean waters (ICES Area X)
- Western Mediterranean, including Tyrrhenian Sea (FAO subarea 37.1)
- Central Mediterranean, including Adriatic and Ionian Seas (FAO subarea 37.2)
- Eastern Mediterranean, including Aegean Sea (FAO subarea 37.3)
- Black Sea

Progress is summarized below:

a) fishing fleet data (e.g. number of vessels by size);
b) fishing metier data (*Nantes level* 4 or similar);
c) fishing effort by fishery (by season where relevant and using appropriate effort descriptor, e.g. number of hooks/year, soak time of gillnets);

However, ICES has not been provided with sufficient data for any of the above items (i.e., a, b, and c).

d) status of seabird populations;

ICES has compiled and assessed information on the distribution and status of many breeding seabird populations within EU waters, but this has not been done for populations breeding in the Baltic, Mediterranean, and Black Seas. The status of seabird species that forage in EU waters—but breed elsewhere—has not been assessed.

e) total annual catch of each seabird species in each fishery (preferably with confidence limits);
ICES has reviewed available information on the catch of seabirds in longline fisheries within EU waters. These data are incomplete, describing only subsets of some longline fisheries and containing no information on gillnet or trawl fisheries (although there is no evidence of significant interactions between trawl fisheries and seabirds).

f) existing mitigation methods;

ICES compiled information on all existing seabird bycatch mitigation methods worldwide and summarized their effectiveness in reducing seabird bycatch. No single mitigation method is likely to be fully effective, and hence a combination of methods used simultaneously is recommended. The specific combination will depend on such factors as the target fishery, gear used, location and suite of seabird species encountered, and sea conditions. Furthermore, this may need to be fine-tuned on an individual vessel basis to optimize performance.

g) systems for monitoring incidental catch of seabirds (observer programmes etc)

ICES has summarized the need for a well-organized and standardized at-sea observer programme. The observer programme should cover a representative sample of fisheries and target species, and should monitor bycatch rates and the efficacy of mitigation methods. ICES has recognized the need for the observer programme to be complemented by a series of questionnaires to fishers concerning their attitudes and reactions to seabird bycatch.

h) systems for appropriate data storage and reporting of seabird bycatch.

ICES has made no progress in devising possible systems for the reporting or storage of relevant data.
1.5.1.4 Format for National Reports made under EU Regulation 812/2004

Request

The National reports under Regulation 812/2004 have proven to be very variable in format and do not cover all issues in the same way, which may result in difficulties for the analysis of these reports under the standing request to ICES. ICES is requested to suggest a standard format for reporting, for instance based on a combination of multiple choice and standardised tables. This would facilitate the analysis and make an overall assessment feasible.

ICES response

The proposed standard format for future reporting under EC Council Regulation 812/2004 is included in the Annex.

Background

ICES notes that the requirement of Member States of the European Union under Regulation 812/2004 is to:

“report annually on the use of pingers and the implementation of the on-board observer programmes, and include all information collected on the incidental capture and killing of cetaceans in fisheries.”

National reports under Regulation 812/2004 may serve different functions:

- to demonstrate that obligations have been met;
- to indicate difficulties in the implementation of the Regulation;
- to provide a basis for a wider analysis of the nature and scale of cetacean bycatch;
- to identify gears/areas/seasons with high bycatch rates;
- to help future co-ordination of monitoring.

There is considerable variation in the format of the national reports submitted under EC Council Regulation 812/2004. The reports showed little evidence of member state cooperation, and most have been the result of independent national efforts. An integrated review of the national reports is problematic, due to:

- differences in the level of detail;
- a variety of ways of describing fishing effort;
- low levels of reporting on total fleet effort and fleet size;
- a lack of data on geographical and seasonal distribution of fleets.

An integrated review of the national reports will only be possible at a higher level of data aggregation on the basis of simple, straightforward tables containing the same information and units. For this purpose a template for a standard reporting format was prepared. The national annual reports under Regulation 812/2004 were provided in several European languages. It would be useful if reports were provided in English in the future.

Sources of information

National reports under 812/2004 for the second half of 2004 to 2006 provided by the European Commission.
Technical Annex

Proposed standard format of National Reports made under EU Regulation 812/2004

The main body of the text (preferably in English) in this proposed standard format contains 6 tables. Any tables and maps that provide more detailed information should be put in the annexes to the report.

Title

Table of contents

Summary (English)

Summary (Native)

1 Introduction

[Why this report is written, with reference to Council Regulation 812/2004]

2 Description of the fleets

[Table 1 should be completed in order to describe relevant fleets, including the number of fishing vessels, the gear types, and target species. Gear type should at least differentiate between the following types: bottom-set gillnet, trammelnet, drift net, single pelagic trawl, pair pelagic trawl, high-opening trawl, or other relevant gear type (specified). If possible, the type of trammelnet (e.g. trammelnet) should be indicated. For static gear also the mesh size should be included.]

Table 1 Description of the fleets.

<table>
<thead>
<tr>
<th>Code number for fleet segment (for use in subsequent tables)</th>
<th>Fishing area (ICES Subarea)</th>
<th>Gear type</th>
<th>Target species</th>
<th>Number of vessels</th>
<th>Months of operation (e.g. Nov–Feb)</th>
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</table>

3 Bycatch mitigation measures

[This section should include information on the use of bycatch mitigation measures, especially the use of acoustic deterrent devices (pingers) as required for certain fisheries by the Regulation. Any difficulties in the implementation of article 2 and 3 of the regulation should be reported here. Information on the type and technical specification of pinger used should be included. For this section, Table 2 should be completed for the relevant fisheries.]

Table 1 Description of the fleets.
Table 2  Description of bycatch mitigation measures.

<table>
<thead>
<tr>
<th>Fleet segment (refer to code in Table 1)</th>
<th>Pingers mandatory?</th>
<th>% of vessels using pingers</th>
<th>Comments</th>
<th>Other bycatch mitigation measures</th>
</tr>
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4 At-sea observer schemes

Observer effort

[This section should contain a short description of observer schemes, including the number of observers used and any training supplied; further details can be put in the Annex. Any integration with EU Council regulations 1543/2000, 1639/2001, and/or 92/43 should be mentioned. Any difficulties in the implementation of article 4 and 5 of the Regulation 812/2004 should be reported. For this section of the report Tables 3a and 3b should be completed; note that the effort of the fleet segments is split by ICES Subarea.]

Table 3a Description of fishing effort and observer effort in static gear.

<table>
<thead>
<tr>
<th>Fleet segment (refer to code in Table 1)</th>
<th>ICES Sub-area</th>
<th>Total fishing effort</th>
<th>Total observer effort achieved</th>
<th>Coverage % (days at sea)</th>
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</table>

Table 3b Description of fishing effort and observer effort in towed gear.

<table>
<thead>
<tr>
<th>Fleet segment (refer to code in Table 1)</th>
<th>ICES Sub-area</th>
<th>Total fishing effort</th>
<th>Total observer effort achieved</th>
<th>Coverage % (days at sea)</th>
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Recording of bycatch

[A short description of how the bycatch was observed and recorded by the observer should be given. This can include the circumstances of the observation of bycatch (such as bycatch observed during hauling or only animals taken on board the ship), and the collection of additional information from bycaught animals.]

Results of the observer schemes

[This section should contain Tables 4 and 5; in Table 5 please choose the most suitable stratum for further analysis.]
Table 4  Bycatch by species and fleet segment.

<table>
<thead>
<tr>
<th>Fleet segment (refer to code in Table 1)</th>
<th>ICES Subarea</th>
<th>Main target species</th>
<th>Pinger in use? (yes/no)</th>
<th>Cetacean species bycaught</th>
<th>Number of incidents</th>
<th>Number of specimens</th>
</tr>
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</table>

Table 5  Bycatch rate by fleet segment and target species.

<table>
<thead>
<tr>
<th>Fleet segment or other stratum</th>
<th>Cetacean species (scientific name)</th>
<th>Bycatch rate expressed per unit of fishing effort*</th>
<th>Total bycatch estimate</th>
<th>CV percent</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

*Units of effort should be specified, for example: specimens/day, /haul, /soak time × km, /hours × metres.

5  Discussion

[Any other information useful in assessing bycatch or understanding failures and success in mitigation should be included in this section. Possible biases in the sampling scheme should be described. Results could be put in the context of bycatch rates found in previous years.]

6  References

[List any publications or other reports relevant to the information presented here.]

7  Annexes

[Examples include more detailed tables or other studies or bycatch of other species such as seals.]
1.5.1.5 Answer to Request on appropriateness of F = 0.4 as a proxy for F MSY for certain cod stocks

DG MARE asked ICES to consider if a fishing mortality of F = 0.4 would be an appropriate proxy for F MSY for cod stocks:

"ICES is requested to evaluate objectives foreseen in the long term management plan and to analyse if a fishing mortality rate of 0.4 will appear well defined for all cod stocks covered by such a plan."

The objective of the cod plan is to exploit the stocks at MSY. ICES has previously advised that a fishing mortality in the range 0.2 to 0.4 is consistent with MSY for the North Sea cod stock. EC and Norway have agreed on F = 0.4 as a target fishing mortality for the North Sea cod. The European Commission, in its proposal to Member States, has adopted this value also as a proxy for F MSY for other cod stocks: in the Kattegat, the West of Scotland the Celtic Sea and the Irish Sea. The Commission would like ICES' advice as to whether alternative values would be better proxies for F MSY for the stocks outside the North Sea, Skagerrak and VIId.

ICES Response

F = 0.4 is not necessarily an appropriate proxy for F MSY for North Sea cod or for other Northeast Atlantic cod stocks. ICES (2005a) advised that F in the range of 0.2–0.4 should result in a low risk of the spawning stock falling below B lim and a high long term average yield, but this should not be interpreted as meaning that F = 0.4 is the best estimate of F MSY for the following reasons:

1. F MSY is the fishing mortality that maximizes long term average yield. A fishing mortality that produces a high long term yield with low risk of stock depletion is desirable, but it is not the same as F MSY.
2. Selecting an F value from the upper end of the range suggested by ICES further diminishes the likelihood that it corresponds to F MSY.

While estimating F MSY is difficult for a variety of reasons, ICES has advised that a fishing mortality rates in the range of F 0.1 to F max are possible proxies for F MSY, (ICES, 2007). For the cod stocks of the Northeast Atlantic for which ICES has estimated F 0.1 and F max, the range is 0.13–0.37.

If fishing mortality is reduced to the range of F 0.1 to F max, stock size is predicted to increase to levels never observed. At such high levels of spawning biomass, ecological factors (such as competition, predation of large cod on small cod) may prevent predicted increases in stock size and associated yields from being achieved. However, the actual increases in spawning stock size and yield that will occur at lower levels of fishing mortality can only be determined by observing what happens when F is reduced.

Background

For the Cod stock in the North Sea, ICES has advised on the target F of 0.4 on the basis of an evaluation in relation to a request regarding the rebuilding the North Sea cod stock (ICES, 2005a).

"In relation to the joint request, the evaluations of harvest control rules for North Sea cod have demonstrated that target fishing mortalities (covering all catches) below 0.4 (ages 2 – 4) result in a low risk of SSB falling below the conservation limit B lim and high long-term yields. With fishing mortalities below 0.4 the following conclusions can be drawn:

- a low risk to reproduction when a constraint on year-to-year variation in TAC (down to ± 5%) is used;
- a constraint to year-to-year variation in TAC of less than ± 20% results in reductions in long-term yields;
- implementation error above 10% results in significant increases in risk to Blim."

ICES interpreted the request in the context of limit reference points. In particular, the request was for an evaluation relative to a limit reference point for biomass (B lim), not target reference points associated with MSY.1

1 The distinction between limit and target reference points is important. Limit reference points indicate conditions to be avoided, such as a low biomass and a fishing mortality associated with a high risk of depleting a stock below a biomass deemed to put the future viability of the population at risk. There are also precautionary limit reference points, such as Bpa and Fpa, aimed at reducing the risk of undesirable outcomes, although these precautionary limit reference points are sometime confused with target reference points. Target reference points are aimed at desirable outcomes, such as...
ICES considers in its advice that fishing mortalities in the range of $F_{0.1}$ and $F_{\text{max}}$ are possible proxies for $F_{\text{MSY}}$, (ICES, 2007, 2008). For the four cod stocks considered (Cod in Celtic Sea, in Irish Sea, in Kattegat, and cod west of Scotland) this suggests that the following ranges would be appropriate:

<table>
<thead>
<tr>
<th>Cod stock</th>
<th>Year</th>
<th>$F_{0.1}$</th>
<th>$F_{\text{max}}$</th>
<th>Age range</th>
<th>High Long Term Yield candidate</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Sea, Eastern Channel, Skagerrak</td>
<td>2004</td>
<td>0.13</td>
<td>0.20</td>
<td>2-4</td>
<td>0.4</td>
</tr>
<tr>
<td>Kattegat</td>
<td>2005</td>
<td>0.15</td>
<td>0.24</td>
<td>3-5</td>
<td>0.2 - 0.3</td>
</tr>
<tr>
<td>West of Scotland</td>
<td>2006</td>
<td>0.13</td>
<td>0.19</td>
<td>2-5</td>
<td>$F_{0.1}$ - $F_{\text{max}}$</td>
</tr>
<tr>
<td>Irish Sea</td>
<td>2008</td>
<td>0.18</td>
<td>0.31</td>
<td>2-4</td>
<td>$F_{0.1}$ - $F_{\text{max}}$</td>
</tr>
<tr>
<td>Celtic Sea</td>
<td>2008</td>
<td>0.23</td>
<td>0.37</td>
<td>2-5</td>
<td>$F_{0.1}$ - $F_{\text{max}}$</td>
</tr>
</tbody>
</table>

(Compiled from ICES Advisory Reports 2005, 2006 and 2008)

It should be noted that these estimates of $F_{0.1}$ and $F_{\text{max}}$ are based on the current size and age selectivity of the fishery. If selectivity shifts towards larger and older cod, the values of $F_{0.1}$ and $F_{\text{max}}$ are likely to increase, and they should result in a higher long term average biomass and yield.

For fishing mortality at or below $F = 0.4$, single species models predict for some of the cod stocks very large stock sizes, e.g. this is the case for North Sea cod (ICES, 2008) even with the current low recruitment. Multispecies models suggest that natural mortality would increase (e.g. due to cannibalism), growth be reduced and recruitment reduced, and therefore the forecast would be very optimistic. However, even if the stock size increases predicted to result if $F$ is reduced below $F = 0.4$ do not occur, $F$ in the range of $F_{0.1}$ – $F_{\text{max}}$ may still be a reasonable range for $F_{\text{MSY}}$, depending on the nature of the spawner-recruit function.

Source of information


ICES. 2005b. ICES Advice Volume 6, ICES Headquarters, Copenhagen, Denmark

ICES. 2006. ICES Advice Book 6, ICES Headquarters, Copenhagen, Denmark

ICES. 2007. ICES Advice Book 6, ICES Headquarters, Copenhagen, Denmark

ICES. 2008. ICES Advice Book 6, ICES Headquarters, Copenhagen, Denmark (in preparation)

MSY. When there is a negative consequence of missing or overshooting a target, precautionary target reference points may be used. For example, a precautionary target fishing mortality may be set below the best estimate of $F_{\text{msy}}$ since the negative impact of overshooting $F_{\text{msy}}$ is often considered more serious than the small amount of yield that is sacrificed by undershooting $F_{\text{msy}}$. 

ICES Advice 2008, Book 1
1.5.2 HELCOM

No advice has been requested for 2008.

1.5.3 NASCO

The advice provided in response to special requests from the North Atlantic Salmon Conservation Organisation (NASCO) can be found in Book 10 of the ICES Advice 2008 Report.
1.5.4 NEAFC

1.5.4.1 Answer to request from NEAFC for evaluation and advice on a proposal to expand the areas closed for fishing on the mid-Atlantic Ridge

Request

A proposal by Norway to expand the areas closed for fishery in the mid-Atlantic Ridge was sent to ICES by NEAFC with a request for evaluation and advice.

Source of information

The ICES Working Groups on Deep-water Ecology (WGDEC) and on Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP) were asked for their comments by correspondence. In addition, the Chairs of the Working Groups on Seabird Ecology and on Marine Mammal Ecology were asked to review relevant parts of the proposals.

ICES Response

The NEAFC request for advice on proposed sites was assessed against the latest draft of the standards and criteria for identifying vulnerable marine ecosystems (VME), developed by UN’s Food and Agriculture Organization (FAO) in response to the United Nations General Assembly resolution 61/105 to support the sustainable management of deep-sea fisheries and responsible fisheries in the marine ecosystem.

According to FAO, vulnerability is related to the likelihood that a population, community, or habitat will experience substantial alteration after disturbance, and the likelihood that it would recover and in what time frame. This is related to the characteristics of the ecosystems themselves, especially biological and structural aspects, where the most vulnerable ecosystems are those that are both easily disturbed and very slow to recover, or may never recover.

The vulnerability of populations, communities, and habitats must be assessed relative to specific threats. Some features, particularly those that are physically fragile or rare, may be vulnerable to most forms of disturbance, but the vulnerability of others may vary depending on the kind of disturbance experienced, caused for example by the type of fishing gear used.

The FAO guidance has identified a set of characteristics that can be used as criteria for VME selection, and ICES considered that it was appropriate to apply these in consideration of the NEAFC proposals (Box 1).

Advice to OSPAR on MPA proposals (see Section 1.5.5.18) was provided using OSPAR’s MPA selection criteria. There are some similarities between these and the FAO guidance; however, applying the FAO criteria is consistent with the obligations on NEAFC to implement an ecosystem approach to fisheries management. Although the request to ICES did not ask explicitly for potential management measures that might be appropriate in light of the vulnerability of the proposed sites, it is suggested that the closure to bottom fisheries to protect vulnerable seabed species and habitats would be a suitable management measure. In the advice provided by ICES, the term “bottom fishing” refers to bottom fishing activities where the fishing gear is likely to contact the seafloor during the normal course of fishing operations.

Despite the more detailed description of the characteristics provided in the FAO Report (Box 1), it is still difficult to identify precisely how they should be interpreted. Interpretation would be easier if specific objectives for the site (or network) were provided. Specific objectives or targets related to the intended spatial extent of habitats, and the biomass, abundance, or rate of recovery of vulnerable species will give precision to the selection of sites and their boundaries. They will also provide the basis for monitoring and assessment of ecosystem status that will be required when NEAFC undertakes scientific evaluation of the effectiveness of the proposals to protect vulnerable marine ecosystems.

The evaluation criteria were applied to each of the five NEAFC closed area proposals, and assessed against the potential threat caused by commercial fishing activity (Table 1.5.4.1.1).

ICES notes that there is considerable overlap between the areas being proposed for protection under OSPAR and those being considered for closure to bottom fishing by NEAFC (Figure 1.5.4.1.1).

ICES recommends that a coordinated approach be taken between the two organizations. If the same boundaries are used where the same features are being protected, there will be less confusion among stakeholders and a better chance of coherent management of these areas. ICES is willing to help in any coordinated approach.
Box 1.


A marine ecosystem should be classified as vulnerable based on the characteristics that it possesses. The following list of characteristics should be used as criteria in the identification of VMEs:

i. *Uniqueness or rarity* – an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include:

   - habitats that contain endemic species;
   - habitats of rare, threatened, or endangered species that occur only in discrete areas; or
   - nurseries or discrete feeding, breeding, or spawning areas.

ii. *Functional significance of the habitat* – discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened, or endangered marine species.

iii. *Fragility* – an ecosystem that is highly susceptible to degradation by anthropogenic activities.

iv. *Life-history traits of component species that make recovery difficult* – ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics:

   - slow growth rates;
   - late age of maturity;
   - low or unpredictable recruitment; or
   - long-lived.

v. *Structural complexity* – an ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Furthermore, such ecosystems often have high diversity, which is dependent on the structuring organisms.
<table>
<thead>
<tr>
<th></th>
<th>Northern MAR Area (Reykjanes ridge)</th>
<th>Middle MAR Area (Charlie-Gibbs Fracture Zone and Sub-polar Frontal Zone)</th>
<th>Southern MAR Area</th>
<th>Altair Seamount</th>
<th>Antialtair Seamount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uniqueness</strong></td>
<td>No evidence</td>
<td>Yes (boundary between 2 ecosystems – basin-wide scale)</td>
<td>Yes (leafscale gulper shark; Portuguese dogfish)</td>
<td>No evidence</td>
<td>No evidence</td>
</tr>
<tr>
<td><strong>Functional significance</strong></td>
<td>Yes (spawning ground of blue ling; fish stocks, e.g. Sebastes)</td>
<td>Probable (but details not available)</td>
<td>Probable (but details not available)</td>
<td>Yes (orange rougthy aggregations; cold-water coral reef habitats)</td>
<td>Yes (orange rougthy aggregations; cold-water coral reef habitats)</td>
</tr>
<tr>
<td><strong>Fragility</strong></td>
<td>Yes (cold-water corals)</td>
<td>Yes (cold-water corals)</td>
<td>Yes (cold-water corals)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Recovery difficult</strong></td>
<td>Yes (cold-water corals)</td>
<td>Yes (cold-water corals)</td>
<td>Yes (cold-water corals)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>High structural complexity</strong></td>
<td>Yes (cold-water corals)</td>
<td>Yes (cold-water corals)</td>
<td>Yes (cold-water corals)</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Other information</strong></td>
<td>Increases representativity by extending well onto the abyssal plain compared to the OSPAR proposal and the original NEAFC Northern MAR closure.</td>
<td>A similar area proposed by OSPAR was reviewed in late 2007 (Charlie Gibbs Fracture Zone). The NEAFC site covers the frontal zone, but does not protect the shallower area to the north. There is a lack of information from this region to advise on the suitability of precise site boundaries. ICES advises that the boundaries between the OSPAR and NEAFC proposals (which are similar) should be combined after negotiation. ICES has no information to indicate whether this region is more or less important to fisheries, and, as most of the MAR, it is unlikely to be pristine.</td>
<td>The boundaries of the area are similar to the OSPAR recommendation for this site. There appear to be more seamounts in the larger OSPAR site compared to the NEAFC site in the south. The OSPAR site also covers more of the abyssal plain. ICES suggests a combined boundary covering the maximum extent of both sites, and extended south to include the MAR-ECO survey area that could act as a scientific baseline.</td>
<td>The boundary should extend beyond the base of the seamount onto the abyssal plain. Either of the OSPAR or recent NEAFC boundaries is acceptable. The OSPAR boundary covers a larger area to the east, including a small hill which is not considered fishable.</td>
<td>The boundary should extend beyond the base of the seamount onto the abyssal plain. Either of the OSPAR or recent NEAFC boundaries is acceptable.</td>
</tr>
</tbody>
</table>

**Table 1.5.4.1.1** Evaluation of the five NEAFC proposals against criteria of uniqueness, functional significance, fragility, life-history characteristics, and structural complexity based on criteria in the FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas.
Figure 1.5.4.1.1  Chart of areas on the mid-Atlantic Ridge proposed as areas closed to bottom fishing by NEAFC (Red). Existing NEAFC closures are indicated in solid red. Areas proposed as Marine Protected Areas by OSPAR are shown in blue.
1.5.5 OSPAR

1.5.5.1 An assessment of the changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature.

1. Summary and conclusions

This is a report examining the evidence for the effect of climate change on the distribution and abundance of marine species in the OSPAR Maritime Area. It focuses primarily on effects that may be linked to changes in sea surface temperature.

ICES examined long-term datasets available to scientists working in its expert groups. The main conclusions are that oceanographic conditions do influence the marine biota in the OSPAR Maritime Area, and that oceanographic conditions are changing. There was evidence to support this in both the narrative and the analytical information examined by ICES for all OSPAR Regions. Effects of climate change varied from weak to very strong, particularly when environmental conditions were exceptionally cold or warm.

ICES undertook a meta-analysis that shows that the changes in distribution, abundance, and other characteristics (particularly seasonality) of marine biota in the OSPAR Maritime Area are consistent with expected climate effects. This does not mean that all changes are consistent with a climate change effect or that climate is the only cause, but it is undoubtedly a recognisably important factor in around ¾ of the 288 cases examined here. These cases include zooplankton (83 cases), benthos (85 cases), fish (100 cases), and seabirds (20 cases). For seabirds only 12 of the 20 changes were consistent with a climate effect, but for the other taxa the proportion of consistent cases was much higher. The overall results for each OSPAR Region were also consistent with a climate change effect. Available information on phytoplankton and other lower trophic organisms did not allow a similar analysis. The majority of the cases examined here were from OSPAR Region II and there were none from OSPAR Region V. This could be influenced by the relative availability of suitable datasets in the Regions.

There is no doubt of a global climate change, driven by anthropogenic factors. However, climate change effects are difficult to detect at a regional scale, given the high degree of both spatial and temporal variability at this finer scale. This is true even for a relatively easily (and routinely) observed variable such as sea temperature. Other key climate variables include advection, vertical mixing, convection, turbulence, light, rainfall, freshwater runoff, evaporation, oxygen concentration, pH, salinity, and nutrient supply. These variables are often interlinked, far less commonly observed, and their effect on biota is less widely investigated and considerably more complex. This is why our analysis is generally confined to temperature effects. Despite climate change occurring, current regional sea surface temperatures are only a few tenths of a degree above the averages recorded in the middle of the 20th century.

In addition to natural spatial and temporal variability in the direct and indirect effects of climate change, a number of other factors affect the abundance and distribution of individual species, population, and communities in the OSPAR marine area:

- Fishing: this is the major non-climate anthropogenic factor. Removal of biota and habitat disturbance are two of the most prominent pressures, for fish and benthos, respectively, which have also shown increasing trends over the past few decades. Population sizes and geographic distributions of many marine species reflect responses to those pressures.
- Oceanographic factors: these may be direct (increased or decreased mortality due to temperature, transport to new areas or arrival at different times, etc.) or indirect, mediated, for example, by a climate-related change in the food available to predators.

The difficulty in identifying the cause of any of these effects may be confounded by:

- Buffering: many fish, marine mammals, seabirds, and some benthos are long-lived and therefore the effects of oceanographic conditions may be buffered at the population scale and integrated over time even at the scale of the individual.
- Complex life histories: most marine invertebrates and fish have complex life histories, with eggs, larvae, juveniles, and adults often in different places both geographically and in the water column. The effects of oceanographic conditions on the different life history stages of even a single species could be different by an order of magnitude, and possibly even in sign.
ICES acknowledges that other factors, such as eutrophication, pollution, diseases, and introduced species, affect the abundance and distribution of species, population, and communities, particularly at the local scale, and that they can interact with climate change and fisheries as drivers of change.

ICES was asked to advise if any observed changes were “beyond what might have been expected from natural variability.” As noted above, this type of analysis is very difficult to carry out at the local or regional level for individual species, populations, or even ecosystems. For this reason, ICES chose to undertake a meta-analysis (an analysis that combines the results of several studies that address a common hypothesis). This allowed a combination of a variety of types of information to be used which, despite being individually inconclusive, collectively allowed the request from OSPAR to be more thoroughly addressed.

The meta-analysis methods employed by ICES were based on those used by the International Panel on Climate Change (IPCC, see Technical Annex on methods). It is acknowledged that our assessment suffered from a number of shortcomings. These were mostly the result of unavoidable limitations in the data and resources available to ICES. However, we used objective data extraction methods and cases were screened to minimize bias in selection. The analytical approaches that were adopted were simple and were not based on strong assumptions about the data or the relationships between the indicators of population state and the oceanographic conditions, and ICES considers the results to be reliable.

1.1 Implications

Although ICES has already made a considerable contribution to the extensive scientific literature on species–environment relationships of marine ecosystems, we are still unable to partition causality between oceanographic conditions and other agents for change at the level of the individual taxon. It is likely this will remain the case even with better data and more in-depth analyses. Therefore, the precautionary approach dictates that it is necessary to consider the possibility that species and populations will respond as the climate changes. These responses may be partially or wholly hidden by other factors causing change such as fishing pressure, habitat alteration, etc. Consequently, this should be taken into account as part of planning, risk assessment, and precautionary management. The individual analyses in this report and ancillary documentation are comprehensive enough to provide some specific guidance into the types of species and communities most likely to be affected and the direction of such change.

An additional issue implicit in the concern about change “beyond natural variability” is the potential for the existence of a “tipping point”, i.e. a threshold of change that, when it is exceeded by even a small incremental amount, would result in species and even communities undergoing dramatic changes in abundance and distribution. This problem is not likely to be readily answerable for marine ecosystems, even ones as comparatively data rich and well studied as the OSPAR Maritime Area. Modelling can explore scenarios, but results will be highly uncertain and dependent on model assumptions that cannot be ground-truthed for conditions that have not yet been observed.

The difficult task of partitioning causality between oceanographic conditions and other agents for change, together with the complex, potentially non-linear interactions between climate and non-climate (natural or otherwise) factors advocate the need to be precautionary in the way we manage human activities in the marine environment. Several actions can contribute to building the necessary precaution into policy and management, and to provide the required scientific support. Science needs to monitor and analyse results in ways that take advantage of spatial and temporal patterns in both hydrographic and species occurrences, and to build consistent time-series and design research programmes aimed at reducing our uncertainty about relationships between oceanography and climate and species and populations, thereby reducing uncertainty about the potential responses of marine ecosystems to climate change.

There is ample evidence for changes in fish distribution and abundance that are consistent with the expected (i) northward shift or deepening of the distribution and (ii) increase in abundance in the northern part and decrease in the southern part of the range. Changes were most prominent in northern OSPAR Regions (I and II) and were observed in bottom-dwelling and pelagic species as well as in exploited and unexploited species. The observed changes cannot be interpreted unequivocally as a response to climate since other factors may be important as well, in particular fishing, although it is highly likely that climate effects are involved. Heavily exploited species will have a diminished gene pool and reduced resilience to environmental change, and consequently they may be perturbed more strongly by climate than less exploited or unexploited species. Measures that reduce large-scale habitat impacts, such as a reduction in fishing pressure, could be a key adaptation strategy to reduce the threat of climate change in marine ecosystems in the OSPAR Maritime Area.

Changes in distribution of fish in response to climate change may have important effects for the design of Marine Protected Areas (MPAs) or the effectiveness of existing MPAs. For example, the ‘Plaice Box’, a partially closed area in the coastal waters of the southern North Sea, established in 1989 to reduce the bycatch of undersized plaice in the flatfish fisheries, may have became less effective, in terms of this original objective, since undersized plaice have moved to deeper water outside the protected area (van Keeken et al., 2007).
Introduction

ICES was asked by OSPAR to provide ‘an assessment of changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature’. Specifically, ICES was asked to consider:

- **ecologically indicative species, including the threatened and declining species identified by OSPAR, for which adequate time-series data exist**
- **changes in their distribution, population and condition**
- **changes beyond what might have been expected from natural variability**

This report is a contribution towards OSPAR JAMP Product BA-3 and includes material that can be included in the Quality Status Report in 2010.

There is ample circumstantial evidence that global climate change is affecting many aspects of life on this planet. However, as scientific effort becomes directed at questions regarding the evidence for changes to the earth’s climate and effects of those changes on the earth’s ecosystem, the evidence is ceasing to be simply circumstantial. Major scientific syntheses, particularly the recent Nobel Prize-winning report of the International Panel on Climate Change (IPCC, 2007; Rosenzweig et al., 2008), have provided compelling evidence for both a warming of the earth’s climate over the past century, and effects of that warming on the earth’s ecosystem at a global scale. The evidence for effects on ecosystems was strongly dominated by information from terrestrial rather than marine ecosystems. The present request from OSPAR for information to include in the next QSR will inform the policy and social debate that has followed release of the IPCC Report more specifically with regard to the likelihood and nature of effects to be expected in marine ecosystems in the OSPAR Maritime Area, should the forecasts for continued warming of the planet prove true. It should be noted that the translation of global change to regional scales is complex, as pointed out by IPCC (2007), and the OSPAR request concerns regional, not global, scales.

The basic premise underlying the OSPAR request was the existence of changes in hydrodynamics and sea temperature (...) beyond what might have been expected from natural variability. A number of changes in hydrographic features over the past few decades and their possible attribution to anthropogenic and natural causes have already been documented. Key ones relative to the OSPAR request are summarized in Section 3 of this report and provide the background against which any changes in the distribution, population and condition of ecologically indicative species should be interpreted.

The process conducted by ICES involved experts in ocean hydrography, ecology of zooplankton, of benthos, of fish, of seabirds, of marine mammals, and of invasive species in assembling relevant information from the OSPAR Maritime Area. The evidence is generally scattered, with most data collected for other purposes, and often not ideal for asking specific questions about the role of ocean conditions and climate on long-term trends in distribution, abundance, and biology of marine species. However, it has been possible to assemble a variety of types of information that, if individually inconclusive, collectively allow the request from OSPAR to be addressed by means of a meta-analysis (an analysis that combines the results of several studies that address a common hypothesis), following a methodology consistent with that used in the IPCC analysis, which it is intended to complement. ICES stresses that, in trying to bring the required consistency to the analyses, it had to balance standardization, so that ‘best practice’ was used throughout the process, against sufficient flexibility to accommodate real differences among taxa and regions.

In the analysis of distribution and abundance of marine species, we need to distinguish between climate and non-climate causes of observed changes and between ‘natural’ and anthropogenic factors. In the case of non-climate causes, the division between natural and anthropogenic factors is fairly clear but, in the case of climate, most factors are the same in both cases and the requirement is to partition them in order to attribute a proportion of the observed changes in marine species in the OSPAR Maritime Area to anthropogenic climate change:

<table>
<thead>
<tr>
<th>CAUSES OF CHANGE</th>
<th>NATURAL</th>
<th>ANTHROPOGENIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>NON-CLIMATE</td>
<td>Competition, predation, internal dynamics, etc.</td>
<td>Fishing, eutrophication, pollution, species introductions, etc.</td>
</tr>
<tr>
<td>CLIMATE</td>
<td>Temperature, vertical circulation, etc.</td>
<td>Temperature, vertical mixing, circulation, pH, etc</td>
</tr>
</tbody>
</table>
The size and direction of a particular climate impact depends on how big the climate change is and on how sensitive the species or biological system is to this change, in addition to where the change is observed within the full biogeographical range of the species or biological system. Also, there are interactions between causes within and among the four categories in the table above, which should not be ignored. A large number of studies show that populations and systems become more sensitive to climate impacts when they are heavily exploited (Brander, 2005; Ottersen et al., 2006; Planque et al., 2008; Perry et al., 2008; Hsieh et al., 2006). The increased sensitivity may be due to reduced age structure, constriction of geographic distributions, and other kinds of loss of diversity.

This document does not include observations on whole ecosystem changes (e.g. Beaugrand, 2004) as the OSPAR request stresses a species-based approach.

ICES has not tried to explain all of the changes in terms of the underlying processes and mechanisms. However, ICES is confident that the following assessment provides a good description of our best knowledge of the changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to hydrographic changes, even if the final step of partitioning causality between oceanographic conditions and other agents for change is likely to remain very hard to complete rigorously for the foreseeable future.

2.1 Geographic terminology

In order to aid reading of this document, Figure 2.1.1 shows the OSPAR Regions.

Figure 2.1.1 The OSPAR Regions. I = Arctic; II = Greater North Sea; III = Celtic Seas; IV = Bay of Biscay and western Iberia; V = wider Atlantic.

Figure 2.1.2 shows the biogeographical provinces used in this document for the OSPAR Maritime Area (after Dinter, 2001).
Biogeographical classification of the benthal and neritopelagial of the shelf and upper continental slope (<1000 m depth), and ice-cover biomes combined with the superordinate holopelagic provinces (<1000 m depth) of the OSPAR Maritime Area (reproduced from Dinter (2001) based on Forbes and Godwin-Austen (1859)).

3 Oceanographic background

3.1 Present situation

Global-scale model simulations to compare 20th century land and ocean surface temperatures with and without anthropogenic greenhouse gasses show a significant divergence from the 1970s onwards (IPCC, 2007; Figure 3.1.1). The simulations including anthropogenic forcing agree well with observations. These results led the IPCC (2007) to state that “most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations”. This statement represented a greater degree of certainty than in previous assessments of the role of human activity on global climate.
“MOST OF THE OBSERVED INCREASE IN GLOBALLY AVERAGED TEMPERATURES SINCE THE MID_20TH CENTURY IS VERY LIKELY DUE TO THE OBSERVED INCREASE IN ANTHROPOGENIC GREENHOUSE GAS CONCENTRATIONS”. IPCC 2007

Figure 3.1.1 Global land (left) and global ocean (right) decadal average temperatures during the 20th century (black lines) compared to climate model simulation, including anthropogenic forcing (pink shading) and only natural forcing (blue shading) (from Solomon et al., 2007).

Whilst the impact of greenhouse gases on surface temperature is clear at the global scale, the signal at regional scales is complicated. Processes working on the regional and local scale like surface advection patterns, convection, evaporation and precipitation mean that the temperature increase has not been uniform over the planet. Some areas have shown more rapid warming than the global mean, whilst others have experienced cooling (Figure 3.1.2). Moreover, the temperature increase in the ocean has been considerably less than over land (Figure 3.1.1), indicating the large heat capacity of the deep oceans. IPCC (2007) noted that natural temperature variability is larger at the regional than at the global scale, and with the smaller temperature increase in the ocean it is apparent that natural variability is still (during the 20th century) a more dominant factor of temperature change in the European oceans than over the continent of Europe. Nevertheless, both sea and land surface temperatures in the OSPAR Maritime Area have increased from 1995 to 2004 at a rate which is well above the global mean.

1995-2004 Mean Temperatures

Figure 3.1.2 Regional variation in global temperature change. This plot is based on the NASA GISS Surface Temperature Analysis (GISTEMP), which combines the 2001 GISS land station analysis data set (Hansen et al., 2001) with the Rayner/Reynolds oceanic sea surface temperature data set (Rayner, 2000; Reynolds et al., 2002). The data itself was prepared through the GISTEMP online mapping tool, and the specific dataset used is available here. This data was replotted in a Mollweide projection with a continuous and symmetric colour scale. The smoothing radius is 1200 kilometre, meaning that the reported temperature may depend on measurement stations located up to 1200 km away, if necessary. Image prepared by Robert A. Rohde from public domain data for Global Warming Art (http://www.globalwarmingart.com/wiki/Image:Global_Warming_Map_jpg).
Temporal patterns of temperature change also show systematic spatial structure at the sub-regional level (Figure 3.1.3). The two longest instrumented time-series of temperature data in the northeast Atlantic (Kola and Faroe–Shetland sections) show strong coherence at time scales and periodicities larger than the decadal scale (Figures 3.1.4 and 3.1.5). The Kola and Faroe–Shetland data reflect ocean water mass conditions, and are closely related to the Atlantic Multidecadal Oscillation (AMO) index (Sutton and Hodson, 2005) (Figure 3.1.6). The North Atlantic is presently in a positive phase of the AMO.

Figure 3.1.3  Sea surface temperature (SST), showing the mean of the period 2003–2007 minus the 1978–1982 mean. The plots are based on NOAA NCDC ERSST version 2, which is an extended reconstruction of global SST data based on ICOADS (Worley et al., 2005) monthly summary trimmed group data (http://www.cdc.noaa.gov/).

Figure 3.1.4  Temperature anomaly of the Atlantic water masses in the Faroe–Shetland Channel (data source: Fisheries Research Services, Marine Laboratory Aberdeen, Scotland) compared to the ocean temperature anomalies of the Northern Hemisphere (data source: http://lwf.ncdc.noaa.gov/oa/climate/research/anomalies/anomalies.html).
Temperature (°C) of the Atlantic water masses at the Kola Section in the Barents Sea (Source: PINRO, Murmansk). Dotted line: Annual mean. Thick lines: 3-year moving average and a 30-year low-pass filter (from Sundby and Nakken, 2008).

Figure 3.1.6 Time-series of the Kola section long-term average temperature with the shorter term filtered out (upper graph) and the Atlantic Multidecadal Oscillation (AMO) index (lower graph). The AMO index is based on the sea surface temperature in the region 0°–60°N and 7.5°–75°W as presented by Sutton and Hodson (2005), but with the long-term detrending removed. The Kola section data were obtained from PINRO (from Skagseth et al., 2008).

In addition to the century-long time-series of the Faroe–Shetland and the Kola sections, the ocean variability in the OSPAR Regions as a whole has been observed with high quality measurements over the last 50 to 60 years (Hughes and Holliday, 2007). Such in situ observations are relatively scarce or unavailable in many places, which restrict our ability to compare changes in marine ecosystem properties with changes in ocean climate. To address this problem we also used the gridded HadISST sea surface temperature data set (Rayner et al., 2003). The long-term variability and trends derived from this data set have been compared with long time-series of in situ measurements from ICES standard sections in the North Atlantic and Nordic Seas (Hughes et al., 2008). The in situ measurements show an interdecadal Atlantic Water temperature increase of about 1°C from the 1970s to date, consistent along the shelf break from Ireland to the Barents Sea and Fram Strait (Figure 3.1.7) (Holliday et al., 2008). In the OSPAR Region II (North Sea) the rate
of warming is even greater (1–2°C) whereas in the western OSPAR Regions the warming is less (0.4–0.8°C) (illustrated for the surface layer in Figure 3.1.3). The increase in temperature in OSPAR Region IV (Biscay and western Iberia) is lower in the south and is also strongly influenced by upwelling. Superimposed on this general warming over the last 30 years are interannual to decadal-scale variations, with amplitudes 2–3 times larger than the size of the long-term change in the past century. The average temperatures in some parts of the North Atlantic during the previous warm period from the 1930s to the 1950s were slightly colder than today (Figures 3.1.4 and 3.1.5).

Figure 3.1.7 Overview of upper ocean temperature anomalies from the long-term mean across the North Atlantic. The anomalies are normalized with respect to the standard deviation (e.g., a value of +2 indicates 2 standard deviations above normal). The maps show conditions in 2006 (colour intervals 0.5, reds are positive/warm and blues are negative/cool) (from Hughes and Holliday, 2007).

A regional scale of natural variability in the North Atlantic is connected to changes in the Subpolar gyre (Häkkinen and Rhines, 2004). The weakening of the Subpolar gyre after 1995 has been shown to have a large effect on hydrographic conditions in the eastern part of the OSPAR region due to the presence of a larger fraction of warmer and more saline water from the eastern Atlantic (Hatun et al., 2005; Figure 3.1.4). Since the 1960s, changes in the large-scale wind pattern, principally the North Atlantic Oscillation (NAO), have resulted in a gradual change of the water mass distribution in the Nordic Seas. In particular, this is manifested by the development of a layer of Arctic intermediate waters, deriving from the Greenland and Iceland Seas and spreading over the entire Norwegian Sea (Blindheim et al., 2000). In the Norwegian Basin it has resulted in an eastward shift of the Arctic front and, accordingly, an upper layer cooling over wide areas due to increased Arctic influence. The extent of sea ice in the Barents Sea has reduced since the 1970s (ICES, 2008a) coinciding with increased temperature of the Atlantic Inflow (Skagseth et al., 2008). Superimposed on the multidecadal temperature (AMO) signal is the interannual to decadal-scale temperature variations that are largely linked to the NAO. While the AMO is a thermal signal, the NAO causes changes in circulation and volume fluxes (Sundby and Drinkwater, 2007) as well as in the thermal regime. The NAO signal also has a smaller spatial scale, resulting in different development and signature in the southern and northern OSPAR Regions.

### 3.2 Effects of oceanography on the OSPAR marine ecosystem

Estimates of the degree of influence of marine climate on marine ecosystems are likely to depend on the rate of change of the marine climate and on the choice of variable used to describe climate. In addition to the temperature, several interlinked climate variables influence marine ecosystems including advection, vertical mixing conditions, convection, turbulence, light, rainfall, runoff, evaporation, oxygen, pH, salinity, and nutrient supply (including aeolian). NAO,
which is an atmospheric pressure phenomenon primarily of decadal time scale, has specific characteristics with respect to influence on ocean circulation, mixing and precipitation (Hurrell et al., 2003) and with respect to spatial extent. Climate phenomena of longer-term periodicity, such as multidecadal-scale oscillations and anthropogenic climate change are interlinked across the range of climate variables and with respect to spatial scales.

The general link between spatial and temporal scales in nature makes it more difficult to reveal the effects of short-term (e.g. interannual variability) climate changes on species distributions simply because such changes are not correlated across larger spatial scales. Analysis of changes even within an explicit spatial context such as the Northeast Atlantic requires observations at decadal time scales and longer.

The present report is primarily focusing on the effects of the longer-term, and hence larger-scale, climate change, as manifested by the change in the thermal regime of the Northeast Atlantic during the second half of the 20th century. It should, however, be emphasized that such ecosystem effects recently observed are not unique to the past century. In 1948 ICES arranged a symposium with the focus on what happened in the North Atlantic during the warming of a relatively cool period at the beginning of the 20th century onto the 1930s and 1940s (ICES, 1949). Similar changes with northward shifts of fish species occurred then both in the Northwest Atlantic and the Northeast Atlantic (Drinkwater, 2006). The subsequent cooling, which reached its lowest temperatures in the 1960s and 1970s, resulted in new distributions and changes in abundances. The ‘gadoid outburst’ in the North Sea (Cushing, 1980) was one result of this new cooling. Hence, in a century-long time scale the recent warming and its effects on marine ecosystems is part of a dynamical change where species are observed to move northward in warm periods and southward in cool periods. With the anthropogenic climate change becoming increasingly dominant compared to long-term natural variability during the present century it could be expected that the past oscillations in species distributions will be replaced by a more permanent northward change.

4 Evidence analysis

4.1 Plankton

4.1.1 Data sources and related information

Information on zooplankton biomass abundance, distribution, or condition in the OSPAR Maritime Area was extracted from peer-reviewed material reported by the Working Group on Zooplankton Ecology (ICES, 2007a, 2008b) and additional peer-reviewed material. Much of this information is a result of the Continuous Plankton Recorder (CPR) time-series. The work of ICES (2006a) was used to identify changes in phenology such as the start of the zooplankton production season and the duration of the zooplankton season. Unlike some of the documented changes in abundance and distribution linked to increase in temperature, changes in phenology (ICES 2006a) tend to be reported at the functional group or genus level.

Beaugrand et al. (2002) report on the distribution of organisms which can be linked to their relative biogeographical affinities and Northern Hemisphere (NHT) anomalies and the NAO index. This allowed understanding of regional modifications in the marine ecosystem modified by changes in the hydrographic regime. Strong biogeographical shifts in all calanoid copepod assemblages were identified with a northward extension of more than 10° in latitude of warm-water species, associated with a decrease in the number of colder-water species. These changes have been attributed to regional sea surface temperature warming. Identifying the biogeographical affinities allows inferences to be made regarding distribution with respect to changes in temperature through marine systems.

Thus there is an expectation that there will be a demonstrable shift/expansion of distribution northward with increasing temperature relating to species’ biological associations and ecological characteristics for pseudo-oceanic temperate species such as Centropages typicus, Candacia armata, Calanus helgolandicus (Bonnet et al., 2005). Similarly, changes in abundance can be correlated with these biogeographical affinities (Lynam et al., 2004). Additionally, the appearance of species in areas where they were previously unknown (Boersma et al., 2007; Faasse and Bayha, 2006; Valdés et al., 2007) can be linked in the same manner.

Temperature changes over time are also thought to alter the timing of annual recursive events such as the phenophases (e.g. timing for seasonal migrations).

4.1.2 Results

The analysis of the CPR time-series has provided evidence that significant changes have occurred in the abundance, distribution, community structure, and population dynamics of zooplankton and phytoplankton in the OSPAR Maritime Area. These events are mainly responses to changes in regional climate, caused predominately by the warming of air and sea surface temperatures, and associated changes in hydrodynamics. Some changes and examples of their effects are outlined below:
Change in biomass: this has been observed in both zooplankton and phytoplankton. For example, the population of the previously dominant zooplankton species in the North Sea (*Calanus finmarchicus*) decreased in biomass by 70% between the 1960s and the 2000s. Species that prefer warmer waters have moved northwards but their total biomass is not as great as the decrease in *Calanus* biomass (Edwards *et al*., 2006). There are reported increases in phytoplankton biomass (i.e. determined by the Phytoplankton Colour Index–PCI, i.e. the degree to which the CPR silk is stained green) since the mid–1980s (Edwards *et al*., 2008). This is mainly reported in OSPAR Regions II, III, and V in relation to increasing sea surface temperature.

Change in distribution: A shift in the distribution of many plankton species by more than 10° latitude northward has been recorded in the OSPAR Maritime Area over the past thirty years (depending on the temperature affinity of organisms this can be an increase in the range, e.g. in temperate pseudo-oceanic species, or a shift of the centre of distribution, e.g. Subartic species) (Figure 4.1.2). This shift is particularly associated with the current running north along the shelf edge of the European continental margin (Beaugrand *et al*., 2002; Edwards *et al*., 2006). In addition, an extension of the seasonal PCI has been recorded in the OSPAR Regions II, III, and V.

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**Figure 4.1.2** Maps showing biogeographical shifts of calanoid copepod communities in recent decades, with the warm-water species shifting northwards and the cold-water species likewise retracting north, by over 10° of latitude (from Edwards *et al*., 2008).
Hydroclimatic changes have been recently related to jellyfish increases recorded in several OSPAR regions (Lynam et al., 2004; Attrill et al., 2007). Temperature appears to be one of the main triggering mechanisms for exceptional outbreaks of these gelatinous carnivores (CIESM, 2001; Purcell, 2005). Furthermore, warm temperatures may be related to a prolonged period of occurrence and increased abundance of the ctenophore Mnemiopsis leidyi (Purcell, 2005). This gelatinous predator has been accidentally introduced into the Black Sea, and has contributed to the reduction in the fisheries there (see references in Purcell, 2005).

4.1.3 Conclusions

Beaugrand et al. (2002) and Edwards et al. (2008) provide strong evidence based on the long-standing CPR survey on observed changes in zooplankton distribution and abundance, specifically biogeographical shifts of calanoid copepod communities in recent decades, with the warm-water species shifting northwards and the cold-water species likewise retracting northwards (Figure 4.1.2).

The information presented here also offers articulate and credible evidence of change in the OSPAR Regions. In our analyses, changes in distribution are by far the most obvious response to climate change displayed by zooplankton. While these changes in distribution have been linked with warming trends, this is not likely to be the sole driver; stronger north-flowing currents on the European shelf edge may also play a role (Appenzeller et al., 2004). Phenology appears to be very sensitive to temperature variation; however, the response appears to vary substantially across functional groups. This may reflect the hierarchical level of analyses, as breaking down the information to the species level may elucidate specific characteristic species trends to temperature variation.

Jellyfish are very often population bloom species, known as co-responsive with climate indices (Attrill et al., 2007; Lynam et al., 2004). In warmer waters associated with climate-change scenarios the frequency of jellyfish is expected to increase (Attrill et al., 2007).

The changes in the zooplankton and phytoplankton communities that are at the base of the marine pelagic food-web can affect higher trophic levels (fish, seabirds, mammals), for instance through loss of synchrony between predator and prey (match-mismatch) abundance/demand. This synchrony can play an important role (bottom-up control of the marine pelagic environment) in the successful recruitment of top predators, such as fish and seabirds (Beaugrand and Reid, 2003; Beaugrand, 2003; Edwards and Richardson, 2004; Richardson and Schoeman, 2004; ICES, 2006b; Frederiksen et al., 2006a).

Kirby et al. (2007) demonstrated that in the North Sea warmer conditions earlier in the year combined with increased phytoplankton abundance have occurred since the late 1980s, which has determined the significant increase of meroplankton (i.e. temporary plankton species), in particular echinoderm larvae of Echinocardium cordatum.

In order to assess climate change effects on the marine community and fishery resources it is important to maintain the few time-series that exist at single sites and along transects, and to expand the CPR survey with the aim of increasing the geographical coverage of zooplankton monitoring in the OSPAR Maritime Area.

4.2 Benthos

4.2.1 Data sources and related information

ICES extracted information from a variety of sources regarding benthos in the OSPAR Maritime Area, which provides the evidence for effects of responses in abundance and range relative to oceanographic conditions.

4.2.2 Main conclusions

The majority of benthic species and communities examined showed changes in distribution and abundance over time, and the most of these patterns were consistent with the expected changes if the species were responding to oceanographic conditions.

Many of the strongest signals in the benthic data were large changes in abundance associated with anomalously cold winter conditions (Kröncke et al., 2001, 2007). However, similarly large effects were evident in response to, for example seabed disturbance and changes in water quality.

This strong effect of extreme temperature conditions on benthic abundance and/or distribution indicates that if climate change results in temperature conditions outside the recent historic range of natural variation, then major effects on at least some species and communities would be likely.
4.2.3 Highlights of published knowledge

The distribution of many benthic species in the Bay of Biscay, including macroalgae, molluscs, and arthropods, has been studied since the end of 19th century. Some latitudinal shifts in distribution, both northward and southward, have been documented and are related to the occurrence of warm and cool periods during the 20th century (Alcock, 2003). Similarly, off La Coruña (Spain) changes in the benthic community could be partly explained in terms of the expansion and contraction of warm- and cold-water species in response to changing environmental conditions linked to the NAO (Lopez-Jamar et al., 1995; S. Parra, pers. comm.).

The sand-burrowing brittle star Amphiura had a long period of absence or rarity in the southern North Sea, but has been recorded in low to moderate abundances since 1975. Temperature is reported as a limiting factor for the distribution of this species, with the apparent range extension of this species to the inner German Bight area linked to the higher winter temperatures as compared to previous decades. The species is reportedly absent from areas where temperatures are higher than 10°C in summer and not less than 3°C in winter (Boos and Franke, 2006).

4.2.4 Interpretation and synthesis

Benthic species and communities may well be sensitive to anomalous oceanographic conditions, especially extremes of temperature, but are also sensitive to other pressures. Most long-term benthic monitoring programmes were implemented to study how other pressures affect benthos or to use benthic indicators to provide information about trends in other pressures (Beukema, 1990, 1992).

The strongest evidence of responses in benthic taxa that would be expected as a result of climate change was:

a) cases where anomalously cold winter conditions led to die-offs of species commonly associated with relatively warmer waters, or outbreaks of species commonly associated with relatively colder water (Beukema, 1990.; Reiss et al., 2006).

b) cases of benthic species being reported as expanding in areas outside their historical ranges that are characteristic of areas to the south or more coastal than the areas into which they are spreading.

Both of these observations are consistent with climate sensitivity in the benthos, but with possibly a non-linear response. This situation could make the benthic biota a particularly high risk community for impacts of climate change, as changes are likely to be abrupt rather than incremental over time.

A number of pathways can be identified by which climate-related changes in oceanographic conditions could be expected to affect benthic populations and communities (Bhaud et al., 1995). Although this report has looked only at temperature effects, these pathways include:

- Temperature (influencing the distribution of ‘northern’ and ‘southern’ species);
- Hydrodynamics (e.g. current velocities, stratification of water layers, wave climate determining the transport of larvae and influencing the sediment composition, which determines habitat suitability for species and reflects food availability to the benthos);
- Precipitation (changes can affect the distribution of suspended particulate matter, changes in the salinity variability, and changes in nutrient run-off. These changes affect nutrient availability to benthos and increase the risk of hypoxia events in estuaries rich in organic matter);
- Acidification (increasing acidification of the ocean caused by increasing atmospheric CO2 is becoming well documented, and poses a threat to corals and other benthos, particularly species requiring calcium or carbonate for shells).

Thus, climate-related changes in a range of physical and chemical conditions in the sea will in turn affect species composition directly or indirectly and, therefore, the trophic structure of benthic communities. These effects are compounded in cases where the benthic species affected create distinct habitats, e.g. coral reefs, mussel beds.

4.3 Fish

4.3.1 Main conclusions

There is ample evidence for changes in distribution and abundance of fish that are consistent with the expected (i) northward shift or deepening of the distribution and (ii) increase in abundance in the northern part and decrease in the southern part of the range. Changes were most prominent in northern OSPAR Regions (I and II) and were observed in bottom-dwelling and pelagic species as well as in exploited and unexploited species. The observed changes cannot be
interpreted unequivocally as a response to climate effects since other factors may be important as well, in particular fishing, although it is highly likely that climate effects are involved.

4.3.2 Introduction (Fish-specific approach)

To interpret the changes for different species, we have followed the classification of fish species according to Ellis et al. (2008) who distinguished between Arctic, Boreal, Lusitanian, African, and Atlantic species. Arctic fishes are those species restricted to the most northern parts of the ICES/OSPAR areas, with southern limits off northern Norway and Iceland (Figure 2.1.2). Boreal fishes extend northwards to the Norwegian Sea and Icelandic waters and have the southern limits of their distribution around the British Isles or west of Brittany. Lusitanian fishes are those southerly species that tend to be abundant from the Iberian Peninsula (including the Mediterranean Sea) to as far north as the British Isles, and may have northerly limits in the southern or central North Sea (although many of these species extend to more northerly latitudes on the western seaboards of the British Isles, and so can also occur in the northwestern North Sea). Many of these species have distributions extending into the Mediterranean Sea and off Northwest Africa. Atlantic fishes are those (often pelagic or deep-water) species that are widespread in the North Atlantic, and includes many of the deeper-water species that may be widely distributed along the continental slope.

Changes in distribution of fish within the respective Regions could only be assessed for OSPAR Regions II and III. Here the expectation was that, for Boreal species, a decrease in the southern area could be expected, while in the northern area no change or an increase should be observed. For Lusitanian species, two outcomes were anticipated: either an increase in the southern area together with no change in the northern area, or increase in the northern area combined with no change in the southern area. Any of the above we considered to be in accordance with expectations of a climate change-driven effect.

For OSPAR Regions II, III, and IV the expectation was that the abundance of Boreal species should decrease whereas that of Lusitanian species should increase. However, for the Barents Sea (OSPAR Region I) many of the Atlantic, Boreal, and certainly Lusitanian species are on their northern boundary and could therefore be expected to increase with increasing water temperature. Therefore we assumed that any increase of an Atlantic, Boreal, or Lusitanian (but not Arctic) species in OSPAR Region I could be interpreted as a result of climate change.

4.3.3 Data sources and related information

The sources of information for the fish component were ICES (2008c) and a selection of peer-reviewed publications. ICES (2008c) provided the results of analyses of groundfish survey data on the changes in abundance and/or distribution for four OSPAR Regions (I, II, III, and IV). For OSPAR Regions II and III a distinction was made between a northerly (N) and a southerly (S) area (respectively the northern versus southern North Sea and West of Scotland versus Celtic Sea). OSPAR Region I was represented by the Barents Sea and Region IV by the Bay of Biscay.

4.3.4 Tabulation

The criteria described in the Technical Annex were used to select records to include in the analysis. For the meta-analysis of the fish data, two periods were compared: (1990–1999 versus 2000–2005). Some comparisons were made with the period 1977–1989, but to ensure that changes in fishing activity during the 1970s and 1980s do not mask the climate change signal, only data from 1990 onwards were included in the analysis.

In order to interpret observed changes in abundance and/or distribution based on the work of ICES, we applied the same approach across all species and Regions. For each period we assessed whether there had been an overall change (decrease or increase) and, if so, this was put in the summary Table 4.3.1 as a change in abundance. For those areas where a northern and southern area was distinguished, both areas needed to show the same direction of change. If this was not the case, then this was interpreted in the table as a change in distribution.

4.3.5 Interpretation and synthesis

4.3.5.1 Observations from the tabulation

Of the cases where changes were observed, abundance and distribution changed in line with expected change in response to the recent warming in more than 70% of these cases (Table 4.3.1). In a minority of the studies no change was observed or the change was opposite to the expected change. Changes of the expected directions are seen in species that are demersal and pelagic, Lusitanian, Boreal, and Atlantic, exploited and unexploited. From this database we determined how many records showed a change and which percentage of these changes was in accordance with expectations from climate change. We assessed this per OSPAR Region for two properties: abundance and distribution. Data were mainly available on changes in distribution and abundance. Data were insufficient and no analyses were conducted to assess change in fish condition.
Although the general outcome is consistent with the expected change due to an increase in temperature, the results may not be interpreted as evidence for climate change as other explanations cannot be ruled out. In particular the observed changes may be influenced by fishing. For example, fishing mortality rates have been higher in the southern North Sea than in the north (Heath et al., 2003, 2007), and so the apparent changes in distribution in this part of the Region could be a consequence of local patterns of fishing pressure (Hutchinson et al., 2001; Wright et al., 2006; Daan et al., 2005; Daan, 2006). The effects of fishing thus interact with the effect of climate. The disentanglement of the effects of hydrographic attributes and other drivers is difficult and must be considered as a work in progress.

### Table 4.3.1

Frequency by which fish species responded to an increase in water temperature by changing their distribution (A) or abundance (B). If a species showed a response, the response was classified as either conforming to or opposite to the expectation.

<table>
<thead>
<tr>
<th>OSPAR Region</th>
<th>No change</th>
<th>Change as expected</th>
<th>Change opposite to expectation</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Change in distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>II</td>
<td>1</td>
<td>33</td>
<td>9</td>
<td>43</td>
</tr>
<tr>
<td>III</td>
<td>9</td>
<td>8</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>IV</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>I-IV</td>
<td>11</td>
<td>46</td>
<td>10</td>
<td>67</td>
</tr>
<tr>
<td>B) Change in abundance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>II</td>
<td>0</td>
<td>10</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>11</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>IV</td>
<td>17</td>
<td>3</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>I-IV</td>
<td>19</td>
<td>32</td>
<td>13</td>
<td>64</td>
</tr>
</tbody>
</table>

The results of these analyses show that in most cases for the four OSPAR Regions considered, both abundance and distribution of fish species have changed. Substantially more than half of these changes are in accordance with expectations regarding climate change, and changes of the expected directions are seen in species that are demersal and pelagic, Lusitanian and Arctic, exploited and unexploited. However, there are questions about the suitability of many of the individual cases as valid sources of information about the effects of climate and oceanographic conditions on fish, because other effects may predominate in individual situations.

#### 4.3.6 Highlights of observations by OSPAR region

Many demersal and pelagic species changed abundance and distribution in all OSPAR Regions and while many of these changes are in accordance with what can be expected from climate change, others are not. The changes in abundance were observed for large areas and over relatively long time periods of one or more decades. The changes observed over the last decade appear to agree more often with the expected climate effect, possibly because over the longer time periods other effects such as fishing may have had a larger effect. Two changes in distribution were apparent: a shift along the depth gradient and a latitudinal shift. The whole North Sea demersal fish assemblage has deepened by ~3.6 m per decade (Dulvy et al., in press) in response to climate change, and the deepening is coherent for most assemblages. The latitudinal response to warming seas is more heterogeneous, and is a composite of at least two patterns: (i) a northward shift in the average latitude of abundant, widespread thermal specialists (e.g. grey gurnard and poor cod), and (ii) the southward shift of relatively small, abundant southerly species with limited occupancy and a northern range boundary in the North Sea (e.g. scaldfish, solenette, bib, sole, and lesser-spotted dogfish). The southward shift of warm-tolerant species in the North Sea is consistent with climate change acting through: i) the warming and increasing availability of shallow habitats in the southern North Sea and ii) the North Atlantic Oscillation-linked inflows of warm water into the NE North Sea. The species showing an expected response in distribution or abundance are summarized in Table 4.3.2.
Table 4.3.2  List of species that showed an expected response to increases in water temperature in OSPAR Regions I–IV.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Association</th>
<th>OSPAR Regions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twaite shad</td>
<td>Alosa fallax</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Wolfish</td>
<td>Anarhichas lupus</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Scaldfish</td>
<td>Arnglossus laterna</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Garfish</td>
<td>Belone belone</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Solenette</td>
<td>Buglossidium luteum</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Dragonet</td>
<td>Callionymus spp.</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Boarfish</td>
<td>Capros aper</td>
<td>Lusitanian</td>
<td>+ +</td>
</tr>
<tr>
<td>European herring</td>
<td>Clupea harengus</td>
<td>Boreal</td>
<td>+ +</td>
</tr>
<tr>
<td>Anchovy</td>
<td>Engraulis encrasicoles</td>
<td>Lusitanian</td>
<td>+ +</td>
</tr>
<tr>
<td>Snake pipefish</td>
<td>Entelurus aequoreus</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Grey gurnard</td>
<td>Eutrigla gurnardus</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Cod</td>
<td>Gadus morhua</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Lesser African threadfin</td>
<td>Galeoides decadactylus</td>
<td>African</td>
<td>+</td>
</tr>
<tr>
<td>Witch</td>
<td>Gephyrocephalus cynoglossus</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Long-rough dab</td>
<td>Hippoglossoides platessoides</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Megrim</td>
<td>Lepidorhombus whiffiagonis</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Dab</td>
<td>Limanda limanda</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Anglerfish</td>
<td>Lophius piscatorius</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Haddock</td>
<td>Melanogrammus aeglefinus</td>
<td>Boreal</td>
<td>+ +</td>
</tr>
<tr>
<td>Whiting</td>
<td>Merlangius merlangus</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Hake</td>
<td>Merluccius merluccius</td>
<td>Lusitanian</td>
<td>+ +</td>
</tr>
<tr>
<td>Blue whiting</td>
<td>Micromesistius polassou</td>
<td>Atlantic</td>
<td>+</td>
</tr>
<tr>
<td>Lemon sole</td>
<td>Microstomus kit</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Common ling</td>
<td>Molva molva</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Striped red mullet</td>
<td>Mullus surmulletus</td>
<td>Lusitanian</td>
<td>+ + +</td>
</tr>
<tr>
<td>Sea lamprey</td>
<td>Petromyzon marinus</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Greater forkbeard</td>
<td>Phycis blemnoides</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Plaice</td>
<td>Pleuronectes platessa</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Saithe</td>
<td>Pollachius virens</td>
<td>Boreal</td>
<td>+ + +</td>
</tr>
<tr>
<td>Thornback ray</td>
<td>Raja clavata</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Cuckoo ray</td>
<td>Raja naiveus</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Four-bearded rockling</td>
<td>Rhinonemus cimbrius</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Pilchard</td>
<td>Sardina pilchardus</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Mackerel</td>
<td>Scombo scombrus</td>
<td>Atlantic</td>
<td>+</td>
</tr>
<tr>
<td>Lesser-spotted dogfish</td>
<td>Scyliorhinus canicula</td>
<td>Lusitanian</td>
<td>+ + +</td>
</tr>
<tr>
<td>Common sole</td>
<td>Solea vulgaris</td>
<td>Lusitanian</td>
<td>+ + +</td>
</tr>
<tr>
<td>Sprat</td>
<td>Sprattus sprattus</td>
<td>Lusitanian</td>
<td>+ + +</td>
</tr>
<tr>
<td>Spurdog</td>
<td>Squalus acanthias</td>
<td>Boreal</td>
<td>+ + +</td>
</tr>
<tr>
<td>Horse mackerel</td>
<td>Trachurus trachurus</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>Norway pout</td>
<td>Trisopterus esmarki</td>
<td>Boreal</td>
<td>+</td>
</tr>
<tr>
<td>Bib</td>
<td>Trisopterus luscus</td>
<td>Lusitanian</td>
<td>+ +</td>
</tr>
<tr>
<td>Poor cod</td>
<td>Trisopterus minutus</td>
<td>Lusitanian</td>
<td>+</td>
</tr>
<tr>
<td>John dory</td>
<td>Zeus faber</td>
<td>Lusitanian</td>
<td>+ + +</td>
</tr>
</tbody>
</table>

It is apparent that warming in some cases has meant that species once considered strays have become much more common. In other cases the warming has improved recruitment for some species, thus creating a shift in the apparent range of the species though not necessarily a change in individual movement.

The warming in the 1980s also ended the period of high recruitment of several gadoids in the North Sea such as cod and haddock. This ‘gadoid outburst’ coincided with the cool period in the 1960s and 1970s.
4.3.7 Highlights of observations by species; case studies

Five species were selected to illustrate a variety of patterns in spatial distribution, in the North Sea between two periods, 1977–1989 vs. 2000–2005. Distribution of each species was mapped using the International Bottom Trawl survey (IBTS) and the Norwegian survey data. Survey data from quarter one were used for this analysis because it was the most consistently surveyed period. The survey coverage was standardized by removing any areas not surveyed in either of the two periods (an area covering 524 400 km2). The maps from the two periods for quarter 1 were overlaid and density at all locations compared. Difference in density was classified to 12 levels (12 equal areas on the map) in a matrix model (spatial modelling in SPANS, Geomatica) – six areas of varying degree of change in density where density in the first period was higher, and six where it was lower. The resulting reclassified map illustrated where the density of fish had changed between periods and to what degree.

4.3.7.1 Atlantic cod *Gadus morhua*

This is a boreal species of prime commercial significance, which is among the top predators inhabiting the northern temperate and cold waters of the Atlantic. This species has decreased significantly in the North Sea between 1977–89 and 2000–05 (Figure 4.3.1). The reduction in density was highest to the southeast along the Dutch coast where density decreased by about a factor of 100, while a limited increase was observed along the northeastern fringe. An increase in density was observed over 11% of the survey area and a decrease over 87%. Within the North Sea, a northward shift in the mean latitudinal distribution of cod has occurred, but there is much controversy as to the causes. Causes could include active migrations (now considered unlikely), higher fishing mortality in the south, local differences in recruitment, or a mixture of this and other causes (Engelhard *et al.*, 2008a). Hedger *et al.* (2004) showed that Atlantic cod in the North Sea were found in deeper water during 1990–1999 compared to 1980–1989, but their distribution with respect to temperature was unchanged.

![Figure 4.3.1](image)

**Figure 4.3.1** Change in distribution of Atlantic cod *Gadus morhua* between 1977–1989 and 2000–2005 in the North Sea, quarter 1 (ICES, 2008c). The upper left panel shows distribution in the initial period (1977–1989) and upper right panel for 2000–2005. The large lower panel shows change in distribution between the two periods, where blue to green colours indicate an increase in density, dark colours indicating the largest change. Yellow to red indicate a decrease in density between the two periods, with red indicating the largest changes. The upper centre graph shows the proportion of the total survey area where an increase and decrease occurred, broken down by degree of increase or decrease (categories 1–6).
4.3.7.2 Monkfish *Lophius piscatorius*

The monkfish or anglerfish is a Lusitanian species that increased in density in the northern North Sea while densities remained largely unchanged in the southern part (Figure 4.3.2). Over the last two decades, an increase in density was observed over 45% of the survey area and a decrease over 18%.

![Figure 4.3.2](image)

Change in distribution of anglerfish *Lophius piscatorius* between 1977–1989 and 2000–2005 in the North Sea, quarter 1 (ICES, 2008c). The upper left panel shows distribution in the initial period (1977–1989) and upper right panel for 2000–2005. The large lower panel shows change in distribution between the two periods, where blue to green colours indicate an increase in density, dark colours indicating the largest change. Yellow to red indicate a decrease in density between the two periods, with red indicating the largest changes. The upper centre graph shows the proportion of the total survey area where an increase and decrease occurred, broken down by degree of increase or decrease (categories 1–6).

4.3.7.3 Haddock *Melanogrammus aeglefinus*

The haddock is a Boreal species that decreased in density in the southern half of the North Sea while slightly increasing in the Skagerrak and central North Sea (Figure 4.3.3). Where haddock concentrate in the northern half of the North Sea, density remained largely unchanged. Haddock densities have increased more strongly in Arctic waters. A decrease in density was observed over 39% of the survey area and an increase over 25%. In general, the spatial change for haddock occurred only where density was low and thus had little impact on the overall abundance of that species.
Figure 4.3.3 Change in distribution of haddock *Melanogrammus aeglefinus* (haddock) between 1977–1989 and 2000–2005 in the North Sea, quarter 1 (ICES, 2008c). The upper left panel shows distribution in the initial period (1977–1989) and upper right panel for 2000–2005. The large lower panel shows change in distribution between the two periods, where blue to green colours indicate an increase in density, dark colours indicating the largest change. Yellow to red indicate a decrease in density between the two periods, with red indicating the largest changes. The upper centre graph shows the proportion of the total survey area where an increase and decrease occurred, broken down by degree of increase or decrease (categories 1–6).

4.3.7.4 Red mullet *Mullus surmuletus*

The red mullet is a Lusitanian species. Its distribution reaches north into coastal waters off Norway, northern Scotland, and to the Faroe Islands, south to the Strait of Gibraltar and into the Mediterranean and Black Seas, and also along the coast of northwest Africa to Senegal and the Canary Islands. Most global red mullet landings are taken from the Mediterranean and Black Seas and a comparatively smaller fraction from the Atlantic Ocean. In the Atlantic, landings before 1975 were mainly from the Spanish coasts and in the Bay of Biscay. Since the 1990s landings have increased, in particular from the Celtic Sea (Figure 4.3.4).
The very marked increases in landings of red mullet in recent years might be partly explained by a northward distribution shift, or increased abundance in northerly parts of the distribution range. However, more targeted fishing in recent years is likely to have contributed significantly to the increased landings.

Surveys showed that red mullet has increased in 48% of the North Sea survey area, and has decreased nowhere in the North Sea. It did not appear in surveys before 1989 (Fig. 4.3.5). It has been suggested that the North Sea population migrates northwards in winter, when water temperatures are higher there (Beare et al., 2005).

The combination of high market value of the species, its potentially increasing presence in northern parts of its distribution range in response to warming climate (Engelhard et al., 2008b), and the likelihood of a more targeted fishery for the species in the future, make red mullet a relevant case study in the context of climate change and fishery management. The species has a relatively fast growth rate and a planktonic egg/larvae stage, which could enhance its ability to rapidly respond to climate warming by colonizing new habitats. Close monitoring of the population dynamics of this species may facilitate the improvement of recruitment models, including temperature effects in relation to habitat connectivity.
4.3.5 Change in distribution of striped red mullet *Mullus surmuletus* between 1977–1989 and 2000–2005 in the North Sea, quarter 1 (ICES, 2008c). The upper left panel shows distribution in the initial period (1977–1989) and upper right panel for 2000–2005. The large lower panel shows change in distribution between the two periods, where blue to green colours indicate an increase in density, dark colours indicating the largest change. Yellow to red indicate a decrease in density between the two periods, with red indicating the largest changes. The upper centre graph shows the proportion of the total survey area where an increase and decrease occurred, broken down by degree of increase or decrease (categories 1–6).

4.3.7.5 Herring *Clupea harengus*

The Atlantic herring is a pelagic, ocean- and coastal-dwelling species, covering a depth range from 0 to 200 m and occupying the temperate zones in the Eastern Atlantic, Baltic Sea, and the Western Atlantic. In recent years herring has been between the third and the fifth biggest fishery in the world (FAO statistics).

The distribution of feeding shoals of herring is correlated with zooplankton abundance and is influenced by the Atlantic inflow. In years when the *Calanus* peak abundance is further north, herring catches are also further north. Variations in the distribution of North Sea herring are driven by changes in stock size, the zooplankton production, and variability in the Atlantic inflow by the Fair Isle Current, but the interaction of year class strength and environmental signals are difficult to interpret. The variability in productivity and distribution in Norwegian spring-spawning herring appears to exhibit patterns that may be associated with climatic cycles such as the Atlantic multidecadal oscillation (Toresen and Østvedt, 2000). The collapse of the herring in the 1960s (Figure 4.3.6) can be ascribed to a combined effect of overfishing and deterioration of the environmental conditions (temperature). The degree to, and mechanism by, which temperature has an association with recruitment is unclear.
Figure 4.3.6  Variations in the spawning-stock biomass of Norwegian spring-spawning herring and sea temperature. Stock collapse in the 1960s was a combined effect of the decrease in sea temperature and high fishing pressure (from Tøresen and Østvedt, 2000).

4.3.7.6  Anchovy *Engraulis encrasicolus* in the North Sea

The anchovy typically is a species with sub-tropical affinity (Petitgas, 2008). Survey data series confirmed the greatly increased densities of anchovy in the North Sea in recent years. In the period from 1977–1989, only occasional records of anchovy were made off Britain and in the Skagerrak. The species is presently widely distributed (over almost 80% of the survey area) and fairly densely concentrated over much of the North Sea, except at the most northerly and westerly extent. An increase in density was observed over 75% of the survey area and a decrease over only 1% (Figure 4.3.7).
Figure 4.3.7 Change in distribution of anchovy *Engraulis encrasicolus* between 1977–1989 and 2000–2005 in the North Sea, quarter 1 (ICES, 2008c). The upper left panel shows distribution in the initial period (1977–1989) and upper right panel for 2000–2005. The large lower panel shows change in distribution between the two periods, where blue to green colours indicate an increase in density, dark colours indicating the largest change. Yellow to red indicate a decrease in density between the two periods, with red indicating the largest changes. The upper centre graph shows the proportion of the total survey area where an increase and decrease occurred, broken down by degree of increase or decrease (categories 1–6).

4.4 Seabirds

4.4.1 Data sources and related information

Data and conclusions were extracted from peer-reviewed publications and summaries produced for reports of the ICES Working Group on Seabird Ecology (ICES, 2007c, 2008d).

4.4.2 Main conclusions

The response of seabirds to climate change is generally mediated through trophic effects. The majority of the scientific data refers to analyses of variation in condition factors such as breeding success and annual survival. It is expected that these factors must be reflected in the population dynamics of the various seabird species, but quantitative evidence for this is lacking due to the scarcity of long-term demographic data. Hence, the evidence base for impacts of climate change on the abundance and distribution of seabird species is lacking, but some inferential conclusions can be produced.

4.4.3 Highlights of the published knowledge

4.4.3.1 Atlantic puffin *Fratercula arctica*

At the northern fringe of the latitudinal range, the fledging success of Atlantic puffin at Røst, Northern Norway, is principally governed by the availability and size-at-age of young-of-the-year herring, which are the main food source of
the chicks (Durant et al., 2003). Interannual variation in the growth rate of larval and juvenile herring and recruitment to the herring stock are positively correlated with the sea temperature of the Norwegian Coastal Current (Toresen and Østvedt, 2000; Sætre et al., 2002). A succession of warm years and of repeated breeding failures have coincided with a decrease in population size over several decades (Anker-Nilssen, 1992). However, fledging success is not in itself able to explain the rate of change in population numbers from year to year (Figure 4.4.1), which must reflect the cumulative effect of a number of factors including, for example, variation in immature survival of different cohorts (Anker-Nilssen and Aarvak, 2006).

In contrast, Atlantic puffin in the North Sea at the southern fringe of the distribution feed their chicks mainly on sandeels. Arnott and Ruxton (2002) found a negative correlation between recruitment of 0-group (first-year) sandeels in the North Sea and SST during the sandeel larval period (January to May). Hence, warming would be expected to have a deleterious effect on fledging success of puffin in the North Sea. In this case, however, the relationship between fledging success and temperature may be obscured by the potentially confounding effect of fisheries on the abundance of sandeels. Overall, there is evidence that the response of Atlantic puffin to warming is likely to be in opposite directions at the northern and southern limits of the latitudinal range (Harris et al., 2005).

Figure 4.4.1  Degree of correlation between a selection of climatic variables and (a) the fledging success (upper) and (b) the ln-transformed change in annual breeding numbers of Atlantic puffins (lower) at Røst, northern Norway in 1979–2007. To test for indirect effects of trophic relationships and demographic processes, the data for puffin performance were also lagged by 1–7 years. Data provided by ICES WGOH, Svein Østerhus (for Ocean Weather Station Mike, OWS M), Harald Loeng (for Fugløya-Bear Island FBI), and Anker-Nilssen and Aarvak (2006, and unpubl. data).
4.4.3.2 Black legged kittiwake *Rissa tridactyla*

Frederiksen *et al.* (2004a) examined changes over time and correlations between black-legged kittiwake population parameters in the North Sea, the local sandeel fishery, and environmental factors, and incorporated the results in a deterministic and a stochastic matrix population model. Breeding success was used as indicator of condition and condition was a factor of temperature mediated through prey availability. In a further study, Frederiksen *et al.* (2007) correlated black-legged kittiwakes breeding productivity in six areas around the UK and Ireland with sea temperature during the winter prior to breeding. Sea temperature in this case was assumed to be a surrogate for the abundance of young-of-the-year sandeel which form part of the diet of kittiwake. Breeding productivity tended to be higher following cold winters in the Orkney and Shetland areas, but not in other areas. In an across-region comparison breeding success was higher in regions with colder average winter sea temperatures.

4.4.3.3 Northern fulmar *Fulmarus glacialis*

The survival of northern fulmars breeding on Eynhallow, Orkney, UK was negatively correlated with the winter North Atlantic Oscillation index one year previously (Grosbois and Thompson, 2005). Thompson and Ollason (2001) investigated the survival/increased population breeding performance over time in fulmar populations, and warmer conditions were proposed to favour increased abundance.

4.4.3.4 Arctic tern *Sterna paradisaea*

Møller *et al.* (2006) found that natal and breeding dispersal of the Arctic tern was responsive to temperature conditions.

4.4.3.5 Balearic shearwater *Puffinus mauretanicus*

Wynn *et al.* (2007) investigated the distribution of the Balearic shearwater in northeast Atlantic waters at several sites in two OSPAR Regions II and III and concluded that northwards range expansion was correlated with rising sea surface temperature. Votier *et al.* (2008) pointed out that other factors unrelated to sea surface temperature could be involved.

4.4.3.6 Seabird community in OSPAR Region I

Sandvik *et al.* (2005) investigated the effect of climate on adult survival in five species (common guillemot *Uria aalge*, Brunnich’s guillemot *Uria lomvia*, razorbill *Alca torda*, Atlantic puffin, black-legged kittiwake,) of North Atlantic seabirds in OSPAR Region I. Annual survival was related to temperature change mediated through prey availability.

4.4.4 Interpretation and synthesis

Seabirds appear to react to climate change and variability in a variety of ways:

- In some circumstances, a warming trend advances the timing of breeding and in others breeding is retarded;
- Seabirds show some flexibility in dealing with climate change in this regard but are ultimately constrained because of the finite (and often lengthy) time required to complete the breeding cycle;
- Because they are long-lived, seabirds are often able to ‘buffer’ short-term (< 10 years) environmental variability, especially at the population level; and
- Seabirds are vulnerable to both spatial and temporal mismatches in prey availability, especially when breeding at fixed colony sites with the foraging constraints that these entail.

Birds possess strategies to survive short-term variability in the environment (e.g. body fat reserves). Sustained changes in the environment, which result in sub-optimal conditions for a seabird species, over a prolonged period, result in changes in population dynamics, e.g. through a decrease in fecundity and/or survivorship (Ashmole, 1971; Jouventin and Mougin, 1981).

Many factors influence range expansions, and while some changes in distributions have been identified, e.g. changes in breeding distribution in a few species (e.g. lesser black-backed gull *Larus fuscus*), it is not clear how changes in hydrodynamics and sea temperature are involved, but it is presumed to be an contributing factor (Mitchell *et al.*, 2004; Wernham *et al.*, 2002).

There is a substantial body of evidence for changes in seabird demography and population dynamics (Table 4.4.1). Theoretical considerations suggest that many of these changes may be caused by climate fluctuations acting through the availability and distribution of food, but it is rarely possible to identify the exact causal mechanisms.
<table>
<thead>
<tr>
<th>SEABIRD PARAMETER</th>
<th>SPECIES</th>
<th>REGION</th>
<th>CLIMATE VARIABLE</th>
<th>SIGN OF CORRELATION WITH WARMING</th>
<th>SOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Common guillemot</td>
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<td>Sea temperature, sandeels</td>
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<td>Negative (hatching), positive (fledging)</td>
<td>Thompson and Ollason (2001)</td>
</tr>
<tr>
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<td>Røst Norwegian Sea</td>
<td>Sea temperature</td>
<td>Positive</td>
<td>Durant et al. (2003)</td>
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<td>Atlantic puffin</td>
<td>Røst Norwegian Sea</td>
<td>Salinity</td>
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</tr>
<tr>
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<td>Greater black-backed gull</td>
<td>Newfoundland</td>
<td>Sea temperature</td>
<td>Positive</td>
<td>Regehr and Rodway (1999)</td>
</tr>
<tr>
<td></td>
<td>Herring gull</td>
<td>Newfoundland</td>
<td>Sea temperature</td>
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<td>Regehr and Rodway (1999)</td>
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<td></td>
<td>Black-legged kittiwake</td>
<td>Newfoundland</td>
<td>Sea temperature</td>
<td>Positive</td>
<td>Regehr and Rodway (1999)</td>
</tr>
<tr>
<td></td>
<td>Leach’s storm-petrel</td>
<td>Newfoundland</td>
<td>Sea temperature</td>
<td>Positive</td>
<td>Regehr and Rodway (1999)</td>
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<td>Black-legged kittiwake</td>
<td>Isle of May (North Sea)</td>
<td>Sea temperature</td>
<td>Negative</td>
<td>Frederiksen et al. (2004a)</td>
</tr>
<tr>
<td></td>
<td>Black-legged kittiwake</td>
<td>Six coastal sections of OSPAR Regions II and III</td>
<td>Sea temperature</td>
<td>Negative within 2 sections, Negative in across-section comparison</td>
<td>Frederiksen et al. (2007)</td>
</tr>
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<td>Grosbois and Thompson (2005)</td>
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<td>Sea temperature</td>
<td>Negative</td>
<td>Frederiksen et al. (2004a, 2006)</td>
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<td></td>
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<td>North Sea, Irish Sea</td>
<td>Sea temperature</td>
<td>Negative</td>
<td>Harris et al. (2005)</td>
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<td></td>
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<td>Sea temperature</td>
<td>Positive</td>
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<td>Sea temperature</td>
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<td>Sandvik et al. (2005)</td>
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<td>Increase with moderate cooling of SST</td>
<td>Irons et al. (in press)</td>
</tr>
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<td></td>
<td>Brünnich's guillemot</td>
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<td>Increase with moderate warming of SST</td>
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<td>Sea temperature</td>
<td>Negative</td>
<td>Frederiksen et al. (2004a)</td>
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<td>NAO index</td>
<td>Positive</td>
<td>Frederiksen et al. (2004b)</td>
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</tbody>
</table>
### Seabird Parameter

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<th>SIGN OF CORRELATION WITH WARMING</th>
<th>SOURCES</th>
</tr>
</thead>
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<td>Harris et al. (1998)</td>
<td></td>
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<td>Harris and Wanless (1988)</td>
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<td>Razorbill</td>
<td>Isle of May Sea temperature</td>
<td>Negative</td>
<td>Harris and Wanless (1989)</td>
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<tr>
<td>European shag</td>
<td>Isle of May Wind</td>
<td>Negative</td>
<td>Aebischer and Wanless (1992)</td>
<td></td>
</tr>
</tbody>
</table>

**Fledging date**
- Common guillemot Baltic Sea Air temperature Negative Hedgren (1979)
- Common guillemot Isle of May Stormy weather Positive Finney et al. (1999)
- Northern fulmar Shetland (North Sea) Wind speed Negative Furness and Bryant (1996)

### 4.5 Marine mammals

#### 4.5.1 Data sources and related information

There is a general lack of reliable baseline information and long-term datasets on distribution, abundance, and condition of marine mammals within the OSPAR Maritime Area with which to perform formal analyses of the possible effects of climate change (ICES, 2007d, 2008e). The problems are further compounded by the difficulty of studying and censusing small populations. Many of the published reports on trends in abundance and distribution are inconclusive with regard to the causal role of climate change.

#### 4.5.2 Theoretical considerations

Mammals are different from other marine biota in that their mortality rates are governed less by natural predation and more by human activity (hunting and bycatch in commercial fisheries). On the other hand, their low annual reproductive output makes them vulnerable to fluctuations in prey and environmental conditions which impact on breeding success, though these are buffered by their longevity such that even sequences of a few years of breeding failure are of lesser consequence than, for example, in short-lived fish species. This presents problems for statistical analyses aimed at distinguishing between climate dependency and chronic effects of human-induced habitat loss, prey depletion, or mortality. In particular, there is a heightened requirement for long time-series of observations, and the relevant space–time scales for integration of environmental data are unclear. For migratory species the geographic range may be responsive to the distribution of optimal prey and environmental conditions, leading to highly non-linear responses of population size to regional climate. For example, diminishing extent and duration of sea ice is considered to be an important factor for both resident and seasonal Arctic species based on understanding of the biology, but demonstrating statistical significance from time-series data is difficult (Heide-Jørgensen and Lydersen, 1998; Härkönen et al., 1998; Stirling et al., 1999).

#### 4.5.3 Case histories

Species whose habitat is dependent on ice extent and duration may show a disruption in breeding/reproductive output. This is evident in polar bears *Ursus maritimus* and seal species that depend on fjord or drift ice (ringed *Phoca hispida*, harp *P. groenlandica*, hooded *Cystophora cristata*, and bearded *Erignathus barbatus* seals; Ferguson et al., 2005; Fischbach et al., 2007; Regehr et al., 2007). Adult body condition, litter production, and sub-adult survival are all dependent on the availability of ice so that the long-term effects on population dynamics of diminishing ice coverage are presumed to be considerable.

Other main marine mammal species identified as possible ecological indicators are those more loosely associated with Arctic sea ice and cold temperature-to-polar seas, such as beluga *Delphinapterus leucas*, narwhal *Monodon monoceros*, and bowhead whale *Balaena mysticetus*.

Species which undertake large-scale migrations (sperm whale *Physeter macrocephalus* and baleen whales) may also be possible indicator species (Learmonth et al., 2006; Simmonds and Isaac, 2007) together with those species which are
identified in conservation legislation (e.g. harbour porpoise *Phocoena phocoena* and common bottlenose dolphin *Tursiops truncatus*).

Specific issues identified with respect to the possible indicator species are:

1) A decline in reproductive output and body mass of polar bears in Svalbard, Norway, between 1988 and 2002, linked to both large-scale climatic variation (Arctic Oscillation index) and the upper trophic level changes in the Arctic marine ecosystem. However, changes could also be as a result of an increase in population abundance in the area;

2) Within the OSPAR Maritime Area, long-term changes in large-scale distribution in the bottlenose dolphin, common dolphin *Delphinus delphis*, and the white-beaked dolphin *Lagenorhynchus albirostris* populations over the last 100 years seem to have occurred. These may be as a result of changes in sea surface temperature (and linked with changes in the North Atlantic Oscillation index);

3) Changes since 1995 in the distribution of harbour porpoises in the North Sea and English Channel, although the reasons for the southwards shift in their distribution have not been fully investigated (Camphuysen, 2004; Kiszka *et al*., 2004);

Apart from these, no other published studies have found any relationship between changes in distribution, abundance, or condition and climate change, within the OSPAR Maritime Area.

Other species in more temperate regimes should show fairly plastic responses, as they are long-lived and are likely to show some degree of adaptation to slowly developing change.

In summary:

- Marine mammals that live in close association with the Arctic ice and/or in the cold temperate to polar seas influenced by Arctic ice will be the ones most affected by climate change;
- The establishment of Natura 2000 protected sites is required under the EU Habitats Directive (subject to certain conditions) with the aim of conserving both harbour porpoises and bottlenose dolphins. Possible changes in distribution of the animals due to climate change could change the importance of such protected sites for these two species;
- As relative population sizes of many marine mammals are at low levels due to earlier exploitation, they may be more susceptible to climate change (Caswell *et al*., 1999; Green and Pershing, 2004);
- Apart from ice-dependent species, where climate change may show a disruption to breeding, feeding habitat, and food availability, most other species should show fairly plastic responses, as they are long-lived and are likely to show some degree of adaptation to slowly developing change.

### 4.6 Invasive species

#### 4.6.1 Data sources and related information

Establishing the absence of a species from an area is in principle more difficult than demonstrating presence, and initial observations of a previously rare or supposedly absent species are usually fragmentary and serendipitous. For this review, data and conclusions were extracted from peer-reviewed publications and data extracted from country reports (not all countries reported each year) of the ICES Working Group on Introductions and Transfers of Marine Organisms (ICES, 2007e).

#### 4.6.2 Theoretical considerations

Invasive species are those which have become a nuisance, while introduced species are those which are found outside their natural geographic range. Vagrant species are those which are indigenous to a region as a whole but spread into previously uncolonized parts as a result of, for example, geographical shifts in the temperature conditions corresponding to the tolerance range of the species. These are distinct from introduced species, i.e. those which have been transplanted intentionally or unintentionally (e.g. ballast water discharges or aquaculture escapes), and which subsequently reproduce and spread in their new location. This section deals only with the introduced species that have been able to establish reproducing populations due to warming. The invasive spread of species which are indigenous to the OSPAR Maritime Area is covered in other sections.
The physiological tolerance of species in their native range is often greater than that implied by the range of conditions under which they are normally encountered. Native ranges are often also limited by physical and biological interactions. However, when a species is introduced into a new area it may face fewer predator, disease, and competition constraints than in its native region, and is thus free to exploit its full physiological tolerance.

4.6.3 Main conclusions

The list of non-indigenous species in the OSPAR Maritime Area that have now become established (i.e. reproducing in the new location) includes algae (*Codium fragile* (a green alga), *Sargassum muticum* (a brown alga)), molluscs (slipper limpet *Crepidula fornicata*, Pacific oyster *Crassostrea gigas*), barnacles (*Megabalanus tinnintalulum*, *Balanus amphitrite*, *Solidobalanus fallax*, *Elminius modestus*), and a bryozoan (*Bugula neritina*).

Two non-indigenous species in the OSPAR Maritime Area seem to be examples of introduced species which have been able to establish as a direct result of warming temperatures: (i) the Pacific oyster *Crassostrea gigas*, which is an escaped aquaculture species, and (ii) a barnacle species *Elminius modestus*.

Natural recruitment of *Crassostrea gigas* occurs in all areas of Europe where the species has been introduced for aquaculture purposes. This was unexpected since, at the time when the introduction occurred, temperatures in European waters were lower than in its native areas. Extended reproductive periods are occurring along the Belgium and British coasts, in Dutch and German waters, and along the Swedish west coast where *C. gigas* appeared after a series of mild winters in the 1990s and early 2000s (Spencer et al., 1994; Reise et al., 2005; Gollasch et al., 2007; Kerckhof et al., 2007). In recent decades, settlements of small numbers of Pacific oysters have been found on the southern and western Irish coasts (Boelens et al., 2005).

In the Wadden Sea, the Pacific oyster *Crassostrea gigas* increased considerably in abundance after 2000, causing the partial disappearance of intertidal beds of blue mussels *Mytilus edulis*, and at the same time creating new oyster reefs with an approximately equally biodiverse accompanying fauna. This increase of the Pacific oyster correlates strongly with the occurrence of higher than average water temperatures during July–August in these years, causing an increased settlement success of spat (Nehls and Büttger, 2007).

*Elminius modestus* has extended reproductive periods due to warmer sea temperatures. Warm winter temperatures appear to favour *E. modestus*, whereas severe winter weather favours the native *Semibalanus balanoides* (Kerckhof and Cattrijse, 2001; Kerckhof, 2002; JNCC, 2008; Kerckhof et al., 2007).

5 Meta-analysis and synthesis

5.1 Interpretation of the meta-analysis

Full details of the meta-analysis are provided in the Technical Annex, including rationale for choice of this form of analysis, description of the method, assembly, screening and tabulation of data, setting expected a priori changes and testing these. The Annex also includes a more complete presentation of the data and results than is given in the tables in this section.

The red and yellow cells in Table 5.1 show area/taxon groups in which more than half of the changes were in the expected direction. Overall 223 of the 288 changes in distribution, abundance, or other characteristics (e.g. seasonality) were in the direction expected as a result of effects of climate change (77%). The null hypothesis that changes are equally likely in either direction is rejected (P< 0.0001).
Table 5.1  Numbers are cases of change in distribution, abundance, or other characteristics (e.g. phenology, seasonality). Colour coding represents the percentages that were in the direction expected as a result of effects of climate (Red >75%; Yellow 50–75%, Blue <50%).

<table>
<thead>
<tr>
<th>OSPAR Region</th>
<th>Zooplankton Distribution</th>
<th>Abundance</th>
<th>Other</th>
<th>Benthos Distribution</th>
<th>Abundance</th>
<th>Fish Distribution</th>
<th>Abundance</th>
<th>Seabirds Distribution and abundance</th>
<th>Total</th>
<th>% change in expected direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>27</td>
<td>74%</td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>9</td>
<td>1</td>
<td>12</td>
<td>32</td>
<td>7</td>
<td>15</td>
<td>10</td>
<td>212</td>
<td>77%</td>
</tr>
<tr>
<td>III</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>13</td>
<td>53</td>
<td>5</td>
<td>5</td>
<td>20</td>
<td>288</td>
<td>76%</td>
</tr>
<tr>
<td>IV</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>13</td>
<td>53</td>
<td>5</td>
<td>5</td>
<td>20</td>
<td>25</td>
<td>77%</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>14</td>
<td>61</td>
<td>53</td>
<td>32</td>
<td>55</td>
<td>45</td>
<td>20</td>
<td>288</td>
<td>77%</td>
</tr>
</tbody>
</table>

% change in expected direction 100% 64% 100% 66% 66% 82% 71% 60% 77%

Notes: For plankton the OSPAR Region I includes some species occurring also in Regions I–IV (Beaugrand et al., 2002)

Table 5.2  Numbers of cases in which there was no change in either direction.

<table>
<thead>
<tr>
<th>OSPAR region</th>
<th>Zooplankton Distribution</th>
<th>Abundance</th>
<th>Other</th>
<th>Benthos Distribution</th>
<th>Abundance</th>
<th>Fish Distribution</th>
<th>Abundance</th>
<th>Seabirds Distribution and abundance</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>II</td>
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<td>7</td>
<td>9</td>
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<td>1</td>
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<td>0</td>
</tr>
<tr>
<td>III</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>1</td>
<td>0</td>
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<td>6</td>
<td>0</td>
<td>2</td>
<td>17</td>
<td>0</td>
</tr>
</tbody>
</table>

Comparison of the numbers in Tables 5.1 and 5.2 shows that the cases where there was a change (in either direction) greatly outnumber the cases in which there was no change in either direction. Only for fish in Region IV did the number of cases with no change outnumber the cases where some change occurred.

The only area/taxon cells in which less than half the changes were in the expected direction were the plankton distribution changes in Region II and the seabird distribution and abundance changes in Region III (the two blue cells in Table 5.1).

In the case of fish, the group with the most available information, markedly more than half of the changes that were considered informative are in accordance with expectations from climate change. For the selection of records that had passed the criteria, and which can therefore be considered the least biased, between 60% (OSPAR Region IV) and 92% (OSPAR Region III) of the changes in abundance were in agreement with what we expect to happen as a consequence of climate change. For changes in distribution, these percentages vary from 79% (OSPAR Region II) to 100% (OSPAR Regions I and IV). These observations are potentially confounded by fishing effects. On the other hand, a large part of the changes in abundance described are directly linked to species expanding their range and increasing in their abundance at their new limit of distribution; these changes are discussed under distribution. The meta-analysis reinforced the evidence that the observed changes are at least partly caused by the changing climate.

6   References


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ICES Advice 2008, Book 1


Toresen, R., and Østvedt, L. J. 2000. Variation in abundance of Norwegian spring-spawning herring (Clupea harengus, Clupeidae) throughout the 20th century and the influence of climatic fluctuations. Fish and Fisheries, 1: 231–256.


7 Technical Annex: methods

7.1 Assembly of information

Nine Expert Groups (EG) of ICES assembled a large body of information for most of the marine biota in the OSPAR Maritime Area in order to address the request. The subjects covered by the groups and the URLs to obtain their reports are given in the table below. The reports represent a major scientific effort by the ICES community and provide a valuable source of information and detail for particular species and the processes affecting their distribution, abundance, and condition in relation to climate change. The reports of the EG can be consulted for further detail.

<table>
<thead>
<tr>
<th>Expert Group</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working Group on Introductions and Transfers of Marine Organisms (WGITMO)</td>
<td><a href="http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGITMO">http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGITMO</a></td>
</tr>
<tr>
<td>Working Group on Fish Ecology (WGFE)</td>
<td><a href="http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGFE">http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGFE</a></td>
</tr>
<tr>
<td>Working Group on Oceanic Hydrography (WGOH)</td>
<td><a href="http://www.ices.dk/iceswork/wgdetail.asp?wg=WGOH">http://www.ices.dk/iceswork/wgdetail.asp?wg=WGOH</a></td>
</tr>
<tr>
<td>Working Group on Seabird Ecology (WGSE)</td>
<td><a href="http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGSE">http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGSE</a></td>
</tr>
<tr>
<td>Working Group on Ecosystem Effects of Fishing Activities (WGECO)</td>
<td><a href="http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGECO">http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGECO</a></td>
</tr>
<tr>
<td>Study Group on Working Hypotheses Regarding Effects of Climate Change (SGWRECC)</td>
<td><a href="http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=SGWRECC">http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=SGWRECC</a></td>
</tr>
</tbody>
</table>

7.2 Integration by ICES Working Group on Ecosystem Effects of Fishing Activities (WGECO)

WGECO (ICES, 2007f, 2008f) reviewed and integrated the contributions of the EG in order to address the request. They adopted a three-step process:

1. assemble and tabulate cases presented by the EG;
2. select suitable cases for meta-analysis;
3. carry out meta-analysis.

The criteria for selecting suitable cases for meta-analysis are set out below.

7.3 Adoption of methodology

In order to detect the effects of climate change, WGECO decided to adopt a method based on the one used by the IPCC (2007). A similar paper which extends the IPCC analysis was published in Nature on 15 May (Rosenzweig et al., 2008). The advantages of adopting this form of meta-analysis are:

1. it uses a recognized methodology to address the question “how strong is the evidence that changes in distribution, abundance and condition go beyond normal?”;
2. it provides a means of summarizing and adding value to the material provided by the EGs;
3. it provides a direct comparison with the IPCC meta-analysis (and greatly increases the amount of marine information beyond what was available to the IPCC);
4. it is straightforward and involves little additional computation or statistics.

Further information about the method can be found in ICES (2008f) and Rosenzweig et al. (2008) and in Chapter 1 of the IPCC report, including the supplementary material


One must be aware of a number of potential biases in carrying out meta-analysis. The first is ‘positive publication or reporting bias’, when results which show a particular type of change are more likely to be transmitted than those which do not. The second potential bias (confirmatory) can develop in advice relying partially on expert judgement, where the expected outcome (e.g. decline in abundance) is based more or less consciously on observed change. To minimize this
risk, to the extent possible, care was taken to develop expectations of patterns that would be present were oceanographic conditions to be a cause of population trends, and to infer the presence and nature of trends from independent information sources provided by different experts.

### 7.4 Assembly and tabulation of data for meta-analysis

The information on zooplankton, benthos, fish, and seabirds provided by the EGs was examined and tabulated. Experts provided information from literature sources considered to report scientifically sound studies, and from databases that had been subjected to suitable quality control in collection and handling of data. Long-term studies were particularly sought after and included where the abundance, distribution and/or condition of a number of species were monitored in a consistent manner. Long-term studies of individual species were also included. Common patterns of change across a number of species can be particularly informative regarding the role of oceanographic conditions as a driver of ecological change. The information available for most taxa, particularly benthos, was strongly biased towards OSPAR Regions II and IV.

Information tabulated includes: taxon (usually species, but occasionally higher group, particularly for plankton and benthos), OSPAR Region, property monitored (abundance, distribution, factor related to condition), pattern or nature of the variation observed, justification for expected trend, correspondence between observed and expected trend or pattern. In the cases of zooplankton and birds, detailed information on the location (latitude and longitude) is presented. For some fish examples, the start and end dates of the studies is noted. In specific cases not all of the columns in the tabulation were informative, and only the informative rows are presented in the tables in the Annex.

[Full tables and additional references are available electronically at: http://www.ices.dk/committe/acom/comwork/report/2008/Special%20Requests/1.5.5.1b%20Tables.xls and http://www.ices.dk/committe/acom/comwork/report/2008/Special%20Requests/1.5.5.1a%20Additional%20references.pdf]

Each tabulation is intentionally as comprehensive as possible, to provide as large a starting basis as possible for evaluating the evidence for effects of climate change. However, the tabulations are likely to include cases where the selection of species to report may have been biased, and where there may be reasons to suspect that the data would not be informative about the effects of oceanographic and climatic conditions. Therefore, following a review and interpretation of the full tabulation, each data set is screened to exclude studies where a confirmatory bias was likely, or where the case was otherwise considered likely to be uninformative or misleading.

### 7.5 Selection of cases for meta-analysis

Some of the specific cases assembled from the EG reports and tabulated in Annex A are inappropriate for rigorous evaluation of the strength of evidence for effects of oceanographic conditions on species and ecosystems in the OSPAR Maritime Area. This does not mean that these cases are not credible or of good quality, but they may be based on too short time-series or lack some other required feature, such as a clear a priori expectation of change. Similarly it is not possible to include in the synthesis all of the information concerning the processes by which climate affects individual species. Hence all the tabulated cases were subjected to a screening process using the following criteria:

- a) remove cases which may have positive reporting bias – papers or reports which stated that they had only reported cases that showed responses to oceanographic conditions were screened out. If we do not know how many species had been examined and not reported then it is impossible to know how many misses, false alarms, and true negatives might correspond to the number of positive matches that were reported.
- b) remove cases in which there was confirmatory bias, i.e. it was clear that the expectation of change arose from the observed changes and was therefore not a priori.
- c) remove cases for which an a priori expectation of pattern of change was not given and could not be decided on – In some cases a time-series of a species abundance or range was reported, but too little independent information could be tracked down to make a biologically justifiable prediction of even first-order effects of climate.
- d) remove cases which specifically report that some pressure other than climate was strongly affecting the species or population These cases would risk missing a true effect of climate, because some other pressure was aliasing its potential effects.
- e) remove duplicate cases – If different studies reported the same response of a species in the same area, only one record was retained. However, if these studies reported different responses, both were kept in the

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1 Noting that the scientific literature is actually a web of cross-references, so information in one source may actually have been partially determined by information in an apparently independent source.
analysis. Some duplication may remain through trophic links. Thus, if the range of an important forage fish changes, then it would be expected that there would be parallel effects range on dependent predators (e.g. large fish, seabirds). As outlined earlier, ICES has not attempted to establish the mechanisms behind the changes observed.

7.6 Methods used for meta-analysis

The cases which passed the screening criteria are combined into an integrated meta-analysis which includes all species groups. The null hypothesis is that for cases which show a change the probability that this change is in the direction expected a priori (due to change in ocean climate) is the same as the probability that it is in the opposite direction (i.e. 50–50). The cases are divided into those which show no change, those which change in the expected direction, and those which change in the opposite direction. An example of the resultant numbers and frequencies is shown below. Thus for benthos in OSPAR Region II, nine cases showed no change and 40 showed a change (Table 7.6.1). Of the 40 cases which showed a change 65% (i.e. 26 cases) were in the expected direction and 14 were in the opposite direction. The null hypothesis is that 50% would be in each direction. The analysis depends on the assumption that the expected change is correct. Changes in the ‘unexpected’ direction could arise because the a priori expectation is wrong or incomplete.

Table 7.6.1 Occurrences of changes in benthos distribution that were in accordance with what is expected from climate change.

<table>
<thead>
<tr>
<th>OSPAR REGION</th>
<th>SCRENNED RECORDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>II</td>
<td>9</td>
</tr>
<tr>
<td>IV</td>
<td>6</td>
</tr>
</tbody>
</table>

7.7 Choice of expected a priori change

The expected a priori changes due to climate are shown in the Annex. They were based on information about species range in relation to temperature and other variables. Warming is expected to cause northward shifts in the distribution of species in the OSPAR Maritime Area. The expected change in abundance depends on whether a species is close to the warm or the cold end of its range. At the warm end an increase in temperature is expected to cause abundance to decline and at the cold end an increase in temperature will cause abundance to rise.

In the case of benthic species, variation in bottom temperatures meant that many of the expected trends were more complex than just ‘warm’ species increase; ‘cold’ species decrease”. Factors other than temperature were only considered in a few cases when choosing expected a priori changes. Residual water currents moving in a particular direction may result in higher immigration rates in that direction. This may confound the expected temperature effects and alter the 50% expectation.

The effects of climate on seabirds are also complex, acting directly and indirectly on different life history stages. This makes it difficult to give a priori expectations of change for use in hypothesis testing, even when the component processes are well known (e.g. effect of SST on abundance of pelagic fish (herring and sandeel) that are important in the diet of Atlantic puffins).

In the case of ice-dependent species of marine mammals climate change may disrupt breeding and feeding (i.e. negative effect of warming), but increase the productivity of their food supply (positive effect of warming).

7.8 Statistical testing of the null hypothesis

Significance testing for the simple binary categorical analysis was carried out by calculating binomial probabilities.
### 7.9 Tables of data and results for meta-analysis

Colour coding represent the percentages that were in the direction expected as a result of effects of climate (Red >75%; Yellow 50–75%; Blue <50%)

**Numbers which changed**

<table>
<thead>
<tr>
<th>OSPAR Region</th>
<th>Zooplankton Distribution</th>
<th>Abundance</th>
<th>Other</th>
<th>Benthos Distribution</th>
<th>Abundance</th>
<th>Fish Distribution</th>
<th>Abundance</th>
<th>Seabirds Both</th>
<th>Total</th>
<th>% expected change</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>4</td>
<td>1</td>
<td></td>
<td>2</td>
<td>13</td>
<td>7</td>
<td></td>
<td></td>
<td>27</td>
<td>74%</td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>9</td>
<td>61</td>
<td>42</td>
<td>15</td>
<td>10</td>
<td></td>
<td></td>
<td>212</td>
<td>77%</td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>4</td>
<td></td>
<td>9</td>
<td>12</td>
<td>3</td>
<td></td>
<td></td>
<td>24</td>
<td>83%</td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>76%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>8</td>
<td>14</td>
<td>61</td>
<td>53</td>
<td>32</td>
<td>55</td>
<td>45</td>
<td>20</td>
<td>288</td>
</tr>
<tr>
<td><strong>% expected change</strong></td>
<td>100%</td>
<td>64%</td>
<td>100%</td>
<td>66%</td>
<td>66%</td>
<td>82%</td>
<td>71%</td>
<td>60%</td>
<td>77%</td>
<td></td>
</tr>
</tbody>
</table>

**Numbers which changed with the expected direction**

<table>
<thead>
<tr>
<th>OSPAR Region</th>
<th>Zooplankton Distribution</th>
<th>Abundance</th>
<th>Other</th>
<th>Benthos Distribution</th>
<th>Abundance</th>
<th>Fish Distribution</th>
<th>Abundance</th>
<th>Seabirds Both</th>
<th>Total</th>
<th>% with expected change</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
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<td></td>
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</tr>
<tr>
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<td>3</td>
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<td></td>
<td></td>
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<td>77%</td>
</tr>
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<td>83%</td>
</tr>
<tr>
<td>IV</td>
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<td>4</td>
<td>9</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>19</td>
<td>76%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
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<td>8</td>
<td>9</td>
<td>61</td>
<td>35</td>
<td>21</td>
<td>45</td>
<td>32</td>
<td>12</td>
<td>223</td>
</tr>
<tr>
<td><strong>% with expected change</strong></td>
<td>100%</td>
<td>64%</td>
<td>100%</td>
<td>66%</td>
<td>66%</td>
<td>82%</td>
<td>71%</td>
<td>60%</td>
<td>77%</td>
<td></td>
</tr>
</tbody>
</table>

**Binominal probability**

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<tr>
<th>OSPAR Region</th>
<th>Zooplankton Distribution</th>
<th>Abundance</th>
<th>Other</th>
<th>Benthos Distribution</th>
<th>Abundance</th>
<th>Fish Distribution</th>
<th>Abundance</th>
<th>Seabirds Both</th>
<th>Total</th>
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<td></td>
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</tbody>
</table>
1.5.5.2 Answer to request from OSPAR for scientific review of proposals to add Balearic shearwater *Puffinus mauretanicus* and thornback ray *Raja clavata* to the OSPAR list of threatened and declining species

Request

To peer review revised nominations for the following species to be added to the Initial OSPAR List of threatened and/or declining species:

a. *Puffinus mauretanicus* (Balearic shearwater)

b. *Raja clavata* (Thornback skate / ray) in OSPAR Regions I, III, IV

including a review of whether the data used to support the nominations are sufficiently reliable and adequate to serve as a basis for conclusions that the species and habitats concerned can be identified as threatened and/or declining species and habitats according to the Texel–Faial criteria. The results of the peer review need to be available by the deadline for the 2008 meeting of the Biodiversity Committee.

ICES was requested to provide the reviews by 29 January 2008.

Source of information

The ICES Working Groups on Seabird Ecology (WGSE) and on Elasmobranch Fishes (WGEF) were asked for their comments by correspondence.

Summary

ICES finds that the evidence used to support the nomination of Balearic shearwater is sufficiently reliable and adequate to serve as a basis for conclusions to be drawn by OSPAR. Conversely, the evidence for thornback ray is insufficient to support a decision that this is a threatened or declining species in OSPAR Regions I, III, and IV.

ICES response regarding Balearic shearwater *Puffinus mauretanicus*

Introduction

The current nomination document has significantly improved relative to the first proposal in 2006. Overall, comments on that previous version by the ICES have been addressed satisfactorily.

Known distribution and annual cycle

The document stresses a recent northwards increase in the range of the species in the Atlantic, based on Wynn *et al.* (2007). However, this apparent increase could be the result of observer bias associated with the split of the species from the Manx shearwater (Votier *et al.*, 2008). Although disputed by Wynn *et al.* (2008), this alternative explanation should be noted in the document.

There is sufficient information indicating a decrease in the post-breeding grounds off western France (Yésou, 2003). The reasons for the distributional change of the species in the Atlantic are unclear, although this may be a prey-related issue. Wynn *et al.* (2007) suggest climate change as the underlying cause (changes in sea surface temperature, SST), however, other factors (particularly fisheries-related changes in prey distribution and abundance), may also be important (Votier *et al.*, 2008).

The Texel–Faial criteria

These six criteria are: Global importance, Regional importance, Keystone species, Rarity, Decline, and Sensitivity.

Global importance

It is difficult to make global estimates, particularly from coastal counts. The current estimate of about 10 000 birds (Wynn and Yésou, 2007) is speculative and should be considered only as a crude figure. Estimating trends based on coastal count data is even more difficult. Only counts from Gibraltar might be reliable, as all birds entering into the OSPAR area (presumably most of the global population) are forced to pass through the Strait. Well-designed surveys at sea would be helpful.
Sensitivity

The document addresses satisfactorily previous criticisms by the ICES. Concerning the resilience of the species, it should be noted that adult birds skip breeding in some years (sabbaticals).

Decline

Trends based on global population estimates through time are of questionable reliability (see Global importance).

 Sufficiency of data

See considerations in Global importance.

Management considerations

Marine IBA work is underway in Spain and Portugal, and France (LPO) is also planning to address this issue, focusing on the Balearic shearwater on the Atlantic coast.

Habitat modelling could help identify potentially significant sites, as indicated in the document. However, such modelling should first assess which environmental variables significantly influence the distribution of the Balearic shearwater within the OSPAR area. The document only highlights SST as an explanatory variable, presumably relying on Wynn et al. (2007). However, this paper does not establish a clear link between SST and shearwater distribution (see Votier et al., 2008).

Concerning long-term monitoring programmes of strategic flyways, additional schemes such as Trekellen and RAM should also be mentioned, all of them based on voluntary work. For Gibraltar, the current coverage is reasonably good (the MIGRES programme).

Minor comments

There is recent evidence of algae poisoning posing a threat to the species (Gutiérrez, 2007).

References


ICES response regarding Thornback ray *Raja clavata* (revised 15 May 2008)

Introduction


Following the review of the 2006 nomination for listing *R. clavata*, the OSPAR BDC agreed that the North Sea stock (i.e. in OSPAR Region II) could qualify as ‘Threatened and Declining’, and noted that further evidence was required to extend the listing to other OSPAR Regions. In 2007, Germany revised the nomination to include *R. clavata* on the OSPAR List of Threatened and Declining Species and Habitats, with emphasis on the stocks outside of OSPAR Region II (OSPAR, 2007).

ICES was asked to peer review the revised nomination for *R. clavata* in the Celtic Seas ecoregion (OSPAR Region III), including a review of whether the data used to support the nomination are sufficiently reliable and adequate to serve as a basis for conclusions that the species in this region can also be identified as threatened and/or declining according to the Texel–Faial criteria (see OSPAR, 2003). The six Texel–Faial criteria are Global importance, Regional importance, Keystone species, Rarity, Decline, and Sensitivity. ICES delivered the response to OSPAR concerning this nomination, which also included the OSPAR Regions I and IV, at the end of January 2008. This response was presented to the 2008 meeting of OSPAR’s Biodiversity Committee (BDC) at its meeting at the end of February 2008 as paper BDC 0407A1. Germany tabled a paper (BDC 0407A2) at that meeting disagreeing with points within, and the conclusion of, the ICES review.

On 31 March 2008, ICES received a letter from OSPAR:

“At BDC 2008, the German delegation submitted a response challenging the ICES advice on the case for listing Raja clavata (Thornback Ray) as threatened and/or declining in OSPAR Region III (Celtic Seas) (BDC 08/4/7 Add.2). BDC agreed that ICES should be invited to consider whether the argumentation put forward by Germany meant that a clarification or updating of the advice was needed and if so to revise the advice. The ICES representative at BDC, Dr Mark Tasker informed that he would need to check on the possibilities for responding to this invitation. In order to feed into the development of conclusions on this issue at the 2008 meeting of the OSPAR Commission, OSPAR would need a response by the end of May 2008.”

The relevant scientific expert group of ICES has considered the issue further and ICES provides further clarification of its view in this response.

Summary

ICES continues to find that the evidence used to support the nomination of thornback ray is insufficient to support a decision that this is a threatened or declining species in OSPAR Regions I, III, and IV.

Global importance

*R. clavata* is widely distributed in the eastern Atlantic and Mediterranean, and as correctly stated in the nomination, the OSPAR area is not of global importance to the species.

Regional Importance

The nomination states that *R. clavata* is “not of regional importance under the Texel–Faial criteria”, which is correct.

Rarity

The nomination states that *R. clavata* is “not rare”, which is also correct.

Sensitivity

The nomination appropriately states that *R. clavata* is “sensitive to very sensitive”. The second paragraph of this section deals with observed declines in the North Sea; this information would have been better placed in the section on Decline.
**Keystone species**

This is not a keystone species.

**Decline**

The nomination reiterated the documented declines in distribution in the North Sea, with this population now concentrated in the southwestern North Sea. Although the nomination used some of the most recent findings of WGEF (ICES, 2007), it was surprising that the issues of species mis-identifications, as highlighted in ICES (2007), were not raised as caveats in relation to earlier assessments made during the DELASS project and earlier WGEF meetings (ICES, 2002; Heessen, 2003), which were also cited in the nomination.

The nomination illustrated the landings of skates and rays in the North Sea, but stated that this figure “likely under-represents the decline in the proportion of *R. clavata* in commercial landings”, citing the decline of larger-bodied species, including *R. clavata*, and the concomitant increase in smaller-bodied species described *inter alia* by Heessen (2003) and Walker and Heessen (1996). However, the lack of long-term data on the species composition in commercial catches prevents further analyses to substantiate the claim.

For OSPAR Region III, the additional area under nomination, the available information used included recent analyses of survey trends (which have been broadly stable in recent years: see ICES (2007)), landings data, an earlier study by Dulvy *et al.* (2000), and also cited studies using historic data (e.g. Rogers and Ellis (2000)).

In terms of the commercial landings of skates and rays from the Celtic Seas eco-region, the nomination stated that “the decline in the proportion of *R. clavata* in commercial landings may be under-represented”, although once again there was no supporting evidence provided on the species composition in commercial landings over the time period. Species-specific landings data could be used, although such data are limited and would need to be viewed in the context of changes in fishing patterns (areas, gears, effects of other regulations, etc.) before a conclusion can be drawn. Changes in species composition over time in research vessel surveys provide limited information on this. WGEF has assembled various data sets on species composition within the Celtic Seas eco-region, and it varies depending on the ICES Division as well as data source (e.g. scientific/commercial). Further work on temporal trends in species composition is required.

The nomination stated that “Dulvy *et al.* (2000) identified a decline in abundance of this species in surveys in the Irish Sea from 52.8% of skate catches in 1958–64, to 42.7% in 1988–97”. Nevertheless, given that 1988–1997 groundfish surveys used a 4 m-beam trawl, which can under-represent larger batoids, while the 1958–1964 surveys were conducted with otter trawl and were undertaken specifically to tag and release skates, it is hardly an appropriate comparison. The nomination also cited Dulvy *et al.* (2000) for illustrating a decline in *R. clavata* between 1988–1997, although this analysis is potentially biased by changes in the spatial distribution of sampling stations (with proportionately more inshore stations prior to 1993). The trends in the relative abundance of *R. clavata* since 1993, when the survey grid has been better standardized, are more stable.

The nomination also cited Rogers and Ellis (2000); though this study reported a historic decline in the relative abundance of some elasmobranchs, including thornback *R. clavata*, it only covered small areas (including Start Bay in ICES Division VIIe and the NW Irish Sea), and did not cover the wider parts of OSPAR Region III.

Overall, there was no clear evidence presented indicating major recent declines of *R. clavata* in OSPAR Region III. Observed historic declines only covered small parts of the species’ range.

**Threats**

*R. clavata* is taken in targeted fisheries and as a bycatch in various demersal fisheries, as rightly highlighted in the nomination, and the nomination also acknowledges that *R. clavata* “is still one of the most abundant rajids in the North-eastern Atlantic and Mediterranean”.

**Other comments**

The section on sufficiency of data states erroneously “Fishery-independent survey data are also lacking in most regions”. As *R. clavata* is most abundant on the inner continental shelf, extensive areas of its distribution are covered by the various groundfish and beam trawl surveys conducted by national fisheries laboratories (though obviously the density of stations can be improved).
Completeness, sufficiency, and interpretation of data

Adequate evidence was provided in the revised nomination for this species in the North Sea (Region II), as already supported by ICES (2007). The data were, however, insufficient to identify widespread and major declines in the relative abundance and distribution of R. clavata in OSPAR Region III (Celtic Seas ecoregion).

Conclusion

ICES considers that there are insufficient data presented to conclude that R. clavata should be listed as a threatened and/or declining species over OSPAR Region III.

References

1.5.5.3 Development of proposals for environmental assessment criteria

Request

ICES has received the following request from OSPAR:

*Development of proposals for Environmental Assessment Criteria (OSPAR 1-2008)*

To ensure EACs are available for assessments of concentrations of hazardous substances in the marine environment, which will contribute to the QSR 2010. This request is based upon the following:

(i) review of proposals for updated EACs for PCBs developed by the Netherlands according to the 2004 methodology;
(ii) peer review of proposals for updated EACs for PAHs developed by the Netherlands;
(iii) review of the basis for the updated EACs for metals in sediments proposed in 2004, with particular emphasis on the selection of partition coefficients and, as appropriate, the development of alternative proposals for these EACs;
(iv) development of proposals for updated EACs for components included in the pre-CEMP, giving emphasis to the development of EACs for HBCD;

ICES should seek to ensure that work is well co-ordinated with work on environmental quality standards of the Priority Substances Working group under the Water Framework Directive Common Implementation Strategy and the associated Expert Group on EQS.

Further instructions were received from OSPAR following the meeting of OSPAR SIME 2008, directing ICES to focus its attention on items (i) and (ii) in the initial request with particular focus on the EACs for biota.

**ICES Response**

**Summary**

The ICES response to this request takes into account activities within various OSPAR working groups and committees since the original request was made. The proposed Environmental Assessment Criteria (EACs) for polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) in water and sediment are usable for the OSPAR assessment in the sense that with the exception of the values for 3 PAHs the EACs are greater than the BCs being used by OSPAR. ICES supports the use of the proposed EACs for PAHs in biota but encourages OSPAR to research and take note of research results on the influence of phototoxicity on EACs and the importance of secondary poisoning of top predators. ICES is not able at this time to recommend a scientifically defensible approach to defining reference points, i.e. EACs, for PCBs in biota. The situation is complicated due to the varied composition of the commercial PCB mixtures and their environmental fate and by various modes of toxicity for different PCB congeners. The nature of the data available for the assessment further complicates the issue. There will likely be important caveats or limitations associated with any approach and ICES recommends that OSPAR take into account the issues raised in this document in its decision regarding reference points to be used in the assessment for the QSR 2010.

**Background**

In 2004, OSPAR held a Workshop on Background Concentrations (BCs) and EACs. The outcome of the Workshop concerning EACs was discussed by various groups, and OSPAR decided that the values required further refinement. This process has resulted in two papers being submitted by the Netherlands to OSPAR SIME 2008, one on EACs for PAHs and the other on EACs for PCBs, in water, sediment, and biota. ICES provided a preliminary response to these documents in time for the Netherlands to respond prior to the proposals being considered by the OSPAR ASMO meeting. At the OSPAR ASMO meeting there was considerable discussion about the setting of meaningful “upper level” reference points for the JAMP. Although OSPAR may decide on an alternate approach to EACs when setting reference levels for the QSR 2010 assessment, OSPAR requested ICES to continue with the development of this advice. The present advice from ICES is provided in the context of these activities within OSPAR.

**General comments**

Given the importance of the Netherlands’ proposal as the basis for the EACs to be used in the JAMP, the documents from the Netherlands need to be more thoroughly referenced. A broad database of toxicity data should support the development of EACs. Data for all species for which relevant chronic toxicity data (i.e. on growth, reproduction, behaviour, or other effects causing a risk for survival) are available and should be included.
ICES is aware of the need to develop relevant EAC values to assess the environmental risks of measured contaminant levels for the OSPAR QSR 2010. However, ICES recognises that contaminants never occur alone in the environment and that observed biological effects are therefore a more dependable method of assessing ecosystem health. Also, when a contaminant is in fact a complex mixture like PAHs or PCBs more consideration should be given to possible additive effects of several compounds, e.g. PCB congeners, which have a similar mode of action (e.g. endocrine disruption, impaired neurological development, immunotoxicity).

EACs for PAHs and PCBs in sediment and water

In general, due to the lack of sediment toxicity data for most of these compounds the new EACs for sediment have been derived from the EACs for water, including the use of assessment factors where necessary. In order to facilitate comparison with the existing BCs and Background Assessment Concentrations (BACs) the proposed values for EACs in sediment have been normalized to 2.5% organic carbon. In Table 1.5.5.3.1 the revised EACs are compared to the BCs and BACs used by OSPAR MON 2007.

The proposed EACs for sediment for most PAHs are consistent with the BCs and BACs. Only for three compounds (benz[a]anthracene, benzo[ghi]perylene, and indeno[123-cd]pyrene) are the proposed EACs less than the current BCs. The assessment factors applied in the derivation of EACs for most of the compounds are quite low (10), whereas the assessment factors, i.e. safety factors due to uncertainty, for these three compounds are greater (100–1000). The proposed EACs for these compounds may be particularly precautionary. Improvements in the underlying database of toxicity information for these compounds and corresponding reductions in the assessment factors may lead to increases in the proposed EACs, bringing them into line with the present BCs.

Even though the assessment factors used in the derivation of EACs for CBs in water are all rather high (100–5000 for data not derived from Quantitative structure–activity relationships (QSARs)), all of the proposed values are greater than the BC/BACs and will not introduce inconsistencies in data assessments.

ICES therefore suggests that data assessments by OSPAR MON, for example in preparation for the QSR 2010, could make use of the proposed new EAC values for sediment without introducing any internal inconsistencies with the exception of assessments of benz[a]anthracene, benzo[ghi]perylene, and indeno[123-cd]pyrene. While the proposed EACs are consistent with the BCs ICES is not able at this time to comment on the relevance of the proposed EACs to any observations of biological effects.
Table 1.5.5.3.1  Comparison of EACs proposed at SIME 2008 and BC/BACs used by OSPAR MON 2007.

<table>
<thead>
<tr>
<th>Compound</th>
<th>EAC water</th>
<th>Assessment factor</th>
<th>EAC sediment</th>
<th>BC 2.5% OC</th>
<th>BAC 2.5% OC</th>
<th>EAC sediment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µg/l</td>
<td></td>
<td>mg/kg 1% OC</td>
<td>µg/kg</td>
<td>µg/kg</td>
<td>µg/kg 2.5% OC</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>2</td>
<td>10</td>
<td>0.017</td>
<td>5</td>
<td>8</td>
<td>42.5</td>
</tr>
<tr>
<td>Anthracene</td>
<td>0.1</td>
<td>10</td>
<td>0.031</td>
<td>3</td>
<td>5</td>
<td>77.5</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>1.3</td>
<td>10</td>
<td>0.5</td>
<td>17</td>
<td>32</td>
<td>1250</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>0.01</td>
<td>low</td>
<td>0.1</td>
<td>20</td>
<td>39</td>
<td>250</td>
</tr>
<tr>
<td>Pyrene</td>
<td>0.023</td>
<td>10</td>
<td>0.14</td>
<td>13</td>
<td>24</td>
<td>350</td>
</tr>
<tr>
<td>Chrysene</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>11</td>
<td>20</td>
<td>nd</td>
</tr>
<tr>
<td>Benz[a]anthracene</td>
<td>0.0012</td>
<td>1000</td>
<td>0.0006</td>
<td>9</td>
<td>16</td>
<td>1.5</td>
</tr>
<tr>
<td>Benzo[ghi]perylene</td>
<td>0.00082</td>
<td>100</td>
<td>0.00084</td>
<td>45</td>
<td>80</td>
<td>2.1</td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td>0.027</td>
<td>10</td>
<td>0.0014</td>
<td>15</td>
<td>30</td>
<td>625</td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>0.05</td>
<td>10</td>
<td>0.25</td>
<td>50</td>
<td>103</td>
<td>1.575</td>
</tr>
<tr>
<td>Indeno[123cd]pyrene</td>
<td>0.00027</td>
<td>1000</td>
<td>0.00063</td>
<td>50</td>
<td>103</td>
<td>1.575</td>
</tr>
</tbody>
</table>

EACs for PAHs and PCBs in biota (fish and shellfish)

EACs for PAHs in biota (Table 1.5.5.3.2)

Phototoxicity\(^1\) of the PAHs is included in the derivation of EACs for the PAHs anthracene, fluoranthene, and pyrene. There is a scientific debate as to whether or not phototoxicity should be included in environmental risk assessment of PAHs since many laboratory studies are considered not environmentally relevant. Many laboratory studies overestimate this type of toxicity because of unrealistic exposure conditions to both UV light and PAHs and underestimation of natural protection mechanisms of exposed organisms. However, several studies using realistic environmental conditions have shown that phototoxicity can increase the toxicity by several orders of magnitude. ICES therefore supports the inclusion of data from laboratory phototoxicity experiments in the derivation of the EACs giving priority to results of field studies when available. In instances where field data are unavailable, data from laboratory studies on phototoxicity should be included to determine provisional EACs.

The proposed EACs are calculated based on direct toxicity of the compound to the test organism. No EACs have been determined for secondary poisoning of top predators consuming prey contaminated with 5- to 6-ring PAHs and their metabolites. While it is unrealistic to consider observation of such effects in marine organisms, data from laboratory PAH toxicity studies on rodents, used to determine human consumption guidelines, could be used to elaborate those secondary poisoning EACs, particularly for benzo[a]pyrene-like carcinogenic PAHs. Data from oral PAH toxicity studies in fish should be used to develop secondary poisoning EACs for piscine top predators. In particular due to the high bioaccumulation potential of PAH in mussels compared to fish (and because more data on PAH burdens in mussels are available) it will be most relevant to develop secondary poisoning EACs for mussels. ICES recommends that OSPAR pursue the issue of secondary poisoning in future revisions of the EACs.

\(^1\) Changes in toxicity due to the exposure of a chemical to light.
Table 1.5.5.3.2  EACs for PAHs in biota as proposed to OSPAR SIME 2008².

<table>
<thead>
<tr>
<th>Compound</th>
<th>EAC water µg/l</th>
<th>EAC sediment mg/kg dw</th>
<th>EAC mussel mg/kg dw</th>
<th>EAC fish mg/kg ww</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f/p 1% TOC</td>
<td>f/p</td>
<td>f/p</td>
<td>f/p</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>2 f 0.017 p</td>
<td>0.34 p</td>
<td>0.58 f</td>
<td></td>
</tr>
<tr>
<td>Anthracene</td>
<td>0.1 f 0.031 p</td>
<td>0.29 p</td>
<td>0.13 p</td>
<td></td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>1.3 f 0.5 p</td>
<td>1.7 f</td>
<td>8.8 f</td>
<td></td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>0.01 f 0.1 f</td>
<td>0.11 f</td>
<td>0.09 f</td>
<td></td>
</tr>
<tr>
<td>Pyrene</td>
<td>0.023 f 0.14 p</td>
<td>0.10 f</td>
<td>0.11 f</td>
<td></td>
</tr>
<tr>
<td>Chrysene</td>
<td>nd</td>
<td>nd p nd</td>
<td>nd p</td>
<td></td>
</tr>
<tr>
<td>Benzo[a]anthracene</td>
<td>0.0012 p</td>
<td>0.08 p</td>
<td>nd nr</td>
<td></td>
</tr>
<tr>
<td>Benzo[ghi]perylene</td>
<td>0.00082 p</td>
<td>0.11 p</td>
<td>nd nr</td>
<td></td>
</tr>
<tr>
<td>Benzo[k]fluoranthene</td>
<td>0.027 p</td>
<td>0.26 p</td>
<td>nd nr</td>
<td></td>
</tr>
<tr>
<td>Benzo[a]pyrene</td>
<td>0.05 f 0.25 p</td>
<td>0.6 f</td>
<td>f nr</td>
<td></td>
</tr>
<tr>
<td>Indeno[123cd]pyrene</td>
<td>0.00027 p</td>
<td>0.00063 p</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

nd = not determined; nr = not relevant; f/p = firm or provisional value³.

Overall ICES supports the use of the proposed EACs for PAHs in biota, but encourages OSPAR to research and take note of research results on the influence of phototoxicity on EACs and the importance of secondary poisoning of top predators.

EACs for PCBs in biota

ICES recognizes that the development of EACs for PCBs is difficult due to the complex nature of the PCB mixtures, the lack of toxicity data for specific PCB congeners, and limited data on environmental concentrations of the planar PCBs and PCBs in general. Because of the limited toxicity data large assessment factors are used to calculate the EACs for water upon which the EACs for sediments and biota are based. While this has not created an untenable situation with the recommendations for PCBs in sediments, i.e. the EACs are greater than the BCs, ICES has not, however, commented on the relevance of the proposed EACs from the perspective of biological effects.

For biota ICES recommends that the proposed EACs for PCBs for direct effects in fish and mussels should not be used for the assessment for the QSR 2010. While the proposed EACs may be realistic they could result in an incorrect assessment of the state of PCB contamination. Most of the data available for the assessment concerns the non-planar PCBs such as PCB-153. Based on the proposed EAC of 358 and 3200 µg/kg ww for CB153 in mussels and fish respectively (Table 1.5.5.3.3) or the EACs for secondary poisoning of 5.3 and 53 µg/kg ww it would likely be concluded that most, if not all concentrations of PCBs are not of concern. However, we know from limited field observations that concentrations of PCB-153 lower than the secondary poisoning level are associated with observed toxicity of PCBs in the field. This means that levels of PCB below 53 µg/kg ww in fish are associated with levels of the more toxic planar PCBs that result in observed toxic effects. For example, during the 1970-80s in the Baltic Sea, severe environmental effects of PCBs such as reproductive impairment of fish-eating Baltic seals were recognised, while the mean PCB levels in muscle from Baltic fish (herring) at the same time were estimated at about 7.5 µg PCB-153/kg ww).

² Data on phototoxicity has been considered where available.  
³ The EAC is considered firm if ecotoxicological information is available on the chronic toxicity of the relevant compound for 3 marine species, including one fish, one invertebrate, and one algal species.
Table 1.5.3.3  EACs for PCBs in biota as proposed to OSPAR SIME 2008.

<table>
<thead>
<tr>
<th>Congener</th>
<th>EAC water (ng/l)</th>
<th>EAC sediment (μg/kg 1% TOC) (direct effects)</th>
<th>EAC mussel (μg/kg ww)</th>
<th>EAC Fish (μg/kg ww)</th>
<th>EAC mussel secondary poisoning (μg/kg ww)</th>
<th>EAC fish secondary poisoning (μg/kg ww)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCB-28</td>
<td>0.7</td>
<td>0.67</td>
<td>6.0</td>
<td>2.9</td>
<td>2.7</td>
<td>27</td>
</tr>
<tr>
<td>PCB-52</td>
<td>0.86</td>
<td>1.08</td>
<td>16.2</td>
<td>163</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCB-101</td>
<td>0.02</td>
<td>0.121</td>
<td>1.02</td>
<td>3.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCB-118</td>
<td>0.026</td>
<td>0.25</td>
<td>0.195</td>
<td>0.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCB-138</td>
<td>0.02</td>
<td>0.317</td>
<td>19.9</td>
<td>79.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCB-153</td>
<td>1.0</td>
<td>15.85</td>
<td>358</td>
<td>3200</td>
<td>5.3</td>
<td>53</td>
</tr>
<tr>
<td>PCB-180</td>
<td>0.2</td>
<td>4.69</td>
<td>6.5</td>
<td>126</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCB-169 (dioxin-like)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.011</td>
<td>0.11</td>
</tr>
</tbody>
</table>

ICES is not able at this time to recommend a scientifically defensible approach to defining reference points, i.e. EACs, for PCBs in biota. The situation is complicated due to the varied composition of the commercial PCB mixtures and their environmental fate and by various modes of toxicity for different PCB congeners. The nature of the data available for the assessment further complicates the issue. There will likely be important caveats or limitations associated with any approach and ICES recommends that OSPAR take into account the issues raised in this document in its decision regarding reference points to be used in the assessment for the QSR 2010.

Sources of information

1.5.5.4 Tools for coordinated monitoring of dioxins, planar CBs, and PFOS

Request

ICES has received the following request from OSPAR:

Tools for coordinated monitoring of dioxins, planar CBs and PFOS (OSPAR 4-2008)

To prepare the following tools to support the coordinated monitoring of dioxins, planar CBs and PFOS under the OSPAR CEMP:

a. technical annexes to the JAMP Guidelines for monitoring Contaminants in Sediments (OSPAR agreement 2002-16) and JAMP Guidelines for monitoring Contaminants in Biota (OSPAR agreement 1992-2) according to the structure of the existing technical annexes covering the following:

(i) monitoring of dioxins in biota in sediments, taking into account advice from SIME 2007 that monitoring of dioxins in sediments should only be carried out in specific areas (such as sedimentation areas or estuaries) because of time lag (10 – 12 years) in deposition of quantities required for sampling;
(ii) monitoring of PFOS in sediments, biota and water;

b. to review the existing technical annexes on monitoring of chlorinated biphenyls in biota and sediment and propose revisions so that they are adequate for monitoring of planar CBs in these compartments, taking into account advice from SIME that monitoring in sediments should be undertaken only if levels of marker PCBs are e.g. 100 times higher than the BACs and that for biota monitoring of concentrations in seabird eggs could provide an alternative matrix;

c. to develop background concentrations for dioxins (see Section 1.5.5.15).

ICES Response

Summary

A Technical Annex is provided for the analysis of perfluorinated compounds in biota. The annex for PFOS in sediments will be finalized in 2009, and the need for the Annex for PFOS in water will be reassessed pending the outcome of an ISO proposal. ICES recommends reorganization of the technical annexes for chlorinated biphenyls (CBs), planar CBs, chlorinated dibenzo-dioxines and -furans analyses in sediments and biota into a single annex. This one technical annex would be for both the JAMP Guidelines for Monitoring Contaminants in Sediments (OSPAR agreement 2002-16) and the JAMP Guidelines for Monitoring Contaminants in Biota (OSPAR agreement 1992-2). This document will be prepared by ICES in 2009.

a (i) Monitoring of dioxins and planar CBs in biota and sediments

Dioxins and planar CBs are often analysed together as they require similar analytical methods, in terms of extract purification and instrumental analysis. For this reason, it is suggested to include these two compound groups in the same technical annex previously prepared for chlorinated biphenyls in biota and sediments, with necessary revisions of the text on analytical methodology. Request a(i) and b will therefore be merged into one response from ICES.

ICES will prepare this draft technical annex for dioxins/co-planar PCBs in sediment and biota for inclusion in the JAMP Guidelines for Monitoring Contaminants in Sediments (OSPAR agreement 2002-16) and the JAMP Guidelines for Monitoring Contaminants in Biota (OSPAR agreement 1992-2). This annex will be finalized 2009.

Monitoring of PFOS in sediments, biota, and water

A draft technical annex for analyses of PFOS and other selected PFCs in sediments will be finalized in 2009.

A technical annex for analyses of PFOS and other selected PFCs in biota is attached (Annex 1).

Regarding analyses of PFOS and other selected PFCs in water ICES notes that an ISO proposal for analysis of PFCs in water is under preparation and will be finished 2008. ICES will review the ISO proposal when it is available to consider whether it meets the requirements of OSPAR for a technical annex for PFOS in seawater. Pending completion of the proposal by ISO and its availability ICES will review the document and provide a recommendation to OSPAR in 2009.
Sources of information

Annex 1 -Technical Annex: Perfluorinated compounds in biota

1. Introduction

Per- and polyfluorinated compounds (PFCs) are man-made chemicals and are ubiquitous in the environment (1). PFCs are widely used as processing additives during fluoropolymer production and as surfactants in consumer applications, including surface coatings for carpets, furniture and paper products. They are also components in breathable, waterproof fabrics, fire-fighting foams and insulators for electric wires (2). From the production and use of these products, PFCs can be released into the environment.

In this document, the name PFCs refers to compounds with a hydrophilic functional group and a hydrophobic fully fluorinated chain which can vary in length. The polyfluorinated acids have high water solubilities, low pK_a values and are therefore dissociated at environmentally relevant pH values (2). Perfluorinated sulfonamides and fluorotelomer alcohols (FTOhs) are neutral compounds currently discussed as precursors to perfluorooctane sulfonate (PFOS) and perfluorinated carboxylic acids (PFCAs) (3).

The objective of this technical annex is to provide advice on the analysis of PFCs in biota. The detection of PFCs at ppb levels is complex because of a risk of contamination during sample handling, storage, preparation and instrumental analysis. Several methods to determine PFCs in biota tissue are applied in various laboratories, but they generally apply extraction with medium polar organic solvents, clean-up steps and liquid-chromatography (LC) with mass spectrometric detection (MS). International Standard Organisation (ISO) has already promoted a standard for the determination of PFOS and perfluorooctanoic acid (PFOA) in water (4), but at present no standard is available for the analysis of biota samples.

2 Analytes

Table 1.5.5.4.1 gives an overview of PFCs relevant for analysis in biota. They are chosen from the following groups: Perfluorinated sulfonates (PFSAs), perfluorinated sulfinates (PFSiAs), PFCAs and perfluorinated sulfonamides. For monitoring purposes, the high-volume chemicals PFOS and PFOA are considered the most important PFCs and should be included in biota monitoring. Additionally, it is suggested that long-chained PFCs (≥C_8) should be included in analysis due to their bioaccumulative potential. The substitute perfluorobutane sulfonate is likely to bioaccumulate to a lesser extent and might be more relevant for water monitoring. However, until more information is available, perfluorobutane sulfonate might be included in biota monitoring as well. Table 1.5.5.4.1 also includes suggestions for appropriate internal standards (IS). It is strongly recommended to use mass-labelled compounds as IS for PFC-analysis.
Table 1.5.5.4.1  Full names, acronyms, formulas, and Chemical Abstract System (CAS) numbers of PFCs relevant for biota analysis.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Acronym</th>
<th>Formula</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfluorobutanoic acid</td>
<td>PFBA</td>
<td>C₃F₇COOH</td>
<td>375-22-4</td>
</tr>
<tr>
<td>Perfluoropentanoic acid</td>
<td>PFPA</td>
<td>C₄F₆COOH</td>
<td>2706-90-3</td>
</tr>
<tr>
<td>Perfluorohexanoic acid</td>
<td>PFHxA</td>
<td>C₆F₁₁COOH</td>
<td>307-24-4</td>
</tr>
<tr>
<td>Perfluorohexanoic acid</td>
<td>PFHpA</td>
<td>C₆F₁₁COOH</td>
<td>375-85-9</td>
</tr>
<tr>
<td>Perfluorooctanoic acid</td>
<td>PFOA</td>
<td>C₈F₁₇COOH</td>
<td>335-67-1</td>
</tr>
<tr>
<td>Perfluorononanoic acid</td>
<td>PFNA</td>
<td>C₈F₁₇COOH</td>
<td>375-95-1</td>
</tr>
<tr>
<td>Perfluorodecanoic acid</td>
<td>PFDA</td>
<td>C₁₀F₁₉COOH</td>
<td>335-76-2</td>
</tr>
<tr>
<td>Perfluoroundecanoic acid</td>
<td>PFUnDA</td>
<td>C₁₀F₂₁COOH</td>
<td>4234-23-5</td>
</tr>
<tr>
<td>Perfluorododecanoic acid</td>
<td>PFDoDA</td>
<td>C₁₁F₂₃COOH</td>
<td>307-55-1</td>
</tr>
<tr>
<td>Perfluorotridecanoic acid</td>
<td>PFTriDA</td>
<td>C₁₃F₂₅COOH</td>
<td>72629-94-8</td>
</tr>
<tr>
<td>Perfluorotetradecanoic acid</td>
<td>PFTeDA</td>
<td>C₁₃F₂₅COOH</td>
<td>376-06-7</td>
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<tr>
<td>Perfluorohexadecanoic acid</td>
<td>PFHxDA</td>
<td>C₁₅F₃₁COOH</td>
<td>67905-19-5</td>
</tr>
<tr>
<td>Perfluorobutane sulfonate</td>
<td>PFBS</td>
<td>C₆F₁₃SO₂O⁻</td>
<td>29420-49-3</td>
</tr>
<tr>
<td>Perfluorohexane sulfonate</td>
<td>PFHxS</td>
<td>C₆F₁₃SO₂O⁻</td>
<td>3871-99-6</td>
</tr>
<tr>
<td>Perfluoroheptane sulfonate</td>
<td>PFHpS</td>
<td>C₆F₁₃SO₂O⁻</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoroctane sulfonate</td>
<td>PFOS</td>
<td>C₈F₁₇SO₂O⁻</td>
<td>1763-23-1</td>
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<tr>
<td>Perfluoro-1-decanesulfonate</td>
<td>PFDS</td>
<td>C₁₀F₂₁SO₂O⁻</td>
<td>13419-61-9</td>
</tr>
<tr>
<td>1H,1H,2H,2H-perfluorooctane sulfonate</td>
<td>T HPFOS (6:2 FTS)</td>
<td>C₈F₁₇C₂H₄SO₃⁻</td>
<td>27619-97-2</td>
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<td>Perfluorooctane sulfonate</td>
<td>PFOSi</td>
<td>C₈F₁₇SO₂⁻</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluorooctane sulfonamide</td>
<td>PFOSA</td>
<td>C₈F₁₇SO₂NH₂</td>
<td>754-91-6</td>
</tr>
</tbody>
</table>

**Internal Standards**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Acronym</th>
<th>Formula</th>
<th>CAS Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfluoro-n-(1,2,3,4-¹³C₄)butanoic acid</td>
<td>[¹³C₄]-PFBA</td>
<td>[2,3,4-¹³C₄]F₃¹⁵COOH</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoro-n-(1,2-¹³C₂)hexanoic acid</td>
<td>[¹³C₂]-PFHxA</td>
<td>C₆F₆[2-¹³C₂]F₁¹⁵COOH</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoro-n-[1,2,3,4,¹³C₅]octanoic acid</td>
<td>[¹³C₅]-PFOA</td>
<td>C₆F₆[2,3,4,¹³C₅]F₆¹⁵COOH</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoro-n-[1,2,3,4,5-¹³C₅]nonanoic acid</td>
<td>[¹³C₅]-PFNA</td>
<td>C₆F₆[2,3,4,5-¹³C₅]F₈¹⁵COOH</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoro-n-[1,2,3,¹³C₄]decanoic acid</td>
<td>[¹³C₄]-PFDA</td>
<td>C₈F₁₇CF₂¹³COOH</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoro-n-[1,2,1³C₂]undecanoic acid</td>
<td>[¹³C₂]-PFUnDA</td>
<td>C₁₀F₂₁CF₂¹³COOH</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoro-n-[1,2,1³C₂]dodecanoic acid</td>
<td>[¹³C₂]-PFDoDA</td>
<td>C₁₀F₂₁CF₂¹³COOH</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoro-1-[1,2,3,4,¹³C₄]octanesulfonate</td>
<td>[¹³C₄]-PFOS</td>
<td>C₈F₆[1,2,3,4-¹³C₄]F₈SO₂O⁻</td>
<td>n.a.</td>
</tr>
<tr>
<td>Perfluoro-1-[1,2,3,4,¹³C₅]octanesulfinate</td>
<td>[¹³C₅]-PFOSi</td>
<td>C₈F₆[1,2,3,4,¹³C₅]F₈SO₂⁻</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

ₐ, Chemical Abstract System; n.a., not available
3. Species and tissue for analysis

The same species as those commonly used in the monitoring of other bioaccumulative and persistent contaminants, such as organochlorine compounds, are recommended. The most suitable monitoring species are described in the main text of these guidelines.

However, the accumulation behaviour of PFCs is different from that of other halogenated contaminants. PFCs primarily bind to the plasma protein albumin and accumulate in blood, especially serum, and organs, for example in liver and kidney (5). Therefore, the highest concentrations are often found in blood and liver.

Regarding mussel analysis, the soft tissue is recommended, while liver should be favoured in environmental PFC monitoring of fish. At present, experience with PFC monitoring of seabird eggs is limited, but the compounds have been detected e.g. in guillemot and herring gull eggs (6, 7).

4. Sampling, transportation and storage

The dissection and the collection of eggs and blood has to be carried out by trained staff/personnel as incorrect handling of biota samples can contaminate the sample for PFC analysis. Materials and clothes which contain or can adsorb fluorinated compounds must be avoided. In particular the containers or bags which come in direct contact with the sample should not contain fluorinated polymers like Teflon™. Instead, polypropylene materials are recommended. After collection, samples should be stored in closed containers at a temperature lower than $-20^\circ$C until sample preparation. The handling time at room temperature should be short because of the possible degradation of precursors to PFCAs and PFSAs.

5. Sample preparation

The sample preparation for analysis of PFCs requires clean conditions if possible on a clean bench. The laboratory has to be kept as free as possible from any material which can contain fluorinated compounds (e.g. Teflon™). Every material which can come in contact with the sample must be free of fluorinated compounds. Materials used in the PFC analysis should be cleaned with solvents such as methanol and acetone and covered with solvent rinsed aluminium foil to keep out any dust. The septa of vials should be Teflon™-free such as Barrier™ septa made of silicone polymer and aluminium. Solvents including ultrapure water should be of high purity and must be tested for residues of PFCs prior to use.

Within every sample batch, a method blank should be analysed. If measurable blanks occur, the analytical instrumentation and every sample preparation step have to be checked for contamination.

5.1 Homogenisation

An Ultra-turrax® disperser with plastic dispersing (e.g. polycarbonate and polysulfone) is one option to obtain a homogeneous extract. Depending on matrix and expected concentrations, an appropriate sample amount is weighed in polypropylene tubes for the extraction. After homogenisation the extract should be spiked with an IS mixture at concentrations close to the environmental level. Before extraction the sample should be incubated with the IS for about 12 h at 4°C so that the IS can be incorporated into the matrix.

5.2 Extraction

Three methods are commonly used for the extraction of PFCs in biota. One is published by Hansen et al. (6) and uses an ion pair extraction with tetrabutylammonium (TBA) and the extraction solvent methyl tert-buty1 ether (MTBE). The second method is described by Powley et al. (7) and uses ultrasonic extraction (UE) with a subsequent clean-up. The third method is described by So et al. (8) and includes alkaline digestion followed by solid phase extraction (SPE) on WAX™ cartridges. In the following section, the UE method with acetonitrile or methanol is described because of its easy handling and good recoveries, but the other two methods will be acceptable alternatives. The UE method includes a minimum of three extractions, each with 10-fold solvent of the sample volume and 30-min extraction time. After the extraction, the three extracts are combined for clean-up.

5.3 Clean-up

Because of matrix effects on ionisation enhancement/suppression in electrospray tandem mass spectrometry (ESI-MS-MS), a clean-up of the extracts is necessary. Different methods can be used, either separately or in combination, depending on the biota tissue, extraction solvent and concentration level.
Gel permeation chromatography (GPC) for lipid removal is not advisable because lipids are poorly separated from some target compounds (with long chain lengths (>8)). Preliminary results indicate that retention on silica can be used for lipid removal, but is likely to lead to losses of PFOSA. Lipids can also be removed from methanol or acetonitrile extracts by precipitation at −20°C (9). The extract is then centrifuged for 1 minute and the supernatant is decanted into a clean vial.

After lipid removal, additional clean-up steps will be required. An appropriate method is described by Powley et al. (7). Briefly, 25 mg of graphitized carbon adsorbent (e.g. ENVI-Carb™, 100 m² g⁻¹, 120/400 mesh) and 50µL acetic acid are added into a small tube. The extract is concentrated to 1 mL and transferred into the tube. The extract is mixed, centrifuged and finally, 0.5 mL of the supernatant is transferred to another flask.

Alternatively, commercially available SPE cartridges can be used (e.g. ENVI-Carb™, 100 mg, 1 mL, 100–400 mesh). If necessary, a second freezing out step can be used if the matrix still interferes with the measurement. Additional clean up might be required, depending on sample type and concentration levels.

Sample extracts should be concentrated according to the required sensitivity. Concentration techniques at low temperature (< 40°C) and controlled pressure conditions are preferred in order to avoid losses of the more volatile PFCs. Evaporation to dryness should be avoided.

An injection standard (InjS) can be added to the final extract for correction of the injection volumes and calculation of the recoveries of the mass-labelled IS. The InjS should not occur in environmental samples; this can be avoided if a mass-labelled InjS is used.

The solvent composition of the final extract should correspond to the mobile phase of the LC method in order to obtain a satisfactory peak shape of the compounds, in particular of the short-chain PFCs. Unless the samples are analysed immediately, the vials should be kept at 4°C or lower.

6. Instrumental analysis

LC coupled with a tandem mass spectrometer and interfaced with an electrospray ionisation source in a negative-ion mode (LC-(−)ESI-MS/MS) (6, 10) or LC coupled with an (−)ESI time-of-flight mass spectrometer (LC-ESI-QTOF-MS) (11) is the best choice for PFC analysis. Tandem MS and QTOF-MS have the advantage of low instrumental noise with a high selectivity.

6.1 Liquid chromatography

For the liquid-chromatography C₈ or C₁₈ reversed phase columns can be used. A guard column may improve the peak performance and extend the lifetime of the chromatography column. As the mobile phase, water with methanol or acetonitrile can be used, both with 2–10 mM ammonium acetate as an ionisation aid. Gradients from 10% to 100% methanol or acetonitrile will be necessary for the separation of the compounds listed in Table 1.5.5.4.1.

Modifications of the instrument might be necessary to minimize contact with fluorine-containing materials (12). For example, Teflon™-containing tubing, filters for the mobile phase solvents and degassers can be sources for contaminations. A scavenger cartridge can be installed between the pump and injector to trap contaminants from the mobile phase.

To ensure stability of retention times, the use of a temperature controlled column oven is strongly recommended.
6.2 Detection methods

The most widely used instrument for detection of PFCs is by tandem MS. Typical precursor and product ions are given in Table 1.5.5.4.2. MS-parameters for the individual compounds, such as collision energy, declustering potential and cone voltage, have to be optimised for each instrument. The sensitivity of tandem MS is usually about one order of magnitude higher than that of QTOF-MS (13).

Table 1.5.5.4.2 Precursor and product ions for PFCs analysed using LC-(−)ESI-MS/MS.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Precursorion (m/z)</th>
<th>Product ion (m/z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFBA</td>
<td>112.9</td>
<td>168.7</td>
</tr>
<tr>
<td>PFPA</td>
<td>262.8</td>
<td>218.9</td>
</tr>
<tr>
<td>PFHxA</td>
<td>312.9</td>
<td>268.8</td>
</tr>
<tr>
<td>PFHpA</td>
<td>362.9</td>
<td>318.9</td>
</tr>
<tr>
<td>PFOA</td>
<td>413.0</td>
<td>368.9</td>
</tr>
<tr>
<td>PFNA</td>
<td>462.9</td>
<td>418.9</td>
</tr>
<tr>
<td>PFDA</td>
<td>512.9</td>
<td>469.0</td>
</tr>
<tr>
<td>PFUnDA</td>
<td>562.9</td>
<td>519.0</td>
</tr>
<tr>
<td>PFDoDA</td>
<td>613.0</td>
<td>568.9</td>
</tr>
<tr>
<td>PFTriDA</td>
<td>663.1</td>
<td>618.9</td>
</tr>
<tr>
<td>PFTeDA</td>
<td>713.0</td>
<td>669.0</td>
</tr>
<tr>
<td>PFHxDA</td>
<td>812.8</td>
<td>769.1</td>
</tr>
<tr>
<td>PFBS</td>
<td>298.9</td>
<td>79.8</td>
</tr>
<tr>
<td>PFHxS</td>
<td>398.9</td>
<td>79.8</td>
</tr>
<tr>
<td>PFHpS</td>
<td>449.0</td>
<td>79.3</td>
</tr>
<tr>
<td>PFOS</td>
<td>499.0</td>
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</tr>
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<td>PFDS</td>
<td>598.9</td>
<td>79.5</td>
</tr>
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<td>THPFOS (6:2 FTS)</td>
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<td>406.7</td>
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<td>PFOSi</td>
<td>482.8</td>
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</tr>
<tr>
<td>PFOSA</td>
<td>497.9</td>
<td>77.9</td>
</tr>
<tr>
<td>[13C4]-PFBA</td>
<td>216.8</td>
<td>171.8</td>
</tr>
<tr>
<td>[(13C4]PFOA</td>
<td>314.9</td>
<td>269.9</td>
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<tr>
<td>[(13C4]PFDA</td>
<td>417.0</td>
<td>371.8</td>
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<td>[(13C3]PFNA</td>
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<tr>
<td>[(13C3]PFDA</td>
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<td>469.8</td>
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<td>[(13C2]PFUnDA</td>
<td>565.0</td>
<td>519.8</td>
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<td>[(13C2]PFDoDA</td>
<td>614.9</td>
<td>569.9</td>
</tr>
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<td>83.9</td>
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<td>[(13C2]PFOS</td>
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<tr>
<td>[(13C3]PFOSi</td>
<td>486.9</td>
<td>422.9</td>
</tr>
</tbody>
</table>

7. Calibration and quantification

7.1 Standards

The use of commercially available standards with a purity of >99% is recommended. The purity of standards should be verified, as impurities from the same homologue group and isomers can occur.

Suggestions for mass-labelled IS are given in Table 1.5.5.4.1. Mass-labelled IS and an InjS are strongly recommended for the quantification of PFCs in biota. The IS and InjS have to be added before the extraction and the measurement, respectively. If possible the corresponding mass-labelled IS should be used for each target analyte. In case a mass-labelled standard is not available, an IS with similar physicochemical characteristics and recovery rates to the target compound can be used but matrix suppression/enhancement effects must first be checked in LC-ESI-MS/MS.

7.2 Calibration

The calibration curves must include the IS and InjS in the same range as the spike level. Linearity has to be checked for the calibration range and the correlation coefficient (R) should be better than 0.99. The lower linear range is defined by
the quantification limits and blank level of the method. The blank response should be lower than 20% of the lowest
calibration standard. A multilevel calibration should have at least five calibration levels.

In case of matrix effects, standard addition may be an alternative calibration option.

7.3 Quantification

Every detection and quantification must satisfy defined criteria for quality assurance (14). If possible, two mass
transitions should be recorded for each target analyte, one for quantification (quantifier) and one for qualitative
identification (qualifier). The abundance ratio of these two masses in the sample is compared with that of the calibration
standards. Usually, a positive detection is obtained if the ratio in the sample deviates less than 30% from the average
ratio of the calibration standards. Relative retention times should also be used for identification.

For quantification the peak height must have a signal to noise ratio of over 10, exceed a measured blank by a factor of 5
and be above the lowest calibration point.

Some PFSAs and sulfonamides show more than one peak in the chromatogram, which is due to the presence of
branched isomers. The ratio of the isomers can be different between the calibration standards and environmental
samples. These isomers cannot be quantified precisely because of the lack of calibration standards. If the peak area of
the branched isomer exceeds 10% of that of the linear isomer, it is recommended to estimate its concentration based on
the response factor of the linear standard.

The PFCAs and PFSAs are almost dissociated completely in environmental matrices. If salts are used for the
preparation of calibration standards, quantification should be calculated for the corresponding acids.

8. Quality Assurance and Quality Control

Prior to the analysis of environmental samples, the method should be subject to a full method validation according to
the requirements of the monitoring programme. This should include the determination of limits of detection, limits of
quantification, trueness, precision, linearity of calibration, measurement uncertainty, and robustness.

Every sample batch should include a procedural blank which is prepared in the same way as the samples. The number
of samples per batch may differ between laboratories and depend on how many samples can be processed under
comparable conditions.

If mass labelled standards for the analytes are used, absolute recoveries between 50% and 150% are acceptable. In other
cases, recoveries should be between 80% and 120%.

Within each batch, at least one sample should be extracted in duplicate. Laboratory control samples should be included
in each batch of samples. The results should be documented and monitored in control charts.

At present, no certified reference material is available for PFCs in biota. Possible bias in the analytical method should
be checked by the analysis of spiked laboratory control samples.

The laboratories should demonstrate their competence by participation in proficiency testing or intercalibration
exercises relevant for the monitoring programme.

9. Data reporting

For routine analysis, the data report should be in accordance with the relevant monitoring program; it should include
information about, for example, sampling, sample processing, storage, and analysis. Results should be reported along
with the associated measurement uncertainty.
10. References


1.5.5.5 Development of an ecological quality objective (EcoQO) on seabird population trends

Request

ICES was requested by OSPAR to:

“To further develop an ecological quality objective on seabird population trends, through work to complete previous ICES work on:

a. compiling meta-data on monitoring across the OSPAR Maritime Area;
b. developing standardised monitoring methods and protocols;
c. standardising interpretation of monitoring results;

and to begin the development of seabird population related indicators of ecological quality, comprised of “objectives,” “targets” and “limits.” At least one EcoQO indicator with its associated objective, target and limit, should be prepared as an example of what others might look like.”

[ICES interpreted the last sentence as: At least one EcoQO with its associated indicator, target and limit, should be prepared as an example of what others might look like.]

The meaning of EcoQO reference/target levels and limits were defined as follows by the OSPAR Commission in 2001:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference level</td>
<td>the level of EcoQ at which the anthropogenic influence on the ecological system is minimal. The criteria on which the reference level is set can change from EcoQ to EcoQ, or over time, leading to changes in the reference level as well. The reference level may refer to a range of possible points that allows for natural variation around a point.</td>
</tr>
<tr>
<td>Target Levels</td>
<td>values of the EcoQ that management should be trying to maintain with high probability.</td>
</tr>
<tr>
<td>Limit</td>
<td>a value of the EcoQ that, if violated, is taken as prima facie evidence of a conservation concern, i.e. there is an unacceptable risk of serious or irreversible harm to the EcoQ.</td>
</tr>
</tbody>
</table>

In relation to this EcoQO, the proposed target level is the same as the reference level, and the terms “upper bound” and “lower bound” have been used to refer to the edges of the range of possible points that allows for natural (or measurement) variation.

ICES Response

ICES advises that the EcoQO on seabird population trends should aim to ensure the intrinsic health of seabird communities and to provide triggers for appropriate action. Appropriate action would include both research and/or management, depending on how well the causes of change are understood at the time.

The EcoQO on Seabird population trends as an index of seabird community health should be as follows:

“Changes in breeding seabird abundance should be within target levels for 75% of the species monitored in any of the OSPAR regions or their sub-divisions”.

ICES advises that there should be separate EcoQOs for each OSPAR Region or sub-region. Each associated indicator will consist of species-specific trends in abundance for those species with good quality monitoring data. There is sufficient collated information to establish EcoQOs for OSPAR Regions III and V. There is sufficient information available to establish an EcoQO for OSPAR Regions II and IV, but this has yet to be collated.

Why use breeding seabird abundance?

ICES advises that the EcoQO be based on trends in abundance of breeding seabirds. ICES recognises that breeding abundance represents only one aspect of seabird community health, and only partially reflects the state of non-breeding populations. Insufficient data exist to enable trends in non-breeding abundance to be estimated. Data on breeding abundance have been widely collected and trends can be estimated relatively easily.

Seabirds tend to be generally long-lived and slow to reproduce. Changes in their breeding numbers are a poorer indicator of short-term environmental change than are other breeding parameters (e.g. breeding success). Abundance is a good indicator of long-term changes in seabird community structures where density-dependent effects may reduce the usability of other population parameters.
Species and regions

ICES acknowledges that the number of species that could be included in each regional indicator is limited by the quality of the available monitoring data and is therefore likely to be biased towards certain ecological niches\(^1\). If a more balanced indicator is desired, then some expansion of monitoring of seabird abundance will be needed. Species trends can be added to the indicator when the data allows, but the EcoQO would remain unchanged.

ICES has already collated sufficient data to provide regional indicators for OSPAR Regions III and V. ICES presents as an example the indicator for OSPAR Region III in Figure 1.5.5.5.1. The indicator was composed of trends in abundance of eight species during the period 1986–2006. The EcoQO was not achieved (i.e. abundance was outside target levels for three or more species) in seven out of 21 years: during 1988–1990, 1992, and 2003–06. Appropriate action would have been triggered in these years.

ICES is aware that good quality monitoring data are available for 10 and 5 species respectively in OSPAR Region II and Region IV, but these data have not been fully collated. Indicators for these regions could be constructed in one or two years.

ICES is unsure how long it will take before an indicator can be constructed for OSPAR Region I because monitoring data are spatially and temporally sparse. Monitoring of only two species has been sufficient to produce good quality trend data across the entire region. ICES advises that separate indicators should be constructed for subdivisions of OSPAR Region I to take account of the large geographical variation in trends. Further investigation would be needed with respect to the quality of data available within each subdivision.

![Figure 1.5.5.5.1](image)

**Figure 1.5.5.5.1** The proportion of species (n=8) in OSPAR Region III that were within target levels of abundance during 1986–2006. The EcoQO was not achieved in years when the proportion dropped below 75%.

Reference levels

The reference level for each seabird population should be set at a population size that is considered desirable for each individual species within each geographical area. This should be set for each species based on expert judgement of when population levels were considered to be least impacted by human activities.

Targets levels

ICES advises that target levels used within this EcoQO be based on the magnitude of change in population size compared to preset reference levels.

Target levels were set to trigger an action about one-third of the time. This occurs when the indicator is beyond approximately one standard deviation of the mean. This led to an upper bound of 130% of the reference level for all species, while a lower bound of 80% of the reference level was set for species that lay one egg, and a separate lower

\(^1\) Ecological niches were described according to feeding behaviour and feeding area: Inshore surface-feeders (ISF), Inshore divers (ID), Offshore surface-feeders (OSF), Offshore divers (OD).
bound of 70% for species that lay more than one egg. These different lower levels were set according to the resilience of populations to decline.

ICES recognises these target levels could be changed or set individually for each of the species-specific trends without altering the EcoQO.

Implementation of the EcoQO

In order to ensure coordination within the OSPAR Area, ICES could report annually to OSPAR on whether or not the EcoQO has been achieved. Where appropriate, ICES could recommend actions to reverse those trends. In years when the EcoQO has been achieved, ICES will take note of any species-specific trend that is outside target levels and consider recommending remedial action to OSPAR. ICES would use demographic parameters, such as breeding success, to provide interpretation of changes in seabird abundance.

Source of information

Technical Annex

An example of a regional indicator for the EcoQO on seabird population trends as an index of seabird community health: OSPAR Region III.

Introduction

Seabird trend data from OSPAR Region III were used to construct an indicator of the proposed EcoQO:

Changes in breeding seabird abundance should be within target levels for 75% of the species monitored in any of the OSPAR Regions or their sub-divisions.

Methods

There are inherent features of seabird monitoring data that create problems when attempting to measure year-to-year changes in the abundance of seabirds at large spatial scales (e.g. within an OSPAR Region). These problems mainly stem from the fact that in most countries only a sample of colonies has been surveyed each year, with some colonies monitored less frequently than others. Comparing counts from one year to the next is not straightforward and requires some assumptions about the underlying spatial synchronicity of trends in abundance. A modelling approach was used to overcome these problems: for each species, observed counts were used to predict numbers present at colonies during years in which no surveys were conducted.

Following preliminary analyses, data from 14 of the 26 species of seabirds breeding in OSPAR Region III were considered good enough to produce accurate trends in abundance. Problems were encountered when attempting to model trends in six of these species: northern gannet, roseate tern, common tern, Arctic tern, little tern, and great cormorant. These problems are not insurmountable, but will require further investigation. Trends were successfully modelled for eight species: northern fulmar, European shag, great black-backed gull, herring gull, and black-legged kittiwake; Sandwich tern, razorbill, and common guillemot.

Data source

Data for OSPAR Region III were collected as part of the UK and Ireland’s Seabird Monitoring Programme (SMP; www.jncc.gov.uk/smp). SMP data collection is conducted by professional and volunteer observers using standardized methods. The time-series of most species in the dataset are from 1986 to 2006; Sandwich tern data has been regularly collected since 1969.

Trend estimation

TRIM (a Poisson regression model) was used to estimate trends of all species except Sandwich tern. TRIM assumes that abundance changes with time in a log-linear fashion and that there is a degree of synchronicity between the trends in different colonies. These assumptions cannot be applied to Sandwich tern data, because this species exhibits high rates of colony formation and extinction, and low levels of spatial synchronicity in trends. Instead, the Thomas method was used to estimate each missing data point, \( Y_{ij} \), in the Sandwich tern dataset using the formula

\[
Y_{ij} = \sum_{q \in T_i} w_{jq} r_{jq} y_{iq}
\]

where \( T_i \) denotes the set of years for which data are available at site \( i \). The weights \( w_{jq} \) determine the degree of temporal smoothing.

For each species, separate trends models (either TRIM or Thomas method) were produced (where data allowed) for western Britain and for Ireland. These models computed estimates of annual national abundance that were summed to estimate total annual abundance in OSPAR Region III. This approach was required because for most species, changes in abundance over the last 20–35 years have not been synchronous between the populations in western Britain and in Ireland.

Total population counts of western Britain and of Ireland, obtained during complete censuses (see Table 1.5.5.5.1), were used to weight estimated national trends when they were combined to produce trends at the OSPAR regional level. The weighting removed bias due to differences in sampling intensity between the two countries. Total abundance in OSPAR Region III, \( y \), in year \( j \) was calculated as follows:

\[
y_j = \left( \frac{y_{GBj}}{p_{GB}} + \frac{y_{IREj}}{p_{IRE}} \right)
\]
where \( p \) is the proportion of the population in western Britain (GB) or Ireland (IRE) contained within the sample of sites that were monitored in each country. The size of the populations in western Britain and Ireland were taken from the results of complete censuses (see Table 1.5.5.1). If the census was conducted in a single year, then \( p \) was calculated using the abundance in the sample of colonies estimated in the same year, using either TRIM or the Thomas method. If the census was conducted over more than one year, then \( p \) was calculated by computing a weighted average of the ratios of census to estimated values for each year of the census period, with the weights set equal to the proportions of the census counts that were conducted in each of those years.

When using TRIM, the standard error of the estimate of total abundance in OSPAR Region III, \( se \), in year \( j \) was calculated as follows:

\[
se_j = \sqrt{\left(\frac{se_{GBj}}{p_{GB}}\right)^2 + \left(\frac{se_{IREj}}{p_{IRE}}\right)^2}
\]

The Thomas method was used to produce estimates of annual abundance \( y \), of Sandwich tern, separately for the sample of colonies monitored in Britain and in Ireland. Estimates were produced only for years in which at least one colony in each of Britain and Ireland was surveyed. Total abundance of Sandwich terns in OSPAR Region III, \( y \), in year \( j \) was calculated as above. However, uncertainty around the estimates of total abundance in OSPAR Region III was estimated using a bootstrapping procedure.

Estimates of annual abundance of all species were plotted in Figure 1.5.5.2 as a percentage of the respective reference level (see Table 1.5.5.1).

**Assessing trend accuracy**

The accuracy of the annual estimates of total abundance in OSPAR Region III were assessed for each species by comparing the modelled estimates with observed total numbers during years in which censuses were conducted. Close agreement between the modelled data and census data would support the assumption that the sampled colonies provide an unbiased representation of regional trends.

**Reference levels**

Each species-specific reference level was set at a level previously observed, preferably prior to any major population change, particularly those that resulted from anthropogenic pressures. Reference levels were set using population size estimates from Ireland and from western Britain that were obtained during complete censuses (see Table 1.5.5.1). Most species of seabird breeding in Britain and Ireland have been censused three times: during 1969–70, 1985–88, and in 1998–2002. Justification for choosing each of the reference levels for OSPAR Region III is given in Table 1.5.5.1.

**Setting target levels**

An upper target level of 130% of the reference level was set for all species, while a lower target level of 80% was set for species that lay one egg and a separate lower target of 70% for species that lay more than one egg. In order to test the suitability of these target levels, a series of target levels between 50% and 200% were applied. Figure 1.5.5.3 shows the number of years in all of the species dataset in which abundance was outside each target level. There is no particular “scientific” justification for the choice of these target levels; plainly having these set too close to the reference level would trigger a failure of the EcoQO too often, while setting them too far from the reference level would increase the risk that a major change in the marine environment went unnoticed. The two figures chosen result from expert consideration of these values.
### Table 1.5.5.1 Species-specific reference levels for the constituent countries in OSPAR Region III.

<table>
<thead>
<tr>
<th>Species</th>
<th>Britain reference levels</th>
<th>Ireland reference levels</th>
<th>Justification for reference level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scientific name</td>
<td>abundance¹</td>
<td>year</td>
</tr>
<tr>
<td>Northern fulmar</td>
<td><em>Fulmarus glacialis</em></td>
<td>153 385</td>
<td>1998–2000</td>
</tr>
<tr>
<td>Herring gull</td>
<td><em>Larus argentatus</em></td>
<td>73 599</td>
<td>1986–87</td>
</tr>
<tr>
<td>European shag</td>
<td><em>Phalacrocorax aristotelis</em></td>
<td>17 246</td>
<td>1986–88</td>
</tr>
<tr>
<td>Black-legged kittiwake</td>
<td><em>Rissa tridactyla</em></td>
<td>74 002</td>
<td>1985–87</td>
</tr>
<tr>
<td>Sandwich tern</td>
<td><em>Sterna sandvicensis</em></td>
<td>1143</td>
<td>1986–88</td>
</tr>
<tr>
<td>Razorbill</td>
<td><em>Alca torda</em></td>
<td>84 133</td>
<td>1998–2001</td>
</tr>
</tbody>
</table>

¹Unit of abundance is pairs for all species except *Alca torda* and *Uria aalge*, which are listed as the number of birds.
Results

Figure 1.5.5.5.3 shows the trends in abundance in OSPAR Region III of eight species. All the trends except for great black-backed gull and Sandwich tern showed close agreement with the census data. The trend of both species overestimated the observed numbers present in OSPAR Region III during the census in 1998–2002. It may be possible, through resampling these data, to derive more representative samples of great black-backed gull and Sandwich tern. However, for the purposes of demonstrating how the proposed EcoQO will operate, the trends of these two species were retained in the indicator for OSPAR Region III.

The annual estimates of abundance of all eight species over the time-series spanning 21 years (1986-2006) were examined in relation to possible target levels in Figure 1.5.5.5.2. Figure 1.5.5.5.2 plots the number of ‘species-years’ in which annual estimates of abundance exceed each of the lower and upper targets presented. As the lower target level reduces and the upper target increases, the number of ‘species-years’ in which abundance is outside the target levels decreases sharply before levelling out. Figure 1.5.5.5.2 allows a pragmatic assessment of where limits should be set to ensure that the EcoQO is not triggered too often, yet is still effective at triggering action when substantial changes to the seabird community occur. Examination of Figure 1.5.5.5.2 suggests that a lower target level of 70–80% (depending on clutch size) and an upper target level of 130% are suitable for assessing seabird trends in OSPAR Region III. When these target levels were applied to the eight species-specific trends in OSPAR Region III, the EcoQO was not achieved in seven out of 21 years: during 1988–1990, 1992, and 2003–2006. When the lower target level was set more conservatively at 70% for all species, the EcoQO was not achieved in only five years, but this increased to six and nine years respectively when the lower target level was raised to 75% and 80%.

Discussion

ICES concludes that appropriate modelling techniques exist and that sufficient monitoring data are available from OSPAR Region III and other OSPAR Regions to provide adequate indicators for the proposed EcoQO.

ICES considers the main advantage of the proposed EcoQO to be how simply and clearly it can be used to communicate the state of health of seabird communities (see Figure 1.5.5.5.1). The regional indicators can be updated and improved without changing the EcoQO and this will ensure consistent communication on the EcoQO’s progress in future years. Such improvements might include adding new data to the existing time-series, or adding more species, or altering target levels if they prove ineffective, or updating reference levels with new census data if appropriate.

For the OSPAR Region III indicator, reference levels were derived from census results. ICES recognises that censuses have been conducted infrequently or never in other countries. Reference levels for trends in these countries should be derived from estimates of total abundance in the sample of colonies that are regularly monitored.

ICES envisages that the process of assessing and updating seabird trends annually for the EcoQO will ensure that important changes in individual species do not go unnoticed, even if the EcoQO is achieved.

Source of information

Figure 1.5.5.2 Trends in abundance in OSPAR Region III.

- **f) Sandwich tern**
- **g) razorbill**
- **h) common guillemot**
Figure 1.5.5.3  The number of years in which annual estimates of abundance of all eight species exceeded a range of lower and upper target levels.
1.5.5.6 Review of an OSPAR workshop on modelling of predictive eutrophication status and transboundary nutrient fluxes

Introduction

OSPAR has requested that ICES provide an independent review of an OSPAR workshop held in September 2007 that modelled “the results of nutrient reduction scenarios for the North Sea to provide an insight into the response of selected eutrophication assessment parameters to the reduction of nutrient loads to the marine environment. The purpose of this assessment (was) to assist delivery under the 2003 Strategy for a Joint Assessment and Monitoring Programme (JAMP) of an assessment of the expected eutrophication status of the OSPAR maritime area following the implementation of agreed measures (JAMP product EA-5).” There were two general outputs from the workshop: (a) the results of the nutrient reduction scenarios and (b) a draft work plan for predicting the transport of nutrients across national boundaries.

This is part of the continuing work of OSPAR regarding the monitoring and assessment of eutrophication in the OSPAR area. In the past, ICES has responded to OSPAR requests related to eutrophication, most notably in 2003. At that time, ICES identified a number of concerns regarding the suite of Ecosystem Quality Objectives (EcoQOs) for eutrophication and their application. OSPAR has worked towards addressing many of those concerns and in the Workshop report acknowledges that there are some unresolved issues. This response from ICES is very specific to the request from OSPAR as stated below and does not address other outstanding issues and how they might impact the application of the Workshop results.

Request

The initial request from OSPAR was:

a. a review of models used to produce nutrient reduction scenarios, in the light of the results of an assessment of the expected (modelled) eutrophication status of the OSPAR maritime area following implementation of agreed measures (JAMP EA-5), which is to be prepared at the OSPAR workshop on eutrophication modelling in September 2007.

b. to provide advice on further work by OSPAR on the modelling of transboundary nutrient fluxes.

This request was amplified by OSPAR following the September Workshop:

a. on nutrient reduction scenarios:
   i. to review the application of the models in the context of a nutrient reduction experiment, considering the overall approach and the data used (User Guide, Data Description);
   ii. to review the results from the nutrient reduction experiment and the conclusions drawn from them (Annex 4 of the workshop report);
   iii. to make appropriate recommendations for future model applications in the context of predictive assessment of eutrophication.

b. on the calculation of transboundary nutrient transport:
   i. to review a draft Work Programme for Calculating Transboundary Nutrient Transport (OSPAR, 2007c), taking into account progress already achieved (Ménesguen et al., 2006; Wijsman et al., 2003) and especially:
   ii. to review the proposed methodology with a view to achieving the objectives of the Work Programme;
   iii. to identify weakness in methodology and propose any improvements.

The sections of this document are organized as per the request. Within each section there is a sub-section on the nutrient reduction scenarios and a sub-section on the calculation of transboundary nutrient transport. In the detailed section of the report, i.e. “Scientific Background”, each sub-section is further divided according to specific questions from OSPAR as communicated to ICES. It is emphasized that this is an independent review of the OSPAR Workshop – it is not advice to OSPAR on how to predict the impact of nutrient reductions or on how to estimate the transboundary transport of nutrients.
Summary

ICES notes the usefulness of the subject workshop in advancing the scientific understanding of potential tools which can be used to assist management decisions to reduce the frequency and severity of eutrophication events that are induced or enhanced by human activities. However, ICES reiterates its earlier advice that effective management decisions cannot be based simply on one of the suite of identified EcoQOs related to eutrophication; decisions must be based on an integrated assessment. It is not clear to ICES how the predictions of this modelling workshop and the predictions of transboundary nutrient flux will be integrated with the other eutrophication indicators to provide advice to management.

Standard Model Runs and Nutrient Reduction Scenarios

The application of the different validated 3-dimensional models provides the capacity for interpolating results of monitoring programs in time and space. The models are considered useful for evaluating the potential impacts of nutrient reduction. A lot of effort was spent in setting up the models in a similar way. While the use of common boundary conditions for all simulations is considered suitable this may in some cases have led to a degradation of the model performance compared to when boundary conditions were derived from observations. The decision to apply different reductions to take country reductions already achieved into account was found reasonable, permitting an evaluation of the best obtainable water quality according to the OSPAR requirements.

The spin-up procedure apparently causes some deficiencies in the simulations that have been insufficiently addressed. As pointed out by several project partners the spin-up phase is not sufficient to achieve equilibrium for the sediment variables (suspended particulate matter, SPM) or for the benthic system. For the validation, the use of depth-integrated variables could have been useful. The validation for modelled chlorophyll levels is complex and it is not clear how this was done in the experiments. Insight about the relative contributions from different sources in simulations can be gained if mass balances are determined and compared with those calculated from observations. While the use of cost functions as a measure for model performance was useful, consideration should have been given also to other approaches, e.g. Taylor diagrams.

Atmospheric input could contribute significantly to nutrient enhancement of the upper water column in offshore areas and should therefore have been considered and reduction scenarios conducted. For nutrient reduction scenarios the river load reductions already achieved in the period 1985–2002 have been taken into account, but only as a reduced flux of ammonium. This questionable approach might generate unwarranted responses from models in which certain phytoplankton species have a preference for either ammonium or nitrate.

Generally, the reduction scenarios show that the “assessment level” can be achieved for most variables offshore; for coastal areas this is usually not the case. This might indicate that, inter alia benthic–pelagic coupling is not well represented by the models. It is critical that the models are improved in that respect given that four of the six “problem areas” are located near the coast. In analyzing the results of the experiments the use of a few vertically integrated values and sediment state variables would have been desirable. Results of the simulations for selected vertical sections and horizontal plots of the surface/bottom variables would also greatly facilitate the evaluation of the model performance.

The performance of the models is limited by our knowledge of the processes that control algal blooms, including harmful algal blooms. Previous advice from ICES (ICES, 2003) recognized the complexity of this issue and the need for an integrated approach employing a suite of indicators. OSPAR recognizes this in their assessments. As always the validation of the models is limited by the availability of data of appropriate quality and of appropriate temporal and spatial resolution. Specific recommendations for future experiments are provided in the detailed section “Scientific Background.”

Transboundary Nutrient Transport

The proposed work plan is an obvious and potentially useful extension of the predictive modelling of eutrophication status. The work plan will allow calculation of nutrient budgets for the target areas and provide an estimate of the relative contributions of nutrients from various sources, including river and atmospheric fluxes. While it is designed specifically to estimate the flux of nutrients across national boundaries, this application needs to be done in the context of the identified weaknesses in the present models. For the transboundary transport of nutrients (dissolved inorganic nitrogen and phosphorus; DIN, DIP) some potentially important vectors are not considered in the current models. Furthermore, the temporal scale of the modelled transport relative to the time scale of a bloom event needs to be considered in the context of the potential application of the results.
Conclusions

ICES notes the progress that OSPAR has made on the development of the EcoQOs related to eutrophication, but emphasizes the importance and continued relevance of previous ICES advice provided on this issue (ICES, 2003). In particular ICES notes that nutrient levels and enrichment must not be considered in isolation from other information when assessing the potential for eutrophication in marine waters. This is recognized in the OSPAR assessment process, but it is not clear how this consideration will be applied to the results of the modelling exercise and the proposed experiments on transboundary transport. The following recommendations are made on the assumption that the information from the modelling exercises is used in the integrated context as recognized by OSPAR.

ICES also acknowledges that the conclusions provided herein are without the benefit of discussion and feedback from the Workshop participants or its Chair. It is therefore likely that some of these issues have already been considered by the Workshop participants and are accounted for in their findings and recommendations. In the future when requests of this nature are considered, where possible the Workshop Chair or a representative of the workshop should be available for questions of clarification during the review process.

Standard Model Runs and Nutrient Reduction Scenarios

- The performance of these models in the near-shore areas must be improved since this is where most of the problem areas are. The benthic–pelagic coupling and the sediment module need to be enhanced. All models should use the same initialization/forcing for SPM which should in turn impact the light field, density structure, etc.
- It appears that the performance of most models would benefit from a better understanding and hence simulation of light limitation.
- The use of vertically integrated quantities should be considered for facilitating the validation of the models.
- Future projects should pay more attention to clearly defining the diagnostic variables and to presenting the necessary calculations, e.g. how the conversion of nitrogen and carbon (the unit of phytoplankton concentrations in most models) into chlorophyll has been performed.
- Sensitivity testing and evaluation against dynamically different years would help in understanding the results of the model simulations. Describing previous effects of reduced P-loadings will also increase the understanding of the nutrient dynamics in the North Sea.
- Describing the systems by establishing different mass budgets for the different components and evaluating losses and enrichments between the different compartments would increase the understanding and confidence in the model results in general.

Transboundary Nutrient Transport

- The proposed work plan is an obvious and potentially useful extension of the predictive modelling of eutrophication status. However, the plan needs to take into account the identified weaknesses in the present models.
- For the proposed approach, the models have to be run for a period of 10 to 20 years to eliminate the effect of inter-annual variability.
- The temporal scale of the modelled transport relative to the time scale of a bloom event needs to be considered in the context of the potential application of the results.
- The so-called “nutrient-labelling (nutrient tracer method)” appears to be the most appropriate way to calculate the relative proportion of the different sources inducing phytoplankton blooms.
- Some important aspects of nutrient transport have been neglected in the proposed approach; N and P are transported in forms other than DIN and DIP. Also fluxes from the sediment have been neglected and this internal loading might play an important role, particularly in shallow areas.

Scientific Background

ICES again acknowledges that the comments provided herein are without the benefit of discussion and feedback from the Workshop participants or its Chair. It is therefore likely that some of the identified concerns have already been considered during the Workshop and are accounted for in its findings and recommendations.

Trans-national problems, like eutrophication in the North Sea, require a common strategy. The application of 3-dimensional models is helpful in assessing potential consequences of management practices like nutrient reduction. ICES was asked to evaluate the two documents “Revised draft assessment of the predicted environmental consequences for problem areas following nutrient reductions” (OSPAR, 2007a and b) (Document I) and the “Draft work programme for calculating transboundary nutrient transport in the North Sea and adjacent areas” (OSPAR, 2007c) (Document II)
by using the background information given in the document “OSPAR workshop on eutrophication modelling” (OSPAR, 2007b). This background document contains:

- the description of nine (9) model applications for target areas in the North Sea. The following models; NORWECOM (IMR, Norway), GETM-BFM (CEFAS, UK), POLCOMS-ERSEM (POL, UK), Delft3D-ECO/GEM (DELFT, Netherlands), and ECOHAM4 (IFM Hamburg, Germany) conformed to the user guidelines and were used for evaluation of the nutrient reduction scenarios. In addition, the NORWECOM (IMR, Norway) model, which was not entirely compliant with the User Guide, and the MIRO&CO-3D (MUMM, Belgium) model, which has a limited spatial coverage, were used to quantify the effects of nutrient reduction in some target areas. The other four models were either non-compliant or limited in scope and therefore not further considered.
- an agenda concerning transboundary nutrient transport.

**Document I** includes:

- validation of the model runs using cost functions for the variables temperature, salinity, DIN, DIP, chlorophyll a, suspended particulate matter (SPM), and oxygen for the different target areas in the North Sea;
- the results of the nutrient reduction scenarios (50% and 70%) for the variables DIN, DIP, chlorophyll a, and oxygen.

Finally, **Document II** discusses:

- how nutrient loads from different sources can be determined, how nutrient budgets for target areas can be generated, and how the relative contributions of different sources inducing phytoplankton blooms can be quantified (determining the natural and anthropogenic fraction of the bloom biomass).

**Standard Model Runs and Nutrient Reduction Scenarios (Document I)**

**Comments on the general approach**

The application of different validated 3-dimensional models provides the capacity for interpolating results of monitoring programs in time and space. They are, however, particularly useful in evaluating the potential impacts of nutrient reduction in that (a) their application adds confidence in our ability to represent the main processes if the results show similar features, and (b) model inter-comparisons may reveal general deficiencies. The latter can result in model refinements, improving our hind-cast/forecast capabilities. These issues have been noted by the workshop participants in their analyses and evaluation of their model results. Since all models have aspects which are not state-of-the-art (e.g. models which do not include tides, suspended particulate matter, particulate organic matter, etc.), models need to develop continuously.

A lot of effort was spent on setting up the models in a similar way. For example, the boundary conditions for all simulations were taken from POLCOMS. This might in some cases lead to a degradation of the model performance compared to when boundary conditions have been derived from observations (as pointed out by several project partners). It is, however, a suitable way to conduct a model comparison of nutrient reduction scenarios, although this approach has some drawbacks in obtaining the best information on nutrient reduction scenarios, as it does not take advantage of the fine tuning of the individual models.

The decision to apply different reductions by taking country reductions already achieved into account was found reasonable, permitting an evaluation of the best obtainable water quality according to the OSPAR requirements.

**Comments specifically on the data used for spin-up**

The agreed spin-up procedure was to repeat the year 2002 three times (for some models a longer period was chosen). This approach caused some problems which have been insufficiently addressed. At least the beginning of the year is biased by such a procedure and might lead to a different “steady state” than for a model which has been spun-up for several years. The use of three consecutive years would have been more appropriate.

The decision to apply different reductions by taking country reductions already achieved into account was found reasonable, permitting an evaluation of the best obtainable water quality according to the OSPAR requirements.
Comments specifically on the data used for validation

Data from observations have been classified into two bins: surface (0–15m) and “bottom” (the vertical extent of the bottom layer is not clear). It seems, however, that validation has only been carried out for the upper water column variables (DIN, DIP, chlorophyll \(a\), salinity, temperature). Unfortunately depth-integrated quantities, e.g. the standing stocks of phytoplankton biomass, are not shown, although these can be useful indicators of model performance. The use of observed chlorophyll values to validate the phytoplankton biomass in the models is problematic. As indicated by a number of publications in the past years and also briefly addressed in the Workshop report, chlorophyll is easy to determine but is not a suitable measure for phytoplankton biomass. Although there is currently no consistent and easy way to determine phytoplankton biomass, available phytoplankton cell counts and information about the dominant phytoplankton groups could have been used for validation.

In addition, insight about the relative contributions from different sources in simulations can be gained if mass balances are determined and compared with those calculated from observations. As a measure for model performance, cost functions have been introduced and their limitations discussed. Considerations should have been given also to other approaches (e.g. Taylor diagrams).

Comments specifically on the data used for boundary conditions

A lot of effort was spent on setting up the models in a similar way. Taking the boundary conditions for the standard model run and nutrient reduction scenarios from POLCOMS is a suitable way to make the different models comparable but may result in suboptimal performance of some models (see also comments under “General approach”).

Although the river discharges might be the most important “external” nutrient sources in inshore areas, atmospheric input should have been considered and reduction scenarios conducted. It cannot be ruled out that offshore the atmospheric flux contributes significantly to nutrient enhancement of the upper water column. In the 50% and 70% nutrient reduction scenarios, the river load reductions actually achieved during the 1985–2002 period were taken into account, but only as a reduced flux of ammonium. This might lead to a shift in the ammonium to nitrate ratio. While this shift might be irrelevant for models considering only DIN, it may be crucial for models in which certain phytoplankton species have a preference for either ammonium or nitrate.

The participants agreed on using similar forcing fields (European Centre for Medium-Range Weather Forecasts; ECMWF) for their model experiments but it was not clear from the presentations that this was the case. It seems from the documentation that data from the National Centers for Environmental Prediction (NCEP) were also used.

Comments on specific results and conclusions of nutrient reduction experiments

The project participants used the most important quantities (T, S, DIN, DIP, chlorophyll, oxygen) to present the effects of nutrient reduction. The usefulness of the oxygen results is questionable since the models do not appear to have considered wind speed which is an important forcing function for dissolved oxygen. The analysis of a few vertically integrated values (e.g. phytoplankton biomass) and some sediment state variables would have been desirable. Also selected vertical sections (e.g., along EUROGOOS/NOOS transects) and horizontal plots of the surface/bottom variables would greatly facilitate the evaluation of the model performance. Some of these plots are available in the PowerPoint presentations\(^1\), but not in the documentation.

Generally, the 50% and 70% reduction scenarios show that the “assessment level” can be achieved for most variables offshore; for coastal areas this is usually not the case. As one would expect, the largest reductions are observed in DIN and less in DIP. The effects of decreasing nutrient discharges were medium on chlorophyll \(a\) and small on the minimum oxygen concentrations. No obvious inconsistencies in the responses of the state variables were apparent.

However, one result is that generally the model performance is better offshore compared to coastal areas. This might indicate for example that the benthic-pelagic coupling is not well represented by the models. The models need to be improved in that respect. It is important to remember that four of the six “problem areas” are located near the coast.

The introduction of criteria to assess the level of confidence for the nutrient reduction scenarios is laudable. However, criterion 1 (the level of agreement, in terms of simulated concentrations, between model results for the same assessment parameters) should be linked to observations, e.g. by normalizing the values taking into account the cost function. However, even if all models show similar concentrations of a variable in the standard model run and the same level of

\(^1\) The document OSPAR (2007b) contains links to presentations that were made at the OSPAR workshop and the subsequent report of the workshop to OSPAR EUC 2007.
response in the nutrient reduction scenarios, this does not imply that a similar response, criterion 2, might occur in nature. It cannot be ruled out that all models share the same bias.

Comments on overall conclusions of nutrient reduction experiments

The overall conclusions of the nutrient reduction scenarios with respect to the state variables DIN, DIP, chlorophyll $a$, and oxygen are within the realm of expectation. Other statements and conclusions are rather speculative. For example, the spin-up does not convincingly demonstrate that equilibrium can be attained with sediment variables or sediment nutrient fluxes. The underlying physical models and boundary conditions are critically important with respect to the distribution patterns of the biogeochemical variables, but these were not addressed.

The models could be used to conduct hind-casting experiments. If the models are able to correctly predict conditions before the OSPAR reductions were enacted, more confidence would be gained in the performance of the models and in the results for future reduction scenarios.

Differences between the models in the responses of the various state variables to nutrient reduction have been presented. However, a more detailed analysis of the sensitivity of the simulated variables in the specific target areas would have been useful, e.g. what causes the differences in the sensitivity of the variables in some target areas?

Recommendations for future experiments

Are these experiments useful?

These experiments serve a number of useful purposes. Comparison of the results from the different models aids in identifying weaknesses and strengths of different approaches and thus contributes to model development. When taken in the context of other relevant information the modelling results can contribute to evaluating the potential effectiveness of different management measures that might be taken to improve water quality.

What are the practical limitations?

The models are limited by our knowledge of the processes that control algal blooms, including harmful algal blooms. Previous advice from ICES (ICES, 2003) recognized the complexity of this issue and the need for an integrated approach employing a suite of indicators. As always, the validation of the models is limited by the availability of data of appropriate quality and of appropriate temporal and spatial resolution. High quality data on both land-based loadings and atmospheric deposition could further improve the forcing of the models.

As noted by the Workshop participants, specific funding for the experiments would enable more scientists to participate fully, allowing more time for model setup and the carrying out of sensitivity testing.

Recommendations for future work, e.g. models to be used, essential developments in the model, different approaches, etc.

The Workshop noted that the model validation was consistently better in the offshore than in the near-shore areas; cost functions were consistently higher in the near-shore areas. There could be many reasons for this but it is likely that model deficiencies in the simulation of sediment dynamics and in benthic-pelagic coupling contribute to this weakness. The models should use a common approach to initializing SPM and in simulating its impact on the light field and density structure in the near-shore. Improvements in the physical models through implementing advanced turbulence schemes may also be required, as turbulence plays an important role in shallow waters.

There is some difficulty in understanding the modelling results due to lack of documentation and the manner in which results are presented. Future experiments should provide clearer explanations of the validation exercise, i.e. the comparison of the model output to field observations. For example, how is the modelled phytoplankton biomass (usually in mg (or mmol) C or N m$^{-3}$) converted into chlorophyll (usually mg m$^{-3}$) for model-observation comparison? Consideration should also be given to comparing model output and field observations that are integrated over depth, either total depth or depth of the euphotic zone or mixed layer as appropriate.

Consideration should be given to experimenting with long-term model runs with reduced nutrient inputs and using boundary values based on estimates of pre-industrial conditions. This would directly address the issue of defining the reference points identified in the EcoQOs related to eutrophication. Demonstration of the ability of the models to effectively hind-cast will increase confidence in the usefulness of the models.

From a practical perspective once the guidelines for the exercise have been agreed upon only those model simulations that adhere to the guidelines should be included in the experiment.
It is not apparent from the Workshop report that sensitivity analyses or mass budgets were undertaken as part of the exercise. Both of these approaches can contribute significantly to the understanding of and confidence in model output. Sensitivity testing and evaluation against dynamically different years would aid in better understanding the model results. Also describing the effects of reduced phosphorus loadings would increase the understanding of the nutrient dynamics in the North Sea.

**Transboundary Nutrient Transport (Document II)**

**Consistency of proposed work plan with achievements to date**

The proposed work plan is an obvious and potentially useful extension of the predictive modelling of eutrophication status. The proposed work will permit a calculation of nutrient budgets for the target areas and provide an estimate of the relative contributions of nutrients from various sources, including river and atmospheric fluxes. The work plan is specifically designed to estimate the flux of nutrients across national boundaries. However, this application needs to take into account the identified weaknesses in the present models. In addition, some potentially important vectors for the transboundary transport of nutrients (DIN, DIP) are not considered in the current approach. These vectors include the fluxes of all inorganic and organic matter (e.g. dissolved organic matter, DOM), the spreading and advection of phytoplankton blooms, and the movement of secondary and tertiary producers (e.g. fish schools). The role of sediments in the transport and supply of nutrients needs to be addressed particularly in the shallow areas.

**Is the proposed methodology directed at the objectives of the work plan?**

For the proposed approach the models have to be run for a period of 10 to 20 years to eliminate the effect of inter-annual variability. The so-called “nutrient labelling (nutrient tracer) method” appears to be the most appropriate way to calculate the transboundary nutrient flux even though this approach requires considerable computing resources.

**What are the weaknesses, if any, in the proposed approach?**

A number of weaknesses to this approach have been noted above. In particular, there is a critical need to consider the role of sediments in the storage and flux of nutrients in near-shore areas. As well, the temporal scale of the modelled transport needs to be considered in the context of the potential application of the results. Assessing the importance of various nutrient sources in the equilibrium state after removal of short-term and inter-annual variability does not address the potential for nutrients from a given source contributing to a phytoplankton bloom. Short-term events could make a significant contribution to a bloom event while the long-term average contribution is determined to be insignificant. It is also possible that the inverse could be true. What may be required is a statistical approach that accounts for the coincidental timing of nutrient fluxes with other factors necessary for the formation of phytoplankton blooms. This relates specifically to objective (c) of the proposed work plan, i.e. “to determine consequences for target areas of any nutrient transport in terms of direct and indirect effects on parameters used for the assessment of the eutrophication status.”

**Are there alternatives to the proposed approach that should be considered?**

ICES does not have any recommendations regarding potential alternative approaches.

**Sources of information**


Note: the following documents were provided by OSPAR for this review and they include links to additional documents and presentations that were available for the review. These documents are presently, i.e. March 12, 2008, available at http://www.cefas.co.uk/eutmod. It is not known if these documents will become generally available through OSPAR.


OSPAR. 2007a. Revised draft assessment of the predicted environmental consequences for problem areas following nutrient reductions. 2nd OSPAR Workshop on Eutrophication Modelling, 10–12 September 2007. Status: 8 January 2008. (This was a draft of OSPAR (2007b), which became available after the review was in progress).

OSPAR. 2007b. OSPAR Workshop On Eutrophication Modelling, Workshop Report. 2nd OSPAR Workshop on Eutrophication Modelling, 10–12 September 2007. EUC 07/5/3-E.


1.5.5.7 Further development of guidance on integrated monitoring and assessment of chemicals and biological effects

Request

ICES has received the following request from OSPAR:

Development of JAMP monitoring guidelines (OSPAR 8-2008)

To complete the development of JAMP guidance for integrated monitoring of chemicals and their biological effects through preparing technical annexes on:

(i) survey design. The purpose is to provide guidance on the selection of representative stations, taking into account requirements under the Water Framework Directive and the proposed Marine Strategy Directive, and for the selection of stations for integrated monitoring. This work should build on work by WGSAEM 2007 relating to the spatial design of monitoring programmes and should take into account the approach taken by the UK in re-designing their station network;

(ii) groups of biological effects methods to be deployed to address specific questions. This should provide guidance on recommended packages of chemical and biological effects for monitoring on determinand basis to ensure that chemical and biological methods were well matched and that chemical analysis underpinned biological effects monitoring.

ICES Response

Summary

The existing JAMP Guidelines provide appropriate information for undertaking either chemical or biological effects sampling independently, but some revisions are required for integrated sampling. A Technical annex consisting purely of a compilation of references to existing JAMP Guidelines will not provide information consistent with that required for integrated monitoring. A mechanism is required to revise the JAMP Guidelines to accommodate integrated monitoring. The annexes in this document describe packages of methods that combine contaminant-specific effects with the general biological effects methods that are likely to respond to the contaminants. ICES also recommends the continued work on and trial application of emerging methods such as passive sampling. The JAMP guidelines provide more detailed background on the biological effects and chemical analysis methods referred to here and the necessary cofactors that should be recorded for these techniques.

Background

(i) Survey design

Draft Technical Annexes on survey design and sampling and analysis have been developed and will be finalized and released by ICES in autumn 2008. These technical annexes contain relevant information for the collection of samples on a regional basis, considerations on time and place, statistical matters, sample sizes, as well as sampling position.

(ii) Biological effects methods

ICES notes that the integrated packages of chemical and biological effects methods appropriate for monitoring specific groups of (emerging) substances in the marine environment are only partly available and often provide incomplete coverage for fish and invertebrates. This caveat underpins the recommendations for an “overall” integrated monitoring package with high effect level stress indicators that include different ecosystem components. At the same time, there is an urgent need to further the development of new specific and general methods for emerging substances and complex mixtures. Of special interest is the measurement of highly relevant ecological effects and syndromes such as immuno-competence and endocrine disruption and the need to introduce new technologies such as arrays. These new methods should be validated and standardized and marine environmental monitoring programmes augmented accordingly.

Some general points concerning integrated monitoring are noted:

- In some cases the list of contaminants that should be reported under the CEMP (and pre-CEMP) may be insufficient for an integrated approach. In order to aid interpretation of biological effects measurements, an integrated assessment may require data on related contaminants which would elicit a response on the biological effects components of the methods packages. Determinants additional to those required under the CEMP have therefore been added to the packages below.
• It is felt that a fully ‘integrated’ approach to monitoring should include passive sampling of contaminants as part of the package of methods. This will provide information on availability of contaminants in sediments and allows for time-integrated sampling of contaminants in waters.

• The biological effects techniques applied to these packages of methods are listed either in the ICES recommended techniques list (ICES, 2007) or form part of the fish and shellfish methods packages proposed in the draft JAMP guidelines for integrated monitoring and assessment of contaminants and their effects (ASMO, 2007b). The biological effects methods included here are separated into those appropriate for monitoring selected fish species, shellfish (mussels), and bioassays (sediment, water and in vitro tests).

• It should be noted that the biological effects methods listed here are those which may form part of an overall integrated monitoring package and are likely to be affected by the OSPAR priority contaminants in question. Many of the effects measurements listed are ‘general’ biological effects which are indicative of stress or health status of marine organisms or general toxicity in the sediments and water column. These may be affected by a wide range of contaminants and are not specific to the contaminants in question. Therefore, for each group of substances the most specific and relevant biological effects techniques have also been highlighted.

• These packages of methods should be considered supplemental to the existing JAMP guidelines for contaminant-specific (OSPAR – 2003-10) and general (1997-7) biological effects monitoring and the JAMP Guidelines on contaminants in biota (OSPAR 1999-2) and sediment (OSPAR 2002-16). The JAMP guidelines provide more detailed background on the biological effects and chemical analysis methods referred to here and the necessary cofactors that should be recorded for these techniques. The packages of methods presented here combine contaminant-specific effects with the general biological effects methods that are likely to respond to the contaminants. They also deal with groups of contaminants not addressed by the contaminant-specific guidelines and propose further integration of techniques such as passive sampling and invertebrate methods for metals.

The priority chemical determinants from the OSPAR CEMP and pre-CEMP are as follows (taken from ASMO, 2007a). The Appendices referred to are CEMP appendices:

The following components of the CEMP are to be measured on a mandatory basis:

• the heavy metals cadmium, mercury, and lead in biota and sediment (Appendix 2);
• the PCB congeners CB 28, CB 52, CB 101, CB 118, CB 138, CB 153, and CB 180 in biota and sediment (Appendix 3);
• the PAHs anthracene, benzo[a]anthracene, benzo[ghi]perylene, benzo[a]pyrene, chrysene, fluoranthene, ideno[1,2,3-cd]pyrene, pyrene, and phenanthrene in biota and sediment (Appendix 4);
• TBT in sediment (biota voluntary / pre-CEMP) (Appendix 5).

The following components are currently part of the pre-CEMP and are to be measured on a voluntary basis:

• the brominated flame retardants HBCD and PBDEs 28, 47, 66, 85, 99, 100, 153, 154, and 183 in biota and sediment, and BDE 209 in sediment (Appendix 8);
• the planar PCB congeners CB 77, 126, and 169 in biota. Monitoring of those congeners in sediment should be undertaken only if levels of marker PCBs are e.g. 100 times higher than the Background Assessment Concentration (Appendix 9);
• the alkylated PAHs C1-, C2-, and C3-naphthalenes, C1-, C2- and C3-phenanthrenes, and C1-, C2- and C3-dibenzothiophenes and the parent compound dibenzothiophene in biota and sediment (Appendix 10);
• PFOS in sediment, biota, and water (Appendix 12);
• Polychlorinated dibenzodioxins and furans in biota and sediment (Appendix 13).

In the attached annexes methods for integrated monitoring are recommended for:

(i) Metals (Annex 1);
(ii) PCBs, polychlorinated dibenzodioxins and furans (Annex 2);
(iii) PAH and alkylated PAH (Annex 3);
(iv) Organotins (Annex 4);
(v) Estrogenic substances (Annex 5);
(vi) Brominated flame retardants (Annex 6); and
(vii) PFOS (Annex 7).
Sources of information


References

ASMO. 2007b Draft JAMP guidelines for integrated monitoring and assessment of contaminants and their effects. ASMO 07/6/8-E.
Annex 1. Methods package for metals

Although cadmium, mercury and lead are the only mandatory metal determinants under the CEMP, other metal species are needed to interpret the biological effects data as part of an integrated package. Additional metal species needed include copper and zinc. Metals analysis should be performed on sediments and biota collected from the same times and locations where possible. Cofactors for sediment analysis are also required including aluminium and lithium. DGTs present the opportunity to undertake passive sampling for metal species to allow temporally integrated sampling of water and measure availability of metals in sediments.

Metal-‘specific’ biological effects measurements include metallothionein, ALA-D and oxidative stress, although both metallothionein and oxidative stress responses are known to be affected by other contaminants. ALA-D is lead-specific and can be measured in fish blood, although it has limited use / expertise across the ICES / OSPAR community and it is recommended that it is applied only in areas where lead contamination is perceived to be a problem or where chemical monitoring indicates that concentrations are e.g. significantly above background.

ALA-D is relevant for fish only, metallothionein can be applied to fish liver and mussel digestive glands although best results are obtained from mussels. There are a number of oxidative stress measurements that can be made in both fish and mussels which could add value to an integrated package of metals methods, but due to the lack of standardised methods, QA and assessment criteria it is suggested that this method is not an essential part of the metals package.

A number of ‘general’ biological effects measurements in fish and shellfish will be affected by environmental metal contamination and these are shown in diagram Figure A1.1 below. In vivo bioassays are also relevant measurements for the effects of metals.

Metallothionein in mussels and ALA-D in fish are considered the most specific/relevant biological effects methods for metals.

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**Figure A1.1** Package of chemical and biological effects methods relevant to monitoring for metals. The most specific / relevant biological effects methods are underlined.
Annex 2. Methods package for PCBs, polychlorinated dibenzodioxins and furans

Due to the similarity of their toxicological effects, a single methods package was proposed for both PCBs, polychlorinated dibenzodioxins and furans. In addition to the OSPAR CEMP required determinants, additional CBs may cause biological effects and their analysis should be included in an integrated monitoring approach. These include co-planar CBs CB105 and CB 156. A variety of passive sampling devices (e.g. silicone rubber) offer the potential for temporally integrated sampling of these compounds from water and investigation of their availability in sediments and these should be employed where possible.

There are no truly specific biological effects measurements available for PCBs, polychlorinated dibenzodioxins and furans. The most relevant are considered to be induction of CYP1A / EROD activity in fish liver and application of the dioxin receptor based in vitro test, DR-CALUX.

Several other general biological effects measurements in fish and shellfish may respond to exposure to these compounds and are given below in Figure A2.1. DR-Calux is considered the most useful in vitro bioassay technique although chronic in vivo bioassays may also be relevant.

![Figure A2.1](image-url) Package of chemical and biological effects methods relevant to monitoring for PCBs polychlorinated dibenzodioxins and furans. The most specific / relevant biological effects methods are underlined.
Annex 3. Methods package for PAH and alkylated PAH

Due to similar toxicological effects, a single package of methods is proposed for PAH and alkylated PAH. The package of methods is similar to Figure A2.1 above although chemical determinants should be analysed in sediment and shellfish for biota only. Due to rapid metabolism in finfish, PAH should be analysed as metabolites in bile rather than parent compounds in liver or flesh. As above, passive sampling should also be applied where possible.

Additional specific biological effects are applicable for PAH / alkylated PAH. These include PAH metabolites in fish bile and DNA adducts in fish liver. The most relevant / specific biological effects techniques are highlighted as induction of hepatic CYP1A / EROD, DNA adducts and the DR-CALUX in vitro bioassay.

General biological effects measurements will also respond to exposure to these compounds and are given in Figure A3.1 below.

![Diagram of methods package for PAH and alkylated PAH]


- **Biological effects techniques**
  - **Fish**: ‘Specific’ – PAH bile metabolites, DNA adducts, macroscopic liver neoplasms, General – hepatic CYP1A / EROD.
    - Comet assay Liver histopathology, external fish diseases, reproductive success, lysosomal stability
  - **Shellfish (mussel)**: Specific – No specific biological effects measurements available.
    - General - These measurements can be affected by PAHs – Lysosomal stability, Comet assay, MXR, GST, histopathology, Scope for Growth.
  - **Bioassays**: Toxicity identification evaluation (TIE) using SPE. Some chronic in vivo and in vitro tests relevant such as DR-CALUX.

*Figure A3.1* Package of chemical and biological effects methods relevant to monitoring for PAH and alkylated PAH. The most specific / relevant biological effects methods are underlined.

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1 It has been proposed that PAH bile metabolites be considered a chemical technique and the quality assurance will be conducted by QUASIMEME
Annex 4. Methods package for organotins

It was felt that the package of methods appropriate for organotin monitoring was already very well described by the JAMP guidelines on organotin-specific monitoring and included a suite of parameters relevant to imposex / intersex in gastropods, TBT, DBT, MBT, TPhT, DPhT, MPhT in sediments (for offshore monitoring) and in biota where appropriate (voluntary). It was noted that passive sampling for organotins may become an option for integrated monitoring of organotins in the future.

Figure A4.1 Package of chemical and biological effects methods relevant to monitoring for organotins. The most specific / relevant biological effects methods are highlighted.
Annex 5. Methods package for estrogenic substances

Estrogenic substances are a group of chemicals with the same mode of action but which are not chemically similar. A package of techniques is available for fish as well as in vitro tests such as YES and ER-CALUX. It is evident that there are no specific methods available for estrogenic substances in mussels.

![Diagram of chemical and biological effects methods relevant to monitoring for estrogenic substances](image)

Figure A5.1 Package of chemical and biological effects methods relevant to monitoring for estrogenic substances.¹ The most specific/relevant biological effects methods are highlighted.

¹ Note that liver histopathology and external fish diseases should be included under “biological Effects Measurements – Fish” as a general method.
Annex 6. Methods package for BFRs

It was noted that there are currently very few biological effects methods available and tested in a monitoring context for measuring the effects of these compounds. The determinants required for CEMP are HBCD and PBDEs 28, 47, 66, 85, 99, 100, 153, 154, and 183 in biota and sediment, and BDE 209 in sediment. Passive sampling is also relevant.

There are no specific biological effects techniques available. Thyroid hormone receptor assays in fish blood are relevant but have not been well field tested, nor is this an ICES recommended technique. Recent studies on the toxicological properties of these compounds in fish suggest that there are limited overt effects that can be detected by existing techniques.

Annex 7. Methods package for PFOS

PFOS analysis in sediment, biota, and water is included in the list of pre-CEMP determinants; however, no specific biological effects techniques are recommended here. It was noted that the compound may have endocrine disrupting effects and that some ED-relevant endpoints may be appropriate along with general biological effect measurements such as reproductive success. A battery of short-term low volume bioassays (in vitro and in vivo) using extracts can be used to perform a first screening/assessment of unintended impacts and novel contaminants. These extracts can be derived from water, sediment, biota and/or passive samplers. Information obtained from bio-analysis can also be used as input for the design of future monitoring programmes and the development of appropriate higher-level biological effects techniques biomarkers. However, a package of methods relevant to PFOS would require further consideration.
1.5.5.8 Quality assurance of biological measurements

Request

Quality Assurance of Biological Measurements (OSPAR memorandum item 10-2008)

- to review and update the JAMP guidelines for benthos, phytoplankton and chlorophyll according to good current practice and/or international standards for acceptability of biological sampling and analytical practices required by monitoring programmes.

Summary

Based on comprehensive considerations of the JAMP Eutrophication Monitoring Guidelines on Benthos ICES has updated both the document text and the reference list. This document provides general information and references, from sampling strategy to the reporting of the resulting data. Detailed information is provided in 2 technical annexes, one for the hard-bottom macrophytobenthos, soft-bottom macrophytobenthos, and hard-bottom macrozoobenthos, and the other for soft-bottom macrozoobenthos.

Advice on the remaining part of the request regarding phytoplankton and chlorophyll is expected to be finalized in 2009. A new Epifaunal Guidelines document is in preparation and will be published in the ICES TIMES series.

ICES response

The updated JAMP Guidelines on Benthos are attached in the Annex.

Source of information

ANNEX:

JAMP Eutrophication Monitoring Guidelines: Benthos

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2. Purposes ...................................................................... 107
3. Quantitative objectives .................................................. 4
4. Sampling strategy .......................................................... 5
5. Sampling equipment ....................................................... 5
6. Storage and pre-treatment of samples ............................... 5
7. Analytical procedures .................................................... 5
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Technical Annex 1: Hard-bottom macrophytobenthos, soft-bottom macrophytobenthos, and hard-bottom macrozoobenthos

Sampling strategy .......................................................... 8
Sampling equipment .......................................................... 8
Storage and pre-treatment of samples ................................ 10
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Technical Annex 2: Soft-bottom macrozoobenthos

Sampling strategy .......................................................... 12
Sampling equipment .......................................................... 12
Storage and pre-treatment of samples ................................ 13
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JAMP Eutrophication Monitoring Guidelines: Benthos

1 Introduction

Benthic communities (including hard-bottom and soft-bottom macrophytobenthos and hard-bottom and soft-bottom macrozoobenthos) generally occur in recognisable states, depending on the substrate, depth, wave exposure, and salinity, etc. Macrobenthic communities are an appropriate target for monitoring since:

a) an important component of benthic communities is long-lived species which therefore integrate environmental change over long periods of time;
b) they are relatively easy to sample quantitatively;
c) they are well-studied scientifically, compared with other sediment-dwelling components (e.g. meiofauna and microfauna) and taxonomic keys are available for most groups;
d) community structure responds in a predictable manner to a number of anthropogenic influences (thus, the results of change can be interpreted with a degree of confidence);
e) there may be direct links with commercially valued resources, e.g. fish (via feeding) and edible molluscs; and
f) the floral part integrates long-term change of water quality (turbidity).

Nutrient enrichment/eutrophication may increase the food supply to the benthos and may therefore give rise to changes in species composition and numbers, increased biomass, a shift from K-selected to r-selected species, shifts in functional groups, changes in community structure, and an impoverishment of benthic communities due to anoxia. These guidelines are intended to support the minimum monitoring requirements of the Nutrient Monitoring Programme1.

Much information exists on methodology for benthos investigations. The most relevant reports are those by Rumohr (2008), which deals largely with methodology for the collection and treatment of the soft-bottom macrofauna, and by Rees et al. (1991) and Rees (in prep.) which focus on the monitoring of benthic communities around point-source discharges and epibenthic studies, respectively. These accounts also deal more generally with the role of benthos studies in investigations of human impact, including guidance on the sampling of different substrate types. The HELCOM ‘COMBINE’ manual for monitoring in the Baltic Sea is another important reference source (see www.helcom.fi).

A range of other documents are of value in the planning and conduct of marine benthos sampling programmes. The most useful is that by Eleftheriou and McIntyre (2005) which is a standard reference for work of this type. Gray et al. (1992) report on approaches to marine pollution assessment and provide practical examples of applying the PRIMER (‘Plymouth Routines in Multivariate Ecological Research’) package for univariate, graphical, and multivariate data analyses (see Clarke and Gorley, 2001 for further details). Kramer et al. (1994) have produced a manual for the sampling of tidal estuaries. An account of survey methods employed by a team of scientists undertaking a review of marine nature conservation in UK inshore waters together with a rationale for such work is given by Hiscock (1996), Davies et al. (2001), and Connor et al. (2004). A monitoring programme and monitoring guidelines have been prepared for the Wadden Sea ‘Trilateral Monitoring and Assessment Programme’ (TMAP, 2000).

2 Purposes

The monitoring of benthic communities is carried out for, inter alia, the following purposes:

a) to monitor the spatial variability in species composition and biomass within the Maritime Area resulting from anthropogenic nutrient inputs;
b) to monitor temporal trends in species composition and biomass within the Maritime Area (at a timescale of years) in order to assess whether changes can be related to temporal trends in nutrient inputs;
c) to support the development and implementation of a common procedure for the identification of the status of the benthic communities; and
d) to understand the relationship between nutrient concentrations and temporal trends in species/community characteristics.

1 The Nutrient Monitoring Programme as adopted by OSPAR 1995 (OSPAR 95/15/1, Annex 12).
3 Quantitative objectives

The patchy distribution of benthic communities together with the many taxa involved means monitoring programmes are very dependent on the design of the field programme. It is very difficult to formulate a general monitoring model suited to a wide variety of organisms, particularly for epilithic habitats. Furthermore, great care must be taken when transferring techniques developed in less complex systems (e.g. the Baltic Sea) to more complex systems (e.g. the North Sea). Taking into account these precautionary notes, the three primary objectives of benthic monitoring are as follows:

a) to test the hypothesis that eutrophication is responsible for changes in community composition and function, biomass, and community structure;

b) to test the hypothesis that eutrophication is responsible for an increase in the abundance of ephemeral/annual algae such as Cladophora, Enteromorpha, and Ectocarpus and a decrease in perennial algae such as Laminaria and Fucus and the angiosperm Zostera marina (eelgrass); and

c) to test the hypothesis that changes in eutrophication levels are responsible for a decreased depth distribution of the macrophytes (e.g. due to increased turbidity).

Prior to monitoring, it is necessary to determine the number of sample replicates required to describe the species spectrum. This may be done using a species area curve or a comparable advanced technique; alternate methods can be used when fixed frames or transects are utilized. Before sampling begins, levels of acceptable variability must be set and followed for all parameters measured. The effects of organic matter inputs on benthic communities are adequately described by the empirical "enrichment" model of Pearson and Rosenberg (1978) and examples of studies which have postulated links between changes in the benthos and eutrophication are given by ICES (1995). The model, which is equally applicable to trends in space and time, describes cyclical (i.e. non-linear) changes in numbers, densities, and biomass of benthic species along an enrichment gradient. Multivariate analytical methods may be used to examine between-station differences and temporal trends in the data. Univariate measures amenable to statistical testing include:

- a count of species (coverage of plants and colonial animals included);
- a coverage of plant species and colonial forms;
- measurement of densities and biomass;
- quantification of species in terms of functional groups, e.g. feeding types; and
- categorization into r-selected and K-selected species.

The natural patchiness of benthic communities must be accounted for in the analysis. Hierarchical statistical methods may be used. Sophisticated computer packages for the statistical analyses of benthic data are now widely available. Use should be made of at least one established diversity index and one multivariate analytical technique. A consideration of trends in the "primary" variables (i.e. numbers of individuals, taxa, and biomass) should also be undertaken in relation to physical/chemical measures derived from sediment sub-samples. The statistics for these evaluations may be undertaken using appropriate software packages.

4 Sampling strategy

Sample sites should be representative of the whole monitoring area and thus characteristic habitat structures and substrates must be sampled. Prior to temporal trend analysis, checks must be made to ensure that sample sites are inhabited by a homogenous benthic community rather than non-comparable, heterogeneous benthic communities. It is important to establish the baseline community structure and variability at the site under consideration. Sample points must be spread out over the extent of the habitat studied to ensure an adequate consideration of spatial variation. It cannot be assumed that one point is representative of the habitat as a whole. Contrary, the presence of spatial autocorrelation can violate the basic assumptions in standard statistical analyses (Legendre et al., 2002). When measuring anthropogenically induced change, control/reference sites (preferably at least two) are required for each test site. It is critical that similar habitats are selected for comparison. There are several sources of guidance on the design and implementation of field sampling programmes, including Elliot (1971), Cohen (1977), Green (1979), Andrew and Mapstone (1987), Skalski and Robson (1992), Rees et al. (1991 and in prep.), Underwood (1997), and Underwood and Chapman (2005). A eutrophication-related monitoring programme would typically include a desk study and survey planning stage, followed by pilot, baseline and ongoing surveys.

The sampling strategy for macrophytobenthos and hard-bottom macrozoobenthos is described in Technical Annex 1. The sampling strategy for soft-bottom macrozoobenthos is described in Technical Annex 2.
5 Sampling equipment

The sampling equipment for macrophytobenthos and hard-bottom macrozoobenthos is described in Technical Annex 1. The sampling equipment for soft-bottom macrozoobenthos is described in Technical Annex 2.

6 Storage and pre-treatment of samples

The storage and pre-treatment of macrophytobenthos and hard-bottom macrozoobenthos samples is described in Technical Annex 1. The storage and pre-treatment of soft-bottom macrozoobenthos samples is described in Technical Annex 2.

7 Analytical procedures

Analytical procedures for macrophytobenthos and hard-bottom macrozoobenthos are described in Technical Annex 1. Analytical procedures for soft-bottom macrozoobenthos are described in Technical Annex 2.

The data generated will require storage in a database. The database should be of a type capable of storing and/or generating information of the following type:

a) the spatial distribution and size of epilithic communities, particularly concerning mats of green macroalgae, eelgrass meadows, and mussel beds;
b) sketch illustrations showing the distribution of substrate types and the dominant species associated with the substrates;
c) the depth distribution of plant and animal biomass by species, functional group, and any other arbitrary selection, as well as the relative quantities of the primary functional groups such as dominant, annual, and perennial organisms;
d) temporal trends concerning changes in depth distribution, percentage cover, biomass, species composition, and distribution, etc.;
e) a statistical evaluation including explanatory power; and
f) correlations of specific types of benthos data against supporting information (e.g. Secchi depth, salinity, oxygen, nutrients, pelagic primary production, and other types of benthos data).

As a measure of grain size distribution for the upper 5 cm of the sediment the following sieves should be used: 63 μm, 125 μm, 250 μm, 500 μm, 1000 μm, and 2000 μm together with weight loss on ignition (500°C–520°C), total organic carbon, and pigments (recommended). Other more advanced methods such as laser diffraction, sedimentation columns, etc. may also be used. To measure nutrients (particulate N) in sediments samples should be dried at 60°C until constant weight (12–24h), treated with HCl, held for 24h in a desiccator, dried again at 60°C, and analysed in a CHN analyser.

8 Analytical quality assurance

Effectively the quality assurance (QA) programme should ensure that the data are fit for the purpose for which they have been collected (see Rees, 2004). Appropriate QA schemes should be established before the onset of survey work. It is particularly important that adequate resources are allocated for these purposes when co-operative studies involving several institutes are to be conducted, or when the data are to be centrally archived. It is essential that the QA also includes the explanatory power and the experimental design. Thus, the QA must take into account as many steps of the analytical chain as possible in order to determine the contribution of each step to the total variation. Quality assurance methods are still under development for some activities, e.g. biomass determinations. If the abundance estimates are to be carried out by different workers, a calibration of their cover estimates must be performed. This can be done by comparing in situ survey data with digital and point sampling estimates of underwater photo documentation. Underwater photography and/or video may provide an additional means of obtaining cover estimates, but these techniques are more appropriate where foliose phytobenthos does not obscure underlayers. Animals that can be counted often provide a better basis for estimates of cover than subjective assessments or point sampling. The latest taxonomic literature should be used. Name changes and literature used must be recorded. Quality assurance for soft-bottom macrozoobenthos should take account of Rees (2004) and Rumohr (2008) (see also ICES, 1994, 1996). Each Contracting Party which intends to deliver data to a common data pool should take part in regular intercalibration exercises and associated taxonomic workshops.
Reporting requirements

Reporting formats need to be developed which will allow the exchange and evaluation both of the raw data and of all relevant ancillary information. Such formats must be readily usable by both the data centres and the originators of the data. Data for the common pool will have to be submitted via the national data centres in order for them to keep in touch with progress of the work, including the availability of data from each Contracting Party. This procedure should help to guarantee data quality, since the national data centres will be ultimately responsible for the timely submission of completed data sets to the common pool. On request from OSPAR, ICES has established a database for phytobenthos and zoobenthos. Data can be submitted in format 3.2 or in any well-described free format.

References


Technical Annex 1

Hard-bottom macrophytobenthos, soft-bottom macrophytobenthos, and hard-bottom macrozoobenthos

Sampling strategy

An overview of the methods available for monitoring has been given by ICES (1996), Hiscock (1996), Davies et al. (2001), Eleftheriou and McIntyre (2005), and Rees (in prep.). Diver-operated methods in shallow water and remote underwater photography in deeper areas are the most suitable options.

Monitoring should take place annually at a particular time within the four summer months (June–September) for the first three years of the monitoring programme. Subsequent sampling frequency then depends on the expected rate of change in species composition. In areas where large changes are expected sampling should take place on an annual basis. In areas where little change is expected sampling every 5 to 10 years would be sufficient. Three main sampling techniques are available for hard-bottom and soft-bottom macrophytobenthos and for hard-bottom macrozoobenthos: aerial surveillance (in tidal areas), diving transects (in sub-tidal areas), and quantitative sampling.

Aerial surveillance

Aerial surveillance can be used as an optional method to determine the size and distribution of epilithic communities, including mats of green macroalgae, eelgrass meadows, and mussel beds. High-wing monoplanes flying at low altitude (150 m) are an appropriate platform for the relevant sensors. Positions should be located by means of satellite navigation (i.e. GPS). Aerial surveillance can cover large areas and results should always be calibrated by means of quantitative field inspections at selected locations (cf. section entitled “Quantitative sampling”). When applied, aerial surveillance of green algae should take place during May–October at four-week intervals during low tide. One flight should be carried out at the end of the winter for mapping the distribution of mussel beds.

Diving transects

Diving transects are used to provide a description of the depth distribution and abundance of the dominant plant and animal communities. The transects should extend to at least the maximum depth of the algae, but should not be deeper than 30 meters (for diver safety). Depth limits of kelp, dense foliose algae, or the deeper foliose algae may be measured using digital instruments, recorded and corrected for tidal amplitude. Abundance and/or coverage should be determined at sites within the main assemblages or within sub-habitats, if these are distinct. The coverage (Braun-Blanquet) should be used for plants and animals in colonies or high abundance. Reconnaissance surveys, which may include remote sensing (see section under heading “Sampling equipment”) are also useful in helping to choose transect locations. Transects should be undertaken at the beginning of the monitoring programme and should be repeated regularly, for example every 5 to 10 years. As estimates of distribution and percentage cover are carried out in situ, a cord with meter marks should be placed along the transect. Progressing along this cord, divers should note the distribution and type of substrate as well as the degree of cover for the main plant and animal species in a strip 5-10 m wide. Divers should estimate abundance using an appropriate scale (Hiscock, 1990; Kautsky, in prep.; Krause-Jensen et al., 1994; Karlsson, 1995; Pedersen et al., 1995; and Kautsky, 1993). This may be time-consuming under water, but gives a good estimate over the whole depth zone, which is much harder to achieve using frames. An alternative approach would be to apply the abundance estimation scale at fixed sites within the main zonal biotopes. Species/categories that are not immediately obvious may warrant the use of more time-consuming techniques such as quadrat counts (see section under heading “Quantitative sampling”).

The following information should be recorded in the field:

a ) the exact position of the transect (using for example a map, photography, a permanent mark on the shore, GPS);

b ) date and time (including time zone) of observations;

c ) the distance from the shore (using a meter-marked line along the transect);

d ) the depth (according to a calibrated depth gauge and corrected for tidal amplitude);

e ) substrate type (rock, boulders, stones, gravel, sand, mud, glacial clay, etc.);

f ) the presence of loose sediment deposited on plants and substrate (in terms of “none”, “little-covered”, “heavily-covered”);

g ) an estimate of the abundance of different plant and animal species;

h ) the maximum depth of dominant sub-littoral species and the lower limit of vegetation;
i) photographic and/or video documentation (video/photographic profiles of the transect, panoramic views and, at fixed marked sites if possible, stereo photographs); and

j) the degree of wave exposure, Secchi disk depth (i.e. light transmission), and salinity (if possible).

Biological material could also be collected as reference specimens for herbaria, etc. and for algal toxins (in conjunction with other monitoring programmes).

**Quantitative sampling**

Depending on the time spent on the transect, direct observations by divers may overemphasize the importance of particular eye-catching species. Quantitative sampling gives unbiased information about plant and animal communities but is extremely time-consuming. Quantitative samples, obtained via stratified random sampling, are required in order to determine species composition and biomass. At least three parallel quantitative samples of key species/communities should be collected at different pre-selected depth intervals. Sample locations at each depth are chosen by random placement of a quadrat, or by sampling at random distances along the transect from the shore. Tests should establish the number of parallel samples and the minimum sample area, and this will vary according to the type of community/species being sampled and its distributional characteristics (cf. Elliott, 1983). For example, small but randomly distributed species may require large quadrats, whereas it may be possible to use relatively small quadrats for small but evenly distributed species. Rocky habitats are usually architecturally very complex and care is needed to specify slope, aspect, and exposure. These methods follow recommendations by Anon. (1991), Dybern *et al.*, (1976), Hiscock (1987), Hiscock and Mitchell (1989), Jespersen *et al.* (1991), Kautsky (1993), and Davies *et al.* (2001).

The following data should be recorded in the field whenever possible:

a) the exact distance of the sample site from the shore;

b) date and time (including time zone) of observations;

c) water depth (according to a calibrated depth gauge and corrected for tidal amplitude);

d) a photographic image of the site;

e) the number of organisms of each species;

f) the biomass of plant species and animal species; and

g) the size structure of some animals (mainly molluscs).

Biological material could also be collected as reference specimens for herbaria, etc. and for algal toxins (in conjunction with other monitoring programmes).

**Sampling equipment**

Submarine video in combination with GPS is useful for choosing transects and for surveying large areas for approximate species composition and the depth distribution of the vegetation as a whole. Larger areas may be scanned using remote-sensing techniques (e.g. by satellite or aircraft), but only for communities close to the surface. For aerial surveillance in intertidal areas, manual mapping is sufficient. Here vertical images and video films are generally not cost-effective techniques.

Surveys estimating abundance should sample within a large area containing the same biotope in order to reduce edge-effects or effects resulting from irregular species distribution. Quadrangular frames with a side length of 0.10 m to 0.50 m are suggested for quantitative sampling (the smaller frames should be used in the littoral zone for small species such as barnacles).

**Storage and pre-treatment of samples**

Sampled material should be preserved by freezing (−20°C) or by using formaldehyde (2–4%). It should be emphasized that thawing may cause leakage and thus underestimate biomass, and that species may react differently depending on their morphology. The same also applies for preservation with formaldehyde. Fixation using formaldehyde should be avoided for samples which will be analysed for nutrients. Samples for biomass determination must be free of overgrowth and rinsed with freshwater before drying. Sampled animal material should be stored in alcohol (70%) after biomass (wet weight) determination.
Analytical procedures

Macrozoobenthos measurements should comprise individual length, width, volume, etc. Macrophytobenthos determinations should normally be accompanied by the co-monitoring of relevant macrozoobenthos and vice versa.

Samples obtained using quadrangular frames (see section under heading “Quantitative sampling”) may be analysed to determine plant and animal species composition and biomass. In areas where species numbers are low the biomass may be expressed per species. Biomass should be expressed as either “g dry weight” (samples should be dried at 60°C until constant weight (this can be up to one week depending on volume of sample)) or as “g ash-free weight per m²” (samples should be dried at 500°C until constant weight (at least 6h)). Biomass expressed as volume (e.g. using water displacement) should be measured in the field whenever possible.

The degree of accuracy required for taxonomic sorting depends on the purpose of the monitoring programme. For the present programme it should be sufficient to identify organisms, whose taxonomic specification is difficult or time-consuming, to the generic level rather than to the specific level. (e.g. Cladophora spp., Enteromorpha spp.). Rare species should be determined to higher taxonomic levels. Functional groups should be kept intact as far as possible.

References


Technical Annex 2

Soft-bottom macrozoobenthos

Sampling strategy

An initial spatially extensive “baseline” survey will facilitate the selection of representative stations within and adjacent to areas perceived to be vulnerable to the effects of eutrophication. It will be necessary to repeat the baseline survey periodically to check the continued validity of representative stations and to ensure that no unexpected effects are occurring beyond the region predicted to have been affected by eutrophication. Full use should be made of historical information in the planning of surveys.

Large-scale sampling of the macrozoobenthos community in offshore subtidal soft-bottoms should comprise many stations but with few replicates per station. A large-scale sampling grid covering the whole area of investigation should be sampled at intervals of 10 years and this should be sampled by a variety of methods in order to cover the full range of the species spectrum. This large-scale sampling every 10 years is necessary to confirm the representativity of annual temporal trend monitoring stations. For temporal trend monitoring, sampling at a frequency of once per year (at the same time of year) should be adequate, although locally severe effects of nutrient enrichment (such as hypoxia) may dictate a higher sampling frequency. If the sampling frequency is twice per year, then sampling should take place in late winter/early spring to establish the stable community conditions and in late summer/autumn with a view to detecting the possible effects of nutrient enrichment (such as hypoxia) on the macrozoobenthos.

The sampling strategy for macrozoobenthos communities in coastal soft-bottom areas needs site-specific adaptations of site selection, choice of sampler, and sampling frequency (see, e.g., Trilateral Monitoring and Assessment Program, 2000). For example: estuaries should be sampled from the limnic to the Marine Area, backwaters and lagoons should be sampled twice a year at representative stations (a large-scale sampling programme should be performed every 5 years), and fjords should be sampled along a transect ending at the outer edge of the sill.

The following information should be recorded in the field:

a) whether or not the ship was anchored;
b) date and time (including time zone) of observations;
c) depth and position of each replicate; a GPS track plot would be desirable;
d) the weather conditions during sampling and sea state;
e) a description of the sediment, including:
   i. surface colour and colour change with depth (as a possible indicator of redox state);
   ii. smell (H₂S);
   iii. a description of sediment type, including important notes such as the occurrence of concretions, loose algae;
   iv. the type and specification of the sampler;
   v. mesh size of the sieve.

Near-bottom temperature, salinity, and oxygen measurements are desirable. If more than one sample is taken at a station, the depth range of samples should be recorded. All samples must be treated separately, i.e. they must not be pooled. An estimate of the volume of sediment retained should be made for all samples taken, as a measure of sampler efficiency. Criteria for rejection of samples collected by grabs are given by Rees et al. (1991), ICES (1994), and Rumohr (2008). Measurements of redox potential and shear-strength should be made on samples collected by a box corer rather than a grab sampler because grab samplers are likely to distort the sample.

Sampling equipment

Sampling equipment appropriate for soft-bottom macrozoobenthos is described in detail by Rumohr (2008) and Eleftheriou and McIntyre (2005). Coarse sediments which cannot be sampled using normal procedures may be sampled using either a Hamon grab or appropriate dredges (e.g. an anchor dredge). Sediment structure and bioturbation depth may be checked with sediment profile imagery (see below). A hand-operated corer should be used for Wadden Sea sediments (TMAP, 2000). It should be noted that more sophisticated gear, such as epibenthic sledges, might be required for sampling hyperbenthic or bentho-pelagic species. Such gear is particularly valuable for studies of species (especially crustaceans) which constitute an important component of the diet of fish. Epibenthic and hyperbenthic sledges (Rothlisberg and Peary, 1977, dredge; see also Brattegård and Fosså, 1991; Sorbe sledge (Sorbe, 1983)) are useful for the small mobile crustaceans and boundary fauna. If automatic closing mechanisms and dredge distance recorders are added, then these instruments can be quantitative (cf. Gage deep-sea epibenthic sledge). Special attention is drawn to...
the Triple-D dredge which was designed for the quantitative collection of the large and rare epifauna and infauna (Bergman and van Santbrink, 1994). See also Rees (in prep.) for guidance on epibenthic sampling.

Photographic and video records are recommended as a complement to traditional sampling methods (Rumohr, 1995). Sediment profile imaging (cf. Rhoads and Germano, 1982) may provide a useful means for rapid surveys and classification of soft sediment areas. Side-scan sonar images will provide information on bottom topography and substrate type, which can be useful in the planning of benthos monitoring programmes or in the interpretation of the data. These records should be ‘ground-truthed’ by underwater video recording and/or grab sampling of sediments.

Storage and pre-treatment of samples

Procedures for the storage and pre-treatment of soft-bottom macrozoobenthos samples are found in Sections 3.1-3.2 of Rumohr (2008).

Analytical procedures

Procedures for the sorting and biomass determination of soft-bottom macrozoobenthos samples are found in Sections 3.4 and 3.5 of Rumohr (2008).

References


1.5.5.9 Environmental impact of marine fisheries, background document for the 2010 OSPAR Quality Status Report

This text follows the previous Quality Status Reports (QSRs) (OSPAR Commission, 2000) and presents information by OSPAR Region.

The focus of this report is on changes which have occurred over the last 10 years (1998 to present) that is, since the production of the QSR 2000. During this period there have been a number of initiatives to reduce the environmental impact of fisheries through gear modification; we include case studies of some of these in our text. In most cases the case study covers fisheries in more than one OSPAR region; we have distributed these examples across the regions so that there is at least one case study embedded in the section for each of Regions II–V.

OSPAR requested ICES to prepare an initial scoping report on the content and methods for developing an assessment of the environmental impact of marine fisheries by 2008, as a contribution to the OSPAR QSR 2010. However, the information available was very patchy and as a result the regional reports do not address each of the categories with the same level of detail. OSPAR publishes an overview and separate regional reports. Consequently there is some duplication in order for each of these sections to be read as individual documents.

1.5.5.9.a NE Atlantic Quality Status Report for 2010

Introduction

Previous Quality Status Reports (QSRs) have reported on the state of fish stocks and fisheries in the region. Though OSPAR does not have competency with respect to fisheries management (Annex V, Article 4) it is, however, required to raise with the competent authorities any issue of concern it may have with respect to fisheries and the ecosystem. As fisheries are probably the most extensive form of human intervention in marine ecosystems and have a long history it is appropriate to consider the past and future effects this activity has had and will have on marine ecosystem dynamics, biodiversity, and the sustainability of marine resource use. This section therefore focuses on the impacts of fisheries on various components of the marine ecosystem and examines how management initiatives are operating to limit the negative impacts while continuing to provide valuable marine food resources and a viable fishing industry.

The most important issues related to fisheries, as identified by the QSR 2000 (OSPAR Commission, 2000), were:

a) excessive fishing effort and overcapacity in the fishing fleet in some regions;
b) lack of precautionary reference points for the biomass and mortality of some commercially exploited stocks;
c) how to address the particular vulnerability of deep-sea species;
d) the risks posed to certain ecosystems and habitats, for example, seamounts, hydrothermal vents, sponge associations, and deep-water coral communities;
e) adverse environmental impacts of certain fishing gear, especially those leading to excessive catches of non-target organisms and habitat disturbance; and
f) the benefits to fisheries and/or the marine environment by the temporary or permanent closure or other protection of certain areas.

Some of these issues relate to fisheries management, while others relate to the impact of fisheries on the environment.

The development of fisheries management and policy since 1998

The need to manage fisheries to prevent over-exploitation and collapse of fish stocks has long been recognized. In more recent times it has also become clear that healthy fish stocks require a healthy supporting ecosystem and that this is at risk from a range of human actions including pollution, development of infrastructure, and the effects of the fisheries themselves. Fisheries not only kill and remove the target species but also cause mortality and injury to other species, alter habitats, and interfere with ecological processes such as nutrient and carbon cycles. With increasing public and political concerns about marine fisheries and environmental issues, fisheries science and management has become increasingly complex. The move to the ecosystem-based approach to fisheries management has gained momentum. The multiple uses of marine resources have been acknowledged to take account of ecosystem considerations and the recommendations from the numerous international agreements, conferences, and summits held on the subject. Some of the most important of these include:

• The 1982 United Nations Law of the Sea Convention (http://www.un.org/Depts/los/index.htm);
• The 1992 Convention on Biological Diversity (http://www.cbd.int/);
• The 1992 Habitats Directive (http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:HTML);
• The 1995 United Nations Fish Stocks Agreement (http://www.intfish.net/treaties/unfsa.htm);
• The 1995 Fisheries and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries (http://www.fao.org/DOCREP/005/v9878e/v9878e00.htm);
• The 2001 Reykjavik Declaration (http://www.fao.org/docrep/meeting/004/Y2211e.htm);
• The 2002 World Summit on Sustainable Development (http://www.un.org/events/wssd/);
• United Nations 2006 General Assembly to ensure protection of vulnerable marine ecosystems (http://www.un.org/depts/los/general_assembly/general_assembly_resolutions.htm); and

The fishery policy documents relevant for the OSPAR area express similar objectives. The Common Fisheries Policy (CFP) Council Regulation 2371/2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy includes:

“Precautionary approach shall be applied in taking measures designed to protect and conserve living aquatic resources, to provide for their sustainable exploitation and to minimise the impact of fishing activities on marine ecosystems. It shall aim at a progressive implementation of an ecosystem based approach to fisheries management.”

The Marine Strategy Framework Directive 9388/2/2007 establishing a Framework for Community Action in the field of Marine Environmental Policy features the statement that:

“This Directive establishes a framework within which Member States shall take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest. ”

The Maritime Policy Blue Book (COM, 2007) has:

“Fisheries management must take more into account the welfare of coastal communities, the marine environment and the interaction of fishing with other activities. The recovery of fish stocks will be energetically pursued, requiring sound scientific information and reinforcement of the shift to multi-annual planning. The Commission will take action to ensure that the Common Fisheries Policy reflects the ecosystem-based approach of the Strategy for the Marine Environment, and will work to eliminate Illegal, Unreported and Unregulated fishing in its waters and on the high seas.”

The Bergen Declaration (2002) set out that:

“…fisheries policies and management should move towards the incorporation of ecosystem considerations in a holistic, multiannual and strategic context. While the transition towards a full ecosystem approach to fisheries management should be progressive and concomitant with the enhancement of scientific knowledge…”,

“…the current state of scientific knowledge, coupled with a sound application of the precautionary principle, allows the immediate setting of certain environmental protection measures.”

“…encourage the appropriate authorities to promote those fishing activities having less impact on the ecosystem…”

Broad trends in fisheries policy since 1998 have included strengthening governance by creating more transparent scientific advice provision, a precautionary approach, and a shift towards inclusion of ecosystem elements in management. The complex process of translating international agreements into operational and sustainable regional management continues to evolve. In the 2006 State of the World Fisheries and Aquaculture Report (FAO, 2007) the FAO called for strengthening of Regional Fisheries Management Organisations (RFMOs) in order to prevent further erosion and mismanagement of fish stocks. In response to this request the Northeast Atlantic Fisheries Commission (NEAFC) was the first RFMO to initiate such a review process.

In response to an external review NEAFC has implemented the following changes:

- Adoption of conservation and management measures for all major fisheries in the NEAFC regulatory area;
- Ensuring complementary management of straddling stocks between coastal states and NEAFC;
- New Port State Control measures entered into force May 1, 2007 and limits uncertified landings of frozen fish;

*ICES Advice 2008, Book 1*
- Information sharing between NEAFC and the Northwest Atlantic Fisheries Organization (NAFO) on the IUU vessels list in the respective areas; and
- Prohibition of bottom trawling and use of static gear in a further three NEAFC areas to conserve vulnerable ecosystems.

(Source: http://www.neafc.org/news/docs/neafc_review_final_march07.pdf)

The European Union’s (EU) instrument for managing marine resources is the Common Fisheries Policy (CFP). Reforms to the CFP took place in 2002 and can be summarized broadly as:

- Implementing a long-term approach with the aim of improving ecosystem and economic outcomes;
- New fleet policy with the aim of capacity reduction;
- Streamlining and harmonizing enforcement rules across the EU; and
- Stakeholder involvement.


The Cod Recovery Plan was the first long-term management plan to be adopted by the EU in the wake of the 2002 Reform of the Common Fisheries Policy. The overall objective of the plan was to ensure the recovery of the cod stocks concerned to the precautionary stock sizes within a time frame of five to ten years. The plan has recently (April 2008) been amended in order to hasten the recovery of cod in Community waters (amending Regulation (EC) No. 423/2004 as regards the recovery of cod stocks and amending Regulation (EEC) No. 2847/93).

The EU has recently begun a review process of the Data Collection Regulations (DCR) to consolidate the existing data collection activities of member states, and to provide indicators of the integration of ecosystem considerations into fisheries management. Recent progress by the Scientific and Technical and Economic Committee (STECF, 2006) will generate proposals for indicators to be adopted as a formal part of the DCR.


International commissions such as the International Commission for the Conservation of Atlantic Tunas (ICCAT), the International Whaling Commission (IWC), and the North Atlantic Marine Mammal Commission (NAMMCO) have continued to work towards sustainable management and conservation goals through scientific investigation, monitoring, and management plans (with varying levels of success).

**Drivers on fishing activities in the OSPAR maritime area**

Fishing has great economic and social importance for most OSPAR countries, and technical developments have led to more efficient exploitation of commercial fish stocks.

The principal drivers of fisheries activities include the availability of targeted species, the market price paid for fish on landing, the cost of fuel, and the need to operate within the regulatory regime. There is evidence that in some nations (UK, Netherlands) consumers are becoming concerned about the source and ecological impact of the fisheries that supply their fish. This has contributed to some changes in the wholesale and landed prices of some fish. Changes in the distribution of seafood prices can also provide useful insights into the availability of different species to fishers and to fish markets (Pinnegar et al., 2006). A new inflation-adjusted indicator has recently been applied to prices of fish from the Celtic Sea fisheries (Pinnegar et al., 2006). It suggests that a decline in the availability of higher trophic level target species such as cod and hake as well as an increase in the availability of lower trophic level pelagic species has driven the changes in price (Figure 1.5.5.9.1.1).

Global fuel prices (Figure 1.5.5.9.1.2), and hence fuel costs for the fishing industry, have increased dramatically in recent years and this is effecting both the grounds fishers exploit (reducing the time spent travelling between fishing opportunities), but also more fundamental shifts to using fishing gears that are less energy demanding.
Figure 1.5.5.9.1.1 Pattern of change in the price of 26 species of fish captured by UK vessels in the Celtic Sea (ICES area VIIe–k) over a 30-year time-series, expressed as a ‘log-relative-price-index’ (LRPI). Prices are expressed in £ kg\(^{-1}\). The LRPI index takes account of annual inflationary price rises and provides information on changes in mean trophic level of the fish or shellfish species sold. A declining log-relative-price-index (LRPI) can indicate that either the relative price of high trophic level species has declined or low trophic level species are becoming relatively more valuable, while the reverse holds for increasing index values (from Pinnegar et al., 2006).

Figure 1.5.5.9.1.2 Global price of crude oil 1996–2008 (from http://octance.nmt.edu/gotech/Marketplace/prices.aspx).

Fisheries are constantly changing. New fisheries are developed to meet market demand. Fishing grounds move as fish stocks respond to changing environmental conditions. Technical development of gears leads to increased efficiency or allows exploitation of new areas. Fishing practices change to respond to external economic factors such as the cost of capital and fuel.

In the OSPAR region the fisheries in the last decade have continued to decline in terms of number of vessels and people employed in the catching sector but through technical advance there has been only a small decrease in total effort and exploitation has increased in deep-water areas (Salz et al., 2004).

Fishing also results in the mortality of non-target species and towed fishing gears can impact on benthic communities and cause physical disturbance of the seabed. The growing concern about impacts of fisheries on marine ecosystems has stimulated the integration of fishing gear technology research into the framework for fisheries management. Fishing
Gear technologists have tended to focus on the interaction of the gear with a single or multiple commercial fish species. With the exception of charismatic species, very little fishing gear research has focused on non-target fish species and benthic invertebrates. Most of the fishing gear research is driven by the fisheries management objectives, which is in turn mainly driven by the health of commercial fish stocks. Much of current fisheries gear research is focused on the reduction of physical habitat impacts but none of these efforts have been implemented in the actual fisheries. Gear modifications to improve selectivity of commercial fish species through a variety of sorting devices reduces the bycatch and discards rates, mainly of fish species (Valdemarsen and Suuronen, 2003; Suuronen and Sarda, 2008). A number of such initiatives have been applied in European fisheries in the past 10 years and some case studies are described in the Regional accounts below.

**Impacts of fisheries on the ecosystem**

Commercial fishing has direct and indirect effects on the marine ecosystem; these can be summarized as effects on:

1. commercial fish stocks;
2. non-target species, including birds, marine mammals and discarded fish;
3. the sea bed and associated benthic communities and habitats;
4. community structure and food webs; and
5. genetic structure (OSPAR Commission, 2000).

**Effects on commercial fish stocks**

Sparholt et al. (2007) completed a meta-analysis of stock size, recruitment, and fishing mortality over time, in order to evaluate the general status of fish stocks within the ICES Area (i.e. the Northeast Atlantic). Their analysis was based on data for 34 (7 pelagic, 27 demersal) commercial stocks and indicates that most of those pelagic stocks recovered to sustainable levels after several had collapsed in the 1960s and 1970s. In contrast, most demersal stocks have continued to decline over the past half century and are now recruitment-overfished (Sparholt et al., 2007).

Total landings in the OSPAR area have remained at approximately ten million tonnes per year since the 1980s (Figure 1.5.5.9.1.3). Demersal stock landings have shown a decrease from a peak of six million tonnes in the 1970s to currently around three million tonnes. Total pelagic stock landings peaked in the 1970s and have remained consistent at around seven million tonnes since then.

![Figure 1.5.5.9.1.3 Landings in the Northeast Atlantic (ICES Area) of demersal stocks (D), pelagic stocks (P), and other species (crustaceans, squids, tunas, and tuna-like species). Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm) which includes stocks from the Baltic Sea (Subdivisions 22–32) that are not in the OSPAR region.](image-url)

The regional breakdown of landings is given in Figures 1.5.5.9.1.4 to 1.5.5.9.1.8 by pelagic, demersal, and shellfish species. In Region I, shellfish and pelagic catches have declined while demersal catches have remained stable. In Region II, all categories of catches have declined, while in Region III they have all increased. In Region IV, shellfish and pelagic catches have increased while demersal catches have remained stable. In Region V catches of pelagic and demersal species have increased from 0.1 Mt in 1998 to over 0.6 Mt in recent years.
Region I

![Graph showing catch in million t for shellfish, pelagic, and demersal species in OSPAR Area I. Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm).]

**Figure 1.5.5.9.1.4** Total landings for shellfish, pelagic, and demersal species in OSPAR Area I. Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm).

Region II

![Graph showing catch in million t for shellfish, pelagic, and demersal species in OSPAR Area II. Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm).]

**Figure 1.5.5.9.1.5** Total landings for shellfish, pelagic, and demersal species in OSPAR Area II. Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm).
Region III

![Graph showing catch in million t for shellfish, pelagic, and demersal species in OSPAR Area III. Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm).]

Figure 1.5.5.9.1.6  Total landings for shellfish, pelagic, and demersal species in OSPAR Area III. Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm).

Region IV

![Graph showing catch in million t for shellfish, pelagic, and demersal species in OSPAR Area IV. Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm).]

Figure 1.5.5.9.1.7  Total landings for shellfish, pelagic, and demersal species in OSPAR Area IV. Data from the ICES Statlant database (http://www.ices.dk/fish/statlant.htm).
The standardized Spawning-Stock Biomass (SSB) of demersal stocks from the ICES area (Sparholt et al., 2007) shows a negative linear trend throughout the time-series, with mean values showing a decrease from a plateau in the 1970s. This is even more evident following the standardization of SSB using $B_{\text{lim}}$ (Figure 1.5.5.9.1.12). A stock with a SSB $< B_{\text{lim}}$ is suffering reduced reproductive capacity. The standardized SSB of pelagic stocks show a sharp decline in the 1970s associated with a number of stock collapses and subsequent rebuilding (Figure 1.5.5.9.1.13). This is visible in the long-term means trajectory and results in a non-significant time trend. SSB showed a steep decline (15% per annum) to a trough in the 1970s, after which there was a rapid rise (5% per annum) in SSB during the 1970s and 1980s back to levels nearing those observed in the 1950s.

The fishing mortality $F$ on a stock provides a measure of the degree of exploitation by the fishery. For some stocks a reference point $F_{\text{lim}}$ is provided by the ICES assessments, providing an indication of whether the stock is harvested unsustainably ($F > F_{\text{lim}}$) or not. For those stocks where the reference points for both SSB and fishing mortality are present it is possible to provide an indication of the status of the stock (Figure 1.5.5.9.1.9). Note, however, that if a stock is on the safe side of both limits it may still be at risk of suffering reduced reproductive capacity and/or being harvested unsustainably. This cannot be assessed if a precautionary reference point is not defined.

Figure 1.5.5.9.9 Colour codes used to describe the status of a stock based on its spawning-stock biomass and fishing mortality relative to the reference points $B_{\text{lim}}$ and $F_{\text{lim}}$. Note in particular that the “precautionary” reference points $B_{\text{pa}}$ and $F_{\text{pa}}$ are not taken into account. This means that a stock coloured green can still be at risk of suffering reduced reproductive capacity and/or at risk of being harvested unsustainably.
The development of the status of the stocks indicates that a growing proportion of the stocks are moving away from being harvested unsustainably, but at the same time a decreasing proportion of stocks have full reproduction capacity (Figure 1.5.5.9.1.10). This result has to be treated with caution, as the cases where the stock assessments have been able to provide both reference points on SSB and fishing mortality were rather few, in particular for Regions III, IV, and V (Figure 1.5.5.9.1.11). Stocks with both reference points are roughly equally divided between demersal and pelagic stocks. No benthic stocks (e.g. *Nephrops, Pandalus*) have reference points.

**Figure 1.5.5.9.1.10** Development of the status of those assessed stocks where limit reference points were provided for both fishing mortality and spawning-stock biomass from 1986–2006. The estimates from the last two data years have to be treated with caution as these are more uncertain than the rest, due to the convergence feature of fish stock assessment models. Loess smoother (span=0.75 see, e.g. [www.r-project.org](http://www.r-project.org)) has been used.
Figure 1.5.5.9.1.11 Fraction of the total landings in 2001 which are taken from stocks where 1 or 2 of the reference points \( F_{\text{lim}} \) and \( B_{\text{lim}} \) are available; per OSPAR Region I–IV. No reference points are available for Region V.

In those cases where the hard limits were not provided, “soft” criteria for determining the status of a stock can be used (ICES, 2007b) (Table 1.5.5.9.1.1). The soft criteria are mainly based on the whether SSB is below \( B_{\text{lim}} \). In cases where not even the \( B_{\text{lim}} \) is available other, in some cases subjective, criteria are invoked. With many of the stocks for which hard criteria are not available the use of soft criteria leads to these stocks being perceived as being outside safe biological limits. For all regions more than half of the stocks are perceived as being outside safe biological limits. In Region IV this goes for all assessed stocks.

Table 1.5.5.9.1.1 Total catch and number of stocks perceived to be inside or outside safe biological limits per OSPAR region. In cases where hard limits on spawning-stock biomass and fishing mortality are not available the assessment of whether a stock is inside or outside safe biological limits is based on “soft” criteria (based on data from ICES, 2007b).

<table>
<thead>
<tr>
<th>OSPAR Region</th>
<th>Total Catch In Tonnes In 2006</th>
<th>Catch Of Assessed Stocks In Tonnes In 2006</th>
<th>Number Of Assessed Stocks Outside ‘Safe’ Limits, Pr 1 Jan 2007</th>
<th>Number Of Assessed Stocks Inside ‘Safe’ Limits, Pr 1 Jan 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3774783</td>
<td>3712330</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>II</td>
<td>1817719</td>
<td>1759228</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>III</td>
<td>1225211</td>
<td>1109228</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>IV</td>
<td>599649</td>
<td>451204</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>V</td>
<td>542866</td>
<td>535199</td>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

French fishing effort of both towed and fixed gears for demersal species has increased since 1999, and indicators for 51 fish populations and the whole fish community document a steady decline attributed to overfishing (Rochet et al., 2005). Despite a decrease in the number of fishing vessels in the French fleet, fishing effort has increased and, under this continuing pressure, the impact of fishing cannot be said to have decreased over the past ten years. Although some management measures have proven efficient like the Northern hake recovery plan, in general there has been low or no improvement in the status of target species and in the impact of fishing on the community, and the anchovy fishery had to be closed in 2005. Moreover, undersized individuals and bycatch species continue to be caught and discarded in large amounts. Recent changes in fishing gears for example, in the Nephrops fishery, have not yet proven efficient.

Recent Scottish and Irish groundfish surveys (1997–2000 and 1993–2000, respectively) in Region III show declines in the biomass and abundance of cod, whiting, and hake, amongst others, which were more pronounced in the latter part of the time-series (Mahé, 2001; ICES, 2008a). In the North Sea (Region II) declining trends in indicators for 13 fish populations have been reported (Rochet et al., 2005). The strong year classes of cod, haddock, whiting, and saithe of the 1980s have continued to decrease and cod is at the lowest level observed for over 100 years (ICES, 2008d). Spawning biomass of sandeel in the North Sea was at the lowest level observed in 2004 as a result of a targeted industrial fishery (ICES, 2008a).
Figure 1.5.5.1.12 Standardized Spawning-Stock Biomass (SSB) for demersal stocks by year by (a) annual mean SSB; (b) ratio of SSB to the biomass limit value ($B_{lim}$). The black line reflects the mean values by year, and the grey line is the linear regression (parameters are given in each panel) (Sparholt et al., 2007).
Modern fishing fleets are capable of causing a very significant reduction in demersal deep-water fish biomass in just a few years; a consequence of this has been the collapse of several fisheries. There is strong evidence that some deep-water fish (500–1800 m) have been severely depleted in the Celtic Sea (Region V) by the deep-water fisheries carried out in this area (ICES, 2008b). Unlike the commercial groundfish these fish all have attributes which make them particularly vulnerable to overfishing such as slow growth rates, late age of maturity, low or unpredictable recruitment, and long lifespans. Examples include the roundnose grenadier *Coryphaenoides rupestris*, black scabbard fish *Aphanopus carbo*, blue ling *Molva macrophthalmia*, and orange roughy *Hoplostethus atlanticus* as well as deep-sea squalids (sharks) and Macrouridae (ICES, 2008b). Populations of large fish that aggregate on oceanic bathymetric features such as seamounts are particularly sensitive to overfishing, due to low productivity and high catchability. On the southern part of the mid-Atlantic Ridge and adjacent seamounts, populations of alphonsinos were depleted also in the 1970s. More recently, longline fisheries appear to have depleted seamount populations of “giant” redfish on seamounts of the northern mid-Atlantic Ridge (ICES, 2008b).

However, some stocks show some positive trends most likely due to natural variation. For example, haddock recruitment has been particularly strong in recent years in Region I. Except for that of 2001, all year classes between 1998 and 2003 have been strong. In fact, the 2003 year class is estimated to be the strongest in 45 years (ICES, 2008a). Also, the spawning stock of Greenland halibut in Region I is low from a historical perspective, but has increased slowly since 1996 (ICES, 2008a).

**Effects on non-target species, including birds, marine mammals, and discarded fish**

In all five OSPAR regions some fisheries generate a large amount of discards, representing up to 50% of the total catch or even more. The discarded material contains both non-target species and target species which are undersized or exceed quota. In many regions, the *Nephrops* and *Cragonon* trawl fisheries and groundfish trawl fisheries use non-selective gears with small mesh sizes, generating unwanted bycatch that is thrown overboard, most of the time dead or dying. Deep-sea fisheries also catch large amounts of non-target species, of which survival is extremely small due to marked differences in environmental conditions between their usual habitat and the sea surface.

Discarding has been shown to affect the dynamics of target species, non-target species and community structure in all regions. Effort has been invested into research to develop more selective gears over the last decade, but the implementation of the new technology is slow. With only a limited uptake of more selective gears and their applicability in only
some situations discarding remains a major ecological impact of fisheries. Given the high levels of fishing effort in most fisheries in the region and the low SSB (and hence small average size of fish) in most stocks, discarding has increased in some areas, for example the Celtic Sea (Borges et al., 2005) or the Iberian areas (Rochet et al., 2006; ICES, 2008a). The most successful programmes for implementing selective gears and reducing discards were those developed in close collaboration with the industry.

Marine mammals including harbour porpoise, common dolphin, striped dolphin, Atlantic white-sided dolphin, white-beaked dolphin, bottlenose dolphin, and long-finned pilot whale continue to be incidentally caught in fishing gear throughout the OSPAR area (ICES, 2008a). There are indications that the bycatch of marine mammals in the pelagic trawl fishery for albacore in Region V was as high as in the driftnet fishery that it replaced, although in later years this bycatch appears to have reduced considerably. However, at least four species of seabird (northern gannet Morus bassanus, northern fulmar Fulmarus glacialis, Manx shearwater Puffinus puffinus, and Atlantic puffin Fratercula arctica, and two species of turtle, were included in the leatherback turtle Dermochelys coriacea, were also entangled (ICES, 2008a).

Eight species of Cetacea were recorded as bycatch during these fishing operations, including common dolphins Delphinus delphis, and striped dolphins Stenella coeruleoalba. Using landings of albacore tuna as an indicator of effort, the extrapolated decadal scale data from Irish and other driftnet fleets operating in this area suggest that during the period 1990–2000 around 800 000 blue sharks were caught, with a substantial proportion being discarded. An estimated 24 358 dolphins were captured during these years by these fleets, about half of which were common dolphins and half were striped dolphins (CEC, 2002; ICES, 2008a).

Lost gears such as gillnets may continue to fish for a long time (ghost fishing). The catching efficiency of lost gillnets has been examined for some species and areas, but at present no estimate of the total effect is available. Other types of fishery-induced mortality include burst nets, and mortality caused by contact with active fishing gear such as escape mortality. Some small-scale effects are demonstrated, but the population effect is not known. A programme for retrieval of lost gear is in effect along the Norwegian coast towards the Norwegian Sea, and a high number of ghost fishing nets are retrieved. The need for such activity is probably larger than what is currently carried out, given the fish mortality observed in retrieved nets.

**Effects on the sea bed and associated benthic communities and habitats**

The physical impact of bottom tending gear on the benthos remains a concern, particularly with respect to the damage to coral reefs. In the Norwegian Sea (Region I), damage to deep-water coral reefs has been documented in the eastern shelf areas and has resulted in area closures for bottom trawling. It is estimated that 30–50% of the coral areas may be damaged or negatively impacted (Fosså et al., 2002; ICES, 2008b).

Effects on other bottom fauna could be expected from bottom trawling activities in the eastern shelf areas. On the Faroe Plateau trawling activity has caused a significant reduction of the distribution of corals (e.g. Lophelia pertusa) on the shelf and bank slopes, prompting the Faroese authorities to close three coral areas for trawling in 2004 (ICES, 2008a). This species also forms large bioherms or reefs on the offshore banks (Rockall and Hatton) in Region V (Freiwald, 1998; Rogers, 1999) and may occur on the seamounts in this region. Many areas remain to be surveyed for Lophelia pertusa and so the full extent of damage due to fishing gears has yet to be evaluated.

Fishing is a major disturbance factor of the continental shelf communities of OSPAR Region IV and in some areas the area disturbed has increased. The Great Mud Bank (Grande Vasière) stretching from north to south in the centre of the Bay of Biscay is heavily trawled especially by the Nephrops trawler fleet. On average, the northern part is swept six times a year and this is suspected to have changed the sediment grain size through resuspension of fine materials, causing a decrease in the proportion of muds found on the Grande Vasière grounds (Bourillet et al., 2004; Bourillet et al., 2005; ICES, 2008a). Such changes to the physical habitat have the potential to cause substantial and long-term changes to benthic ecosystems, including negative impacts on burrowing animals such as Nephrops (ICES, 2008a). In the heavily exploited areas, the dominant benthic species are opportunistic carnivorous species of minor or no commercial interest and there were no fragile invertebrates (Blanchard et al., 2004).

**Effects on community structure and food webs**

Three of the most important fish populations in Region I – herring, cod, and capelin – have all undergone changes in the recent decades, due in part to overfishing of the top predators with very strong effects on fish community structure and the food web (Daan et al., 2005; ICES, 2008a). With these fish linked to one another through their population dynamics (Anon., 2006), the overfishing of one or the other has repercussions for all. Years with good recruitment of herring and cod have typically resulted in poor capelin recruitment and, subsequently, a weak capelin stock size. In recent years the stock size of capelin off Iceland has decreased from about 2000 Kt in 1996/97 to about 1000 Kt in 2006/07 (Anon., 2007). Herring were very abundant in the early 1960s, collapsed, and have then increased since 1970 to a historical high level in the last decade (ICES, 2008a). This inverse relationship between abundance of capelin and herring is well documented as the young herring are predators on capelin larvae. The reduced stock size of capelin has resulted in a lower food availability of capelin for feeding by the Icelandic cod stock and thus a poorer condition of cod since 2003.
Fall with declining effort and possible regulation, discards may be a less accessible food supply for seabirds (Parsons, 2006; ICES, 2008a). It appears that cod do not readily substitute herring for capelin in their diets. There is also evidence that a change in the distribution of capelin, resulting in less overlap with cod, may lead to a marked detrimental impact on cod growth.

In Region V overfishing has led to major changes in demersal deep-sea fish communities due to the loss of their larger predators and corresponding ecological functions (ICES, 2008b). In addition to catching target species, deep-water fisheries bycatch unwanted species that are either too small or unpalatable. Discarding rates are often high (in the order of 50%); in the roundnose grenadier fishery the bulk of the discarded catch consists of smoothheads (Alepocephalidae) because of their high abundance (Allain et al., 2003).

Ecosystem-wide effects of overfishing of the large predatory fish species and discarding of large numbers of immature fish has had an indirect effect on the trophic structure in much of the OSPAR region. Absolute numbers of small fish belonging to all species and of demersal species with a low maximum length have steadily and significantly increased over large parts of the North Sea (Region II) during the last 30 years while the abundance of large fish has decreased (Daan et al., 2005). In the Celtic Seas (Region III) discarding levels differ between the different fleets but can be as high as two thirds of the total catch, with increasing trends in recent years (Borges et al., 2005; ICES, 2008a). There is general agreement that the size structure of the fish community has also changed significantly; a decrease in the relative abundance of large piscivorous fishes such as cod and hake coincides with an increase in smaller pelagic species, which feed at a lower trophic level (Pinnegar et al., 2003). Zooplankton abundance has declined in the region in recent years and the overall substantial decline in Calanus abundance, which is currently below the long-term mean (ICES, 2008a), may have longer term consequences given the fish community shift towards smaller pelagic species feeding on zooplankton. Some evidence suggests that the decline in Calanus may be due to increased feeding pressure of these smaller fish and hence be an indirect effect of fishing; however, climate change factors are also implicated (ICES, 2008a). In the Bay of Biscay (Region IV), the mixed species fishery has increased its level of discards to the highest yet reported. In the Cantabrian Sea (Region IV), the mean trophic level of the demersal and benthic fisheries declined prior to 1993 and the fish communities are now largely dominated by lower trophic level planktivorous fish (blue whiting, horse mackerel) (ICES, 2008a).

Fisheries have a considerable influence on the distribution of seabirds at sea due to the supply of discard that are used as food for scavenging species. Studies of offshore seabirds in the Gulf of Cadiz, Galicia, and the Cantabrian Sea (Region IV) report a strong correlation between the spatial distribution of the scavengers and that of the demersal trawl fleet (Valeiras et al., 2007). Provision of discards to the environment by trawling fleets has impacted seabird communities directly through food subsidies and indirectly through the food web. In the North Sea (Region II) over the past decade, 12 out of 28 seabird species in the North Sea showed an increasing trend. Now that total discarding rates are expected to fall with declining effort and possible regulation, discards may be a less accessible food supply for seabirds (Parsons et al., in press).

**Effects on genetic diversity**

There is amounting evidence that fishing affects the genetics of populations (ICES, 2002, 2005, 2007c). Fishing may result in genetic change (Kenchington, 2003; Kenchington et al., 2003) and may lead to fisheries-induced evolution in heritable traits (Law, 2000). Genetic change can occur at different levels as fishing may lead to the extinction of genetically distinct local stocks, reduce the genetic variability within populations, or reduce the individual genetic variability (inbreeding).

Fishing mortality is a selective force that can affect the genetic composition of a target population. Fast-growing individuals tend to be selectively removed from the population and over time this may affect phenotypic traits such as size and age of maturation. Fisheries-induced evolutionary effects have been reported for a number of specific fish stocks in the OSPAR region, in particular the onset of sexual maturity, but there is no systematic assessment of the effect on all exploited stocks (Jørgensen et al., 2007). Northeast Arctic cod (Heino et al., 2002) and, in the North Sea, cod (Law and Rowell, 1993), haddock (Wright, 2005), and plaice (Grift et al., 2007) all show indications of fishing-induced effects on reproductive traits. The question is not whether fisheries-induced evolution happens, but rather the rate at which it happens; this is still debated in the scientific community (Dieckmann and Heino, 2007; Law, 2007; Marshall and Browman, 2007). ICES (2007c) advised that firstly, reducing harvest rates will slow the rate and extent of fisheries-induced evolution in most life-history traits; secondly that, raising the minimum size limit well above the size at maturation will slow down the rate of evolution in maturation schedules.

Fishery-induced loss of genetic diversity has been studied for some stocks in the OSPAR region, with diverging results: low effective population sizes were reported for one sub-stock of North Sea cod (Hutchinson et al., 2003) and for North Sea and Icelandic plaice (Hoarau et al., 2005). However, for another North Sea cod stock and for Baltic cod no loss of genetic diversity was reported (Poulsen et al., 2006). The effect of the loss of specific spawning populations on genetic diversity has not been studied.
Assessment of fisheries measures and their effectiveness

A variety of fisheries management measures have been introduced to NE Atlantic fisheries in the last 10 years. These have met with varying levels of success. Table 1.5.5.9.1.2 illustrates a number of these approaches with examples for a variety of types of measure.

Table 1.5.5.9.1.2  A variety of fisheries management measures introduced into European fisheries management in the past 10 years and an indication of their effectiveness.

<table>
<thead>
<tr>
<th>Fishery measures:</th>
<th>Aim:</th>
<th>Effectiveness:</th>
<th>Evidence:</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFP 2002</td>
<td>The 2002 reform of the CFP aimed at ensuring the sustainable development of fishing activities from an environmental, economic, and social point of view. <a href="http://ec.europa.eu/fisheries/cfp_en.htm">http://ec.europa.eu/fisheries/cfp_en.htm</a></td>
<td>Over 20% of the European Community fish catch comes from stocks deemed to be outside safe biological limits. Levels of ecosystem impact remain high, e.g. discard rates, bycatch, and physical impacts on the sea floor.</td>
<td>ICES Advice</td>
</tr>
<tr>
<td>Cod Recovery Plan</td>
<td>Rebuild some cod stocks in the North, Irish, and Celtic Seas to be within safe biological limits. “The aim of the plan was to allow severely depleted stocks to recover at rates ranging from 5 percent to 30 percent per year.” <a href="http://128.227.186.212/fish/Inews/cod2004.htm">http://128.227.186.212/fish/Inews/cod2004.htm</a></td>
<td>SSB has declined from 250 000 t in the 1970s to 40 000 t in 2006. The limit value below which the productivity of stock is considered to be impaired is 70 000 t. North Sea cod effort has declined by 25% since 2000. F has been in decline since 1999/2000 but remains above the value needed to rebuild stocks in the required time frame.</td>
<td>ICES Advice</td>
</tr>
<tr>
<td>Sandeel management</td>
<td>To leave SSB = Bpa after each year of fishing.</td>
<td>Aim achieved after 3 years of compliance with Harvest Rule and a low F of 0.21 in 2007. SSB is estimated to have increased to above Bpa in 2008.</td>
<td>ICES Advice</td>
</tr>
<tr>
<td>GBTM – cetacean pingers</td>
<td>Reduce mortality on small cetaceans in EC waters to below the ASCOBAN levels of ‘unacceptable’ mortality.</td>
<td>Pingers are not widely used. The pingers in use target only one species, the harbour porpoise. Very limited monitoring of the effectiveness of these measures seems to have occurred. Monitoring was a requirement of the Regulation.</td>
<td></td>
</tr>
<tr>
<td>Hake Recovery Plan</td>
<td>To increase SSB of northern hake to within safe biological limits.</td>
<td>Met the SSB of 140 000 t achieved in 2006 and 2007.</td>
<td>ICES Advice</td>
</tr>
<tr>
<td>GBTM – Mesh size increases and square mesh panels</td>
<td>Decrease bycatch mortality and discarding of non-target species and undersize targets.</td>
<td>Some reduction of discards in modified gear has been observed.</td>
<td>This report</td>
</tr>
<tr>
<td>Bay of Biscay anchovy closure in 2005.</td>
<td>Rebuild stocks of anchovy following a recruitment failure.</td>
<td>Only slight signs of stock recovery apparent in 2006 and 2007.</td>
<td>From scientific fishing in 2007; see this report</td>
</tr>
<tr>
<td>Closed areas to protect corals in Regions I and V; including Council Regulation (EC) no. 602/2004 of 22 March 2004</td>
<td>To protect vulnerable habitats and coldwater corals.</td>
<td>Fishing has virtually ceased in more than ten closed areas. No monitoring of the state of coral reefs has occurred.</td>
<td>WGDEC (ICES, 2008c)</td>
</tr>
<tr>
<td>Closed areas in EU Atlantic and North Sea waters</td>
<td>Variety of fish stock conservation measures and in one case for biodiversity conservation.</td>
<td>In most cases impossible to evaluate due to lack of studies or difficulty in separating effects of closed area from other measures taken for fisheries management. Closed area for biodiversity found to be too small.</td>
<td>STECF SGMOS 07-03 report (STECF, 2007)</td>
</tr>
<tr>
<td>EC data collection regulations</td>
<td>Regulation establishing the Community Programme for the collection, management and use of data (including ecosystem considerations) in the fisheries sector</td>
<td>Council Regulation (EC) No. 199/2008 only recently established</td>
<td>Scientific, Technical and Economic Committee for Fisheries</td>
</tr>
</tbody>
</table>
Conclusions and priorities for action

Fisheries are a major economic activity in the NE Atlantic Region. Fish stocks from the area supply almost 10% of the global fisheries yields, but many of the stocks are fished so heavily that the stocks are outside or very close to the safe biological limit for exploitation.

Fisheries management practices in the NE Atlantic continue to evolve with the priority of ensuring a European fishery that is environmentally, economically, and socially sustainable. With growing global pressure on the food supply and the need for high grade protein and health promoting substances such as polyunsaturated fatty acids that are abundant in seafood, the fisheries sector will remain under pressure to deliver high quantities of material. Managing the fishery within ecologically sustainable limits and meeting societal objectives for the conservation of biodiversity against this moral, social, and economic imperative will be a growing challenge for fisheries management.

Gear-based technical measures have made a contribution to reducing the environmental impact of some fisheries. Regulatory and market incentives can both lead to an improvement of fishing practice, as can education and outreach initiatives.

Overall levels of fisheries exploitation are very high and in most fisheries higher yields, more security of supply, and lower environmental impacts would follow from further reductions in fishing effort.

ICES advises that OSPAR should:

- work in partnership with Regional Fisheries Management Organisations (RFMOs) to help deliver ecologically sustainable fisheries and ensure adequate provisions are made for biodiversity conservation. This could include work on the development of ecosystem-based fisheries management plans;
- work with RFMOs to develop a more detailed and more consistent data coverage to underpin evidence-based management;
- continue the development of integrated marine monitoring plans and assessment techniques, for example through the setting of ecological quality objectives and integrated assessments;
- work with Contracting Parties and the European Commission to clarify conservation objectives and the links to management action in marine protected areas, particularly in relation to measures to regulate effects of fishing that compromise conservation objectives;
- encourage the collection of further data and information on elasmobranch species, including common skate, thornback ray, porbeagle, basking shark, blue shark, and thresher shark. Further biological studies to delineate stock structure should also be encouraged;
- develop international agreements to establish robust procedures for the gathering and interpretation of information to allow a full assessment of fisheries and their ecosystem impacts in deep waters and in higher latitudes;
- further encourage programmes for developing and implementing selective gears and reducing discards. These programmes should be in close collaboration with the fishing industry;
- encourage the further reduction in harvest rates in order to slow the rate and extent of fisheries-induced evolution and encourage raising the minimum size limit to levels well above the size at maturation in order to slow down the rate of evolution in maturation schedules;
- derive new measures (metrics) or continue to develop/apply existing ones (e.g. EcoQOs) in order to distinguish between different forces acting on the communities (i.e. partition effects between environmental, economic, and regulatory forces). Ultimately the goal would be to assess the effectiveness of existing management measures (through legislation and/or voluntary measures) to improve stocks and mitigate against detrimental environmental impacts. In addition, it would be informative, as new mitigation or conservation measures are implemented, to recommend or develop appropriate metrics (that can be easily monitored and reported) in order to measure the success of such measures.
References


STECF. 2007. STECF SGOMS 07-03 report. Can be downloaded from STECF’s website at: (https://stecf.jrc.ec.europa.eu/24;jsessionid=b50ca911a3011e806e17bf4d9077b_p_id=20&p_p_lifecycle=0&p_p_state=normal&p_p_col_id=column-


1.5.5.9.b Regional QSR I: Arctic

Introduction

OSPAR Region I is a very large and diverse region. The fish stocks and fisheries of the region are equally diverse, with major differences between parts of the region. This makes summarizing the fisheries of the region, as well as the effects of these fisheries, comparatively difficult. The major demersal stocks in the OSPAR Arctic area include cod, haddock, saithe, and shrimp. In addition, redfish, Greenland halibut, wolf-fish, and flatfishes (e.g. long rough dab, plaice) are common on the shelf and along the continental slope, with ling and tusk also found on the slope and in deeper waters. In the Barents Sea, the spawning stock of the Northeast Arctic cod has been healthy since 2002 and fishing mortality has been reduced, but surveys indicate that the abundance of recent year classes are just above (years 2004 and 2005) or below average. The stock of the Norwegian coastal cod has decreased to a very low level – recruitment is declining rapidly and present fishing mortality is far too high. The stocks of Northeast Arctic haddock and saithe are high, and recent recruitment is above average. Abundance of demersal species around Iceland has been trending downward irregularly since the 1950s, with aggregate catches dropping from over 800 Kt to under 500 Kt in the early 2000s. Large spawning cod have been found in limited areas off East Greenland, indicating that a Greenland offshore spawning stock is being established. At the Faroes, the haddock and saithe stocks are harvested sustainably, but the cod stocks are depleted.

The major pelagic stocks in the area are herring, blue whiting, mackerel, capelin, and polar cod. The spawning stock of Norwegian spring-spawning herring was about 12 million tonnes in 2007, which means it is back to the level it had in the 1950s. The annual catch has been kept at a low level, at about 1.5 million tonnes. The spawning stock of blue whiting may have been close to 12 million tonnes in 2003, but in 2007 it had declined to about half of that level, due to heavy fishing and poor recruitment. The mackerel stock has its main distribution area in the North Sea and west of the British Isles, but large parts of the stock feed in the Norwegian Sea during summer, and its distribution area is expanding to the north and west. There has been no fishery for Barents Sea capelin since 2004, as the spawning stock biomass was too low. The exploitation of polar cod in the Barents Sea has been very low since the 1970s.

In Iceland/East Greenland/Jan Mayen, capelin abundance has been oscillating on roughly a decadal period since the 1970s, producing a yield of just under 1600 Kt at the most recent peak. In recent years the stock size of capelin has decreased from about 3000 Kt in 1995/96 to about 1000 Kt in 2006/07 (ICES, 2008a). Herring around Iceland were very abundant in the early 1960s, collapsed, and then have increased since 1970 to a historically high level in the last decade.

The most widespread demersal gear used is the bottom trawl, but also Danish seines, longlines, and gillnets are used in the demersal fisheries. Purse seines and pelagic trawls are the most commonly used gears for the pelagic fisheries. A range of mitigation measures are in force to limit the adverse impact of these fisheries, including closed areas to protect sensitive seabed habitats, and other technical mesh regulations to prevent capture of juvenile fish.

The development of fisheries management and policy since 1998, and an assessment of their effectiveness

Although Icelandic shrimp trawlers often use a double-rigged gear with a minimum codend square-mesh of only 36 mm, the impact of the fishery on undersized or juvenile fish has been alleviated since the mid-1990s by the compulsory use of a Nordmøre grid, as well as a shrimp sorting grid and 40 mm square-mesh codend in areas known to have large numbers of juvenile fish.

In the Barents Sea, sorting grids in shrimp trawls were made compulsory from January 2003, in order to reduce mortality of young fish. The use of grids in “large mesh” trawls was made compulsory from January 2007 – first in the Barents Sea and later in all areas north of 62°N. There has also been a gradual change from “open” or “Olympic” fisheries to vessel quotas, development of management strategies for the most important commercial species, and a focus on the development of bilateral control regimes in order to ensure that quotas are not exceeded.

In order to prevent further destruction of deep-water corals, trawling in known coral areas is now prohibited in Norwegian and Icelandic waters. A Norwegian programme for mapping the sea bottom, including coral areas, is in progress.

Areas around Spitsbergen and along the Norwegian coast are closed for fishing with specific gears permanently or for part of the year in order to protect juvenile fish or specific stocks.

Since 1 June 1996, a management system based on a combination of area closures and individual transferable effort quotas in days within fleet categories has been in force in the Faroes.

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The Faroe Bank shallower than 200 m is closed to all trawl and gillnet fisheries. Technical measures such as area closures during the spawning periods, to protect juveniles and young fish and mesh size regulations are a natural part of the fisheries regulations. On the Faroe Plateau, three coral areas were closed to trawling in 2004.

A programme for retrieval of lost gear is in effect along the Norwegian coast towards the Norwegian Sea, and a high number of ghost fishing nets are retrieved.

In Iceland a system of transferable boat quotas was introduced in 1984. In 1990, an individual transferable quota (ITQ) system was established for the fisheries and they were subject to vessel catch quotas. The quotas represent shares in the national total allowable catch (TAC) for each species, and all of the Icelandic fleets now operate under this system.

With the extension of the fisheries jurisdiction to 200 miles in 1975, Iceland introduced new measures to protect juvenile fish. A ‘real-time’ closure system has been in force since 1976 aimed at protecting juvenile fish. Fishing is prohibited for at least two weeks in areas where the number of small fish in the catches has been observed by inspectors to exceed a certain percentage. If several consecutive quick closures are introduced in a given area the Minister of Fisheries can close this area for a longer time, forcing the fleet to operate in other areas (Figure 1.5.5.9.2.1). In 2005, 85 such closures took place.

In addition to allocating quotas on each species, there are other measures in place to protect fish stocks. Based on knowledge of the biology of various stocks, many areas have been closed temporarily or permanently to protect juveniles. Figure 1.5.5.9.2.1 shows a map of the legislation in force in 2004. Some of the closures are temporary, while others have been closed to fisheries for decades.

A way to ensure that a mixed fishery does not over-harvest one of the constituent stocks of the fishery is to predict the effects of mixed fisheries. ICES has examined the technical interactions between the fisheries in the Barents Sea using correlations in fishing mortalities among species. The correlation in fishing mortality is positive for Northeast Arctic cod and coastal cod and also for haddock and coastal cod, confirming the linkage in these fisheries. There is also a significant relationship between saithe and Greenland halibut although the linkage in these fisheries is believed to be low. Though this approach is promising, it has yet to be implemented as the correlations are influenced by too many confounding factors, the effects of which cannot be removed without a detailed analysis of data at a higher resolution than is available at present (see Section 2.1).

**Figure 1.5.5.9.2.1** Overview of closed areas around Iceland. The boxes are of various nature and can be closed for different time periods and gear types (see text for further detail) (ICES, 2008b).

Estimates of unreported catches of cod and haddock in the Barents Sea 2002–2007 are relatively high (ICES, 2008a). Discarding of cod, haddock, and saithe is thought to be significant at times even though the discarding of these, and a number of other species, is illegal in both Norway and Russia.

Discarding measurements have been carried out in Icelandic fisheries since 2001, based on extensive data collection and length-based analysis of the data (Pálsson, 2003). The data collection is mainly directed towards fisheries for cod *Gadus*
and haddock *Melanogrammus aeglefinus* and towards saithe *Pollachius virens* and golden redfish *Sebastes marinus* fisheries in demersal trawl and plaice in Danish seine. Sampling for other species is not sufficient to warrant a satisfactory estimation of discarding. The discard rate for cod has been less than 1–2% of the reported landings over the time investigated. The discard estimates for haddock are somewhat higher, ranging between 2% and 6% annually. Discarding of saithe and golden redfish has been negligible in the time period investigated. Estimates of discards of cod and haddock in 2006 by individual fleets are given in Table 7.2. These relatively low discard rates compared to what is generally assumed to be a side effect of a TAC system may be a result of the various measures, including the flexibility within the Icelandic ITQ system. Since the time-series of discards is relatively short, it is not included in the assessments (ICES, 2008).

**Fishing activities in OSPAR Region I**

In Iceland the number of demersal trawlers has decreased from about 110 to 60 since around 1990, while their total demersal catch has dropped from roughly 350 000 tonnes to 200 000 tonnes (Figure 1.5.5.9.2.2). The gross tonnage of the bottom-trawler fleet has remained stable in the last decade at around 100 000 tonnes, but total engine power has decreased by 25% or from 200 000 to 150 000 kW. The most significant development in recent years in Icelandic pelagic fisheries is an increasing size of pelagic trawls and ability to fish deeper due to increasing engine power. There have also been substantial improvements with respect to technological aspects of other gears such as bottom trawl, longline, and handline.

**Figure 1.5.5.9.2.2** Number of Icelandic trawlers during the period 1905–2002 (Garcia et al., 2006).

In addition to the Icelandic bottom-trawl fishery, an offshore shrimp-trawl fishery developed rapidly in the 1980s with catches surpassing 70 000 tonnes by the mid-1990s. Catches have decreased to around 10 000 tonnes or less in recent years. The offshore shrimp fishery led to an increase in bycatch of cod and Greenland halibut on the continental slopes and in deeper muddy areas off the northern part of the country. The fishery for shrimp has in the most recent year been greatly reduced, associated with a decrease in trawling activities in these areas. Trawling effort measured in standardized trawling hours has decreased by some 50% in the last decade with further decrease in the most recent years.

Icelandic *Neprops* catches reached a historical maximum of 6000 tonnes in 1963, but they decreased quickly to some 1500 tonnes a year in the last decade. Due to the use of 80 mm codend mesh, bycatch and discard of juvenile fish may be considerable (Figure 1.5.5.9.2.3). Fishing effort measured in number of trawling hours decreased by some 60–70% in the last decade compared to the early 1970s.
Icelandic scallop stocks have been largely depleted following relatively stable catches, averaging about 10 000 tonnes in 1990–2000, partly due to high natural mortality and low recruitment. It was not possible to rule out the effects of fishing and all local scallop fisheries had been suspended by the year 2003. In Breiðafjörður, West Iceland, the stock was estimated in 2006 to be less than 30% of its average size between 1993–2000 and at only some 20% of its estimated historical high in the early 1980s. Due to the heavy weight of the scallop dredges and a relatively high towing speed of up to four knots or more, the impact on benthic life is thought to be considerable. These areas had been mostly undisturbed by other towed-bottom gear prior to 1970. Total scallop trawling and dredging effort measured in fishing hours has decreased considerably over recent years (Figure 1.5.5.9.2.4), especially since early 1990 as a result of technological advances and the significant decreases in stock sizes of commercial fish species.
Figure 1.5.5.9.2.4 Number of vessels in the Icelandic scallop fleet and mean length of vessel 1970–2004, grouped in 5-year intervals (Garcia et al., 2006).

Figure 1.5.5.9.2.5 Number of Norwegian fishing vessels and aggregated engine capacity 1990–2006.

The Norwegian fishing fleet has been reduced in number of vessels since 1998, but the fishing capacity, measured in tonnes or horsepower, has been maintained (Figure 1.5.5.9.2.5). Partly due to the decline of traditional demersal and shrimp fisheries, trawlers turned to an offshore scallop fishery in the Jan Mayen, Svalbard, and Bjørnøya areas around 1985. In the peak years some 20–25 scallop trawlers, many with onboard freezing facilities, took part in the fishery towing up to three large dredges simultaneously. The Jan Mayen area was closed to dredging in 1987, although a small-scale fishery continued in other areas, mostly around Bjørnøya. Thus, total trawling and dredging effort has decreased in the Barents Sea and Svalbard areas in recent years compared to previous decades, as has happened in Iceland and Greenland (Figures 1.5.5.9.2.6 and 1.5.5.9.2.7). No trawling and dredging effort has taken place in Icelandic waters since 2003.
Figure 1.5.9.2.6  Distribution of fishing effort in the Barents Sea in 2007, based on Norwegian VMS data (vessels moving slower than 6 knots). Darker colour indicates a higher number of position reports.
Figure 1.5.5.9.2.7 Distribution of fishing effort in the 3rd quarter in the Norwegian Sea, aggregated over the years 2004–2006, based on Norwegian VMS data (vessels moving slower than 5 knots). Darker colour indicates a higher number of position reports.

The geographic distribution of fishing effort in the Barents Sea and Norwegian Sea based on Norwegian VMS data shows the concentration of effort in inshore areas, on banks, and associated with ridges (Figures 1.5.5.9.2.6 and 1.5.5.9.2.7). Large areas receive little fisheries impact.

The main fisheries in Faroese waters are mixed-species, demersal fisheries, and single-species pelagic fisheries. There has been an increased effort in recent years in Faroese waters as the deep-water fleet has reduced its effort in other areas.

In the 1990s, a gillnet fishery directed at monkfish *Lophius piscatorius*, and Greenland halibut *Reinhardtius hippoglossoides*, developed in ICES Area Vb and is now well established; bycatches in this fishery are, among others, deep-sea red crab and blue ling. More recently exploratory trap fisheries for deep-sea red crab have been performed.

Impacts of fisheries on the ecosystem

Commercial fishing has direct and indirect effects on the marine ecosystem; these can be summarized as effects on:

1. commercial fish stocks;
2. non-target species, including birds, marine mammals, and discarded fish;
3. the seabed and associated benthic communities and habitats; and
4. community structure and food webs.
Effects on commercial fish stocks

The most important impacts of fishing are likely to be on the fish stocks themselves. Fishing will usually change the age structure of a stock (fewer old and large individuals), and as the fishing mortality increases the spawning stock is likely to become smaller, and based on fewer year classes. This reduces a stock’s ability to resist and recover from both natural and human pressures.

Biomass and fishing mortality limit reference points have only been defined for seven of the ICES assessed stocks allocated to Region I. Total landings from these stocks accounted for 40.75 million tonnes or 47.2% of the total reported landings of 86.28 million tonnes of fish and shellfish from this region in the period 1986 to 2006. Temporal trends in the spawning-stock biomass (SSB) and fishing mortality (F) of these stocks in relation to their limit reference points are shown in Figure 1.5.5.9.2.8.

ICES prefers to give precedence to an analysis based on stocks for which reference points have been defined as the main indicator of fishing impacts on commercial stocks because it is not straightforward to define stock status in relation to a management objective when reference points have not been defined. For demersal stocks, significant fishing impacts on assessed species are often indicative of significant fishing impacts on larger more vulnerable species that are not assessed, but taken as bycatch.

The overall status of assessed stocks for which all reference points have been defined is shown in Figure 1.5.5.9.2.9. To determine the status of assessed stocks in relation to reference points ICES used 2005 rather than 2007 estimates of F and SSB. This is because the 2006 and 2007 estimates are less precise due to the so-called “convergence” feature of the methods used in fish stock assessment. Thus in 2005, 29% (i.e., 2) of those stocks were harvested unsustainably (Faroe Plateau cod (ICES Subdivision Vb1) and Faroe saithe (ICES Subdivision Vb)) with fishing effort, F, below Flim. Of the remaining 5 stocks, 3 are at risk of being harvested unsustainably (Northeast Arctic cod (Subareas I and II), Northeast Arctic haddock (Subareas I and II), and blue whiting combined stock (Subareas I–IX, XII, and XIV) with F above Fpr. Faroe haddock (Division Vb) and Northeast Arctic saithe (Subareas I and II) are harvested sustainably. Only one stock, Faroe Plateau cod (ICES Subdivision Vb1) is suffering reduced reproductive capacity (Figure 1.5.5.9.2.9); all others have full reproductive capacity with SSB above precautionary levels (Bpa).

The biological reference points Fpr and Bpr are developed to take into account the higher uncertainty in the most recent estimates F and SSB when developing fisheries management advice for fish quotas in the near future. Thus, when considering historical performance of fish stocks, Fpr and Bpr are not as relevant as Flim and Blim and the focus is therefore only on the limit reference points. This means that there is no distinction between stocks that are harvested sustainably and at risk of being harvested unsustainably (since in both cases F < Flim), and no distinction is made between stocks at risk of suffering reduced reproductive capacity and at full reproductive capacity (in both cases B > Blim). This is unfortunate, but does reflect the focus of current ICES advice on the avoidance of limits rather than the achievement of targets.
North-East Arctic cod (Sub-areas I and II)

Faroe Plateau cod (Sub-division Vb1)

North-East Arctic haddock (Sub-areas I and II)
Figure 1.5.5.9.2.8  Trends in fishing mortality (F) and spawning-stock biomass (SSB) in assessed stocks allocated to OSPAR Region I and for which fishing mortality and biomass reference points have been defined. Continuous red horizontal lines show the limit reference points (F_{lim} and B_{lim} respectively), while broken red horizontal lines show the precautionary reference points (F_{pa} and B_{pa} respectively, where defined). The age classes for which values of F were calculated are shown in parentheses.
Analyses have shown that the fisheries were a major factor driving the collapse of the stock of Norwegian spring-spawning herring observed during the late 1960s. The stock has gradually been rebuilt since the 1980s (ICES, 2008a).

The demersal fisheries in the Barents Sea are highly mixed, usually with a clear target species dominating, and with low linkage to the pelagic fisheries. Analyses show considerable catches of Norwegian coastal cod and redfishes *Sebastes mentella* and *S. marinus* in the mixed fisheries for Northeast Arctic cod.

Estimates of unreported catches of cod and haddock in the Barents Sea in 2002–2006 indicate that illegal, unreported, and unregulated fishing (IUU) is a considerable problem, adding around 20% to official catches in the period 2002–2005. Discarding of cod, haddock, and saithe is also believed to be significant in periods although the discarding of these and a number of other species, is illegal in both Norway and Russia. Data on discards are scarce. Haddock recruitment has been particularly strong in recent years. Except for 2001, all year classes between 1998 and 2003 have been strong. In fact, the 2003 year class is estimated to be the strongest in 45 years.

Northern shrimp off East Greenland in ICES Divisions XIVb and Va is assessed as a single population, separate from the offshore shrimp stock in northern Icelandic waters. The fishery started in 1978 and, until 1993, occurred primarily in the area of Stredbank and Dohrmbank as well as on the slopes of Storfjord Deep, from approximately 65°N to 68°N and between 26°W and 34°W. In 1993 a new fishery began in areas south of 65°N down to Cape Farewell. Access to these fishing grounds depends strongly on ice conditions. From 1996 to 2003 catches in the area south of 65°N accounted for more than 60% of the total catch. Catches and effort in the area south of 65°N in 2004 and 2005 only accounted for 29% and 47%, respectively, and decreased further in 2006 (Figure 1.5.5.9.2.10).

A multinational fleet exploits the East Greenland shrimp stock. In the recent ten years, vessels from Greenland, Denmark, the Faroe Islands, and Norway have fished in the Greenland exclusive economic zone (EEZ). Only Icelandic vessels are allowed to fish in the Icelandic EEZ. In the Greenland EEZ, the minimum permitted mesh size in the cod-end is 44 mm, and the fishery is managed through catch quotas allocated to national fleets. In the Icelandic EEZ, the mesh size is 40 mm and there are no catch limits. In both EEZs, sorting grids with 22 mm bar spacing to reduce bycatch of fish are mandatory. Discarding of shrimp is prohibited in both areas.

Total catches from the East Greenland shrimp stock increased rapidly to about 15 500 tonnes in 1987 and 1988, but declined thereafter to about 9000 tonnes in 1992 and 1993. Following the extension of the fishery south of 65°N catches increased again to about 13 800 tonnes in 1997. Catches from 1998 to 2003 have been around 12 000 tonnes, but have since decreased. Catches decreased in 2005 to 8000 tonnes and in 2006 further to about 5100 tonnes. Catches in 2007 were projected to stay at this level. Catches in the Iceland EEZ had decreased from 2002 to 2005, and no catches were taken in 2006 and 2007.
The Greenland fishing fleet, (catching 40% of the total East Greenland shrimp catch), has decreased its effort in recent years, and this creates some uncertainty as to whether recent values of the indices accurately reflect stock biomass. The decrease may be related to the economics of the fishery.

Effects on non-target species, including birds, marine mammals, and discarded fish

Incidental catch of non-target species in fishing gears remains an issue. Work is carried out within the framework of ICES in order to sort out the scale of unintentional bycatch of salmon in the pelagic fisheries in the Norwegian Sea, but no such major effects have been documented so far. Estimates of unreported catches of cod and haddock in the Barents Sea in 2002–2006 indicate that IUU fishing is a considerable problem; around 20% in addition to official catches in the period 2001–2005. Discarding of cod, haddock, and saithe is also believed to be significant, although discarding of these and a number of other species is illegal in both Norway and Russia.

Mortality of seabirds occurs in longline fisheries; however, the magnitude and species composition is unknown. In episodes of coastal invasion of arctic seals along the Norwegian coast large mortality of seals has been observed in net fisheries. This mortality has not been regarded as problematic for the state of the seal stocks due to the general good condition and low harvesting level of the stocks. The harbour porpoise, which is common in the Barents Sea region south of the polar front and is most abundant in coastal waters, is subject to bycatches in gillnet fisheries (Bjørge and Kovacs, 2005). In 2004 Norway initiated a monitoring programme on bycatches of marine mammals in fisheries, but no results are available yet.

Effects on the seabed and associated benthic communities and habitats

In the Norwegian Sea, loss of deep-water coral reefs has been documented in the eastern shelf areas and has resulted in area closures for bottom trawling. It is estimated that 30% to 50% of the coral areas may be impacted (Fosså et al., 2002). Up to the mid-1900s it was common for fishers as well as scientists to catch large ‘Bubblegum Tree Coral’ Paragorgia arborea (up to 4 m tall) in bottom gear. This situation has changed and large individual colonies of *P. arborea* are now rarely reported or seen. Large colonies of this species can be more than one hundred years old. Other species of coral, such as the octocoral *Primnoa* spp, are also slow-growing and long-lived and have decreased in abundance. In Faroese waters, trawling activity has caused a significant reduction in the distribution of the reef-building coral *Lophelia pertusa* on the shelf and bank slopes. This led the Faroese authorities to close three coral areas to trawling in 2004. The lack of detailed information on the distribution of soft and stony coral emphasizes a need for coherent mapping of species and habitats in all parts of the region (Klages et al., 2004; Garcia et al., 2006).

The impacts of experimental trawling have been studied on an offshore fishing ground in the Barents Sea (Kutti et al., 2005). Trawling seems to affect the benthic assemblage mainly through resuspension of surface sediment and through relocation of shallow burrowing infaunal species to the surface of the seafloor. These results have not been extrapolated to determine any total fleet effect.

Longlines and gillnets are also used for fishing in coral areas. In such areas, these fishing techniques may cause relatively little breakage and disturbance of corals per fishing operation, but due to the long recovery time, overall damage will depend on the frequency and intensity of fishing operations.
During ROV surveys of reef areas off Norway, lost longlines, gillnets, and other types of fishing equipment have been observed on the seabed. Lost nets have been found covering parts of the coral colonies, but the effect of this is not known. Lost gear may continue to fish for a long time (ghost fishing). The catching efficiency of lost gillnets has been examined for some species and areas, but at present no estimate of the total effect is available. A programme for retrieval of lost gear is in effect along the Norwegian coast towards the Norwegian Sea, and a high number of ghost fishing nets are retrieved.

Several bird-scaring devices have been tested in longline fisheries in the Norwegian Sea and a simple one, the bird-scaring line (Løkkeborg, 2003), not only reduces significantly bird bycatch, but also increases fish catch, as bait loss is reduced. This way there is an economic incentive for the fishers, and where bird bycatch is a problem, the bird-scaring line is used without any forced regulation.

**Effects on community structure and food webs**

The benthic assemblages of offshore sandy seabeds appear to be relatively unaffected by trawling disturbance due to common natural disturbance and large natural variability. Studies on impacts of shrimp trawling on clay-silt bottoms have not demonstrated clear and consistent effects, but potential changes may be masked by the more pronounced temporal variability in these habitats.

Three of the most important fish populations in Region I – herring, cod, and capelin – have all undergone changes in the last decades, due in part to overfishing of the fish predators which has very strong effects on fish community structure and the food web. With these fish linked to one another through their population dynamics, the overfishing of one or the other has repercussions on all. In the Barents Sea, years with good recruitment of herring and cod have typically resulted in poor capelin recruitment and, subsequently, a weak capelin stock size. Abundance of demersal species off Iceland has been decreasing irregularly since the 1950s, with aggregate catches dropping from over 800 Kt to under 500 Kt in the early 2000s.

Cod in Greenland’s waters are at the edge of their range and thus subject to considerable fluctuations in abundance. It is therefore difficult to distinguish these fluctuations in such an important species in the foodweb with any shifts in community structure in these waters.

The impacts of experimental trawling have been studied on an offshore fishing ground in the Barents Sea. Trawling seems to affect the benthic assemblage mainly through resuspension of surface sediment and through relocation of shallow burrowing infaunal species to the surface of the seafloor.

**References**


1.5.5.9.c  Regional QSR II: Greater North Sea

Introduction

The fish resources of the North Sea have been exploited for many centuries. At the peak of the fishery in the 1980s the North Sea provided almost 10% of the global reported fish landings, and the current landings (Figure 1.5.5.9.3.1) are still close to 3% of global landings.

Since the 1980s, the North Sea has supported major pelagic fisheries for herring and mackerel, demersal fisheries for whitefish (cod, haddock, whiting, saithe), flatfish (plaice, sole), and shellfish (Nephrops, crab, lobster, shrimp, scallops), and industrial fisheries focusing mainly on Norway pout and sandeels.

Figure 1.5.5.9.3.1  Landings (and discards) of industrial, pelagic, and demersal fisheries in the North Sea and Division IIIa (ICES, 2007 – Book 6, p. 31).

The development of fisheries management and policy since 1998, and an assessment of their effectiveness

The major driver of the patterns and intensity of fisheries exploitation in the greater North Sea in the last 10 years has been the introduction of specific management measures to halt the decline and promote recovery of the cod stocks ((EEC) No. 2847/93). As cod generally occur alongside other species, notably haddock, whiting, and in places Nephrops, the cod management measures have impacted other fisheries too.

Much management effort has been invested in promoting the recovery of the North Sea cod. Analysis of data and previous advice shows that cuts of at least 60% in the rate of fishing mortality from the high levels experienced in 2000 would be needed to promote recovery. The key to achieving recovery over a period of about a decade, short of complete closure of the North Sea, is through achieving a substantial reduction in F through reduced effort. Technical measures, while having a role to play, can only provide a modest reduction in F on cod.

In 2001, the EU implemented a 10-week area closure for parts of the North Sea because agreement could not be reached on catch or effort reductions. For 2003, a cod Total Allowable Catch (TAC) was agreed that was consistent with a 65% reduction in fishing mortality. The Recovery Plan was finalized in 2004 for cod stocks in the North Sea, Kattegat, west of Scotland, and the Irish Sea. For North Sea cod TAC levels were set that were predicted a 30% annual increase in spawning-stock biomass. In practice, the cut in quota had limited impact because it was not matched by the necessary cuts in effort.

Monitoring the progress of North Sea cod recovery is made difficult by uncertainties in stock assessments associated with low stock size, variable survey indices, and inaccurate catch data. Recent cuts in fishing mortality by restrictions on North Sea effort have reduced fishing mortality rates by about 37%. This is considered insufficient to ensure recovery to the precautionary spawning-stock biomass reference point (Bmp) of North Sea cod within the next decade. The EC regulation for cod was amended in 2004 to address this issue (amending Regulation (EC) No. 423/2004 as regards the recovery of cod stocks and amending Regulation (EEC) No. 2847/93) and speed the recovery of cod in community waters.
Sandeel landings in the North Sea dropped abruptly in 2003/4 to around 350 000 tonnes and further declined the following years as a result of the low total stock size. Landings remained low in 2007 due to a low TAC. In 2007 a TAC of 170 000 t was set for the whole of the North Sea. Because there was no agreement between EU and Norway on how to share the sandeel, the TAC was overfished by 21%, notwithstanding the fishing mortality in 2007 was at the historically lowest level. There are still several fishing grounds in the northern part of the North Sea that have very low abundance of sandeel. ICES advice for sandeel management is that local depletion of sandeel aggregations should be avoided, particularly in areas where predators congregate. Since 2000, the Firth of Forth area on the east coast of Scotland has been closed to ensure sandeel availability to other parts of the ecosystem, e.g. for breeding kittiwakes. In 2004 and 2005, the EU regulated the fishery using effort limitations, while Norway imposed a shorter fishing season in 2005 (1 April to 23 June) to protect 0-group sandeel. Mesh sizes in sandeel trawls are limited to less than 16 mm, and bycatches are restricted to a maximum five percent in the EU zone and 10% in the Norwegian zone. The spawning stock of sandeel has been at a low level for almost a decade until a recovery in 2008 and is considered to have had reduced reproductive capacity from 2001 to 2006. ICES have advised that in-year real-time management, based on monitoring of the sandeel fishery is desirable, to prevent overfishing.

In the North Sea, gear changes have since 1998 been driven by a combination of economic pressures, particularly fuel prices, a myriad of new technical measures, the introduction of the EU cod recovery programme leading to effort control measures, and also increasingly negative public perception forcing fishers in certain countries to adopt more selective gears. Scottish and Danish demersal vessels tended to diversify away from more traditional methods such as seining and pair trawling/seining for cod, haddock, and whiting to twin and multi-rig gears, fishing with three or more nets targeting monkfish, Nephrops, and mixed demersal species. The main motivation was to reduce fuel combustion and/or improve catching efficiency through increasing the area swept by the gear. This has seen the development of new trawl designs with increased footrope lengths and long wings, so-called “scraper trawls”, as well as designs incorporating wider mouth sections such as double bosom and double bag trawls. Net design for targeting roundfish species such as haddock, whiting, and cod in the North Sea have also developed over the period. Generally nets used in these fisheries are high standing heavy rockhopper trawls, allowing effective fishing even over the hardest bottom. Similar designs have also been employed by Scottish fishers specifically to target squid in inshore areas. This fishery has grown in importance in the period since 2005 and the trawls used are fished with 40 mm codends. Discarding of small cod and haddock has been reported to be high in this fishery. There has also been considerable experimentation with trawls constructed in low diameter, high tenacity polyethylene netting and materials such as dyneema to reduce drag. In many cases, when fuel prices were relatively low, the reductions in drag attained were negated as fishers have actually increased trawl size or increased towing speed in an effort to increase capture efficiency. In recent years this tendency has died out and fishers are increasingly down-sizing gear to reduce fuel consumption. The Norwegian fleet fishing for saithe in the northern North Sea is also increasingly using twin-trawl as opposed to the traditional single trawl, giving an approximately 1.9 increase in catch per unit effort with the twin trawl.

With the recent dramatic increases in fuel prices there has also been a trend amongst trawling fleets to use more fuel-efficient gears. There is evidence, particularly in Scotland, of fishers reverting back to seining and pair trawling/seining. In 2006 it was estimated that approximately 20 twin-rig vessels (16–30m) paired up and concentrated on mixed roundfish, e.g. haddock and whiting. The motivation for this was that vessels can catch their quota with a reduction in fuel cost by 33–50% and similarly fewer days at sea for each boat since the catching power (for haddock and whiting) of a vessel in a pair team may be up to 50 to 100% more than a single vessel operating on its own. The re-emergence in recent years of seining as a fishing method has been accompanied by a move to using much heavier seine rope (40–45 mm diameter), and also heavier footropes incorporating rockhopper sections to increase the range of seabed types that can be fished by seiners.

In both the Netherlands (from the beam trawl fleet) and France (demersal trawl fleet) there has also been a shift from beam trawling to Danish seining, again driven by increased fuel costs. These vessels have tended to target non-quota species such as red mullet, squid, and gurnard, as well as experimenting with trawl warps made of dynex rope and also switching to more fuel-efficient methods such as Scottish seining or gillnetting. These shifts seem likely to continue as fuel prices continue to rise.

Changes in the beam trawling fisheries prosecuted by the Netherlands, Belgium, and UK have focused on lessening the impact on benthic communities and diminishing discarding of target species, sole and plaice, but recently also to decrease fuel consumption. There has been considerable research into ways of reducing the drag of the beam trawl by decreasing the length of the beam or reducing the drag of the shoes (e.g. fly-beam, roller gear). The development of electrified beam trawling for flatfish species has also been tested in the Netherlands, although there are still concerns about the possible ecosystem effects of using this system. Beam trawl skippers are also reportedly towing slower and changing gear components, including using larger mesh sizes in forward parts of the trawl and thinner twines in codends. Since around 2004, some beam trawlers have begun to look at alternative fishing methods. These have included converting to outrigger trawling, i.e. towing two sets of smaller trawls from each beam with smaller trawl
doors, changing over to single or twin-rig trawling, seining, or even changing to gillnetting and longlining. Indications are that this trend will continue in Belgium, the Netherlands, and the UK.

Over recent years the importance of the purse net in the North Sea to target pelagic species has declined with pelagic trawling gaining ground. Midwater trawling has the main advantage of being able to target the fish in deeper water than a purse net can be set in. In Scotland and the Netherlands the tendency has been to use large circumference, large mesh trawls for mackerel and horse mackerel, and smaller circumference, smaller mesh trawls for targeting herring. In Scotland pelagic trawling began as a pair fishing method; however, with the arrival of new modern vessels, they now have sufficient power to single trawl. Single boat pelagic trawlers have also adopted modern, hydrodynamic buoyant trawl doors, and there has also been a tendency to fish nets tight to the seabed, particularly when targeting horse mackerel. Most of the design modifications have been stimulated by the need to improve fishing efficiency by increasing trawl opening, improving water flow within the gear, and also improving fish quality through reduced damage against the mesh.

Developments in static gear fisheries have been fairly limited since 1998 in the North Sea. There has been an increase in the use of multi-wall trammel nets for targeting sole, particularly in the Channel. A shift of effort by deep-water gillnetters targeting monkfish from Area VI and VII into the northern North Sea has also been noted, following the introduction of new EU regulations in 2006 restricting the activities of vessels in this fishery with respect to gear length, soak times, and maximum depth. This effort shift is reported to be quite substantial and may lead to gear conflict and the ghost net issues which have occurred in western waters. Another issue to note with respect to static gear fisheries is that driven by high fuel prices, a number of North Sea countries have been experimenting with pots for Nephrops and also lately for fish species, particularly cod and ling. Initial indications are that potting for fish is technically possible, but economic viability is questionable at this stage. There has also been an increase in the use of automatic jiggling machines for pollack, mackerel, and to a limited extent squid in inshore waters around the UK.

There have been several developments in fish finding and gear monitoring equipment on-board vessels and a number of North Sea fleets have adopted these devices. For instance, Belgium beam trawlers are increasingly being equipped with 3D mapping sonar which has opened up new areas to fishing (close to wrecks). This 3D system opens more grounds that were previously unfishable. Another development seen in the Dutch beam trawl fleet is the installation of automatic winch controls, thus avoiding gear fasteners leading to smaller losses in fishing time, and possibly working on new grounds. Pelagic vessels and indeed larger demersal trawlers have increasingly fitted very sophisticated sonar and used sensors fitted to the trawls to monitor gear performance, particularly flow and trawl symmetry as well as catch size and gear damage. There is also increasing use of econometers to monitor fuel consumption.

Considerable research into fishing gear-based measures to improve selectivity has been undertaken in the North Sea over the period. The different behaviours exhibited by the main discarded species in trawl fisheries have increasingly been exploited to improve the selectivity of trawls. Whiting and haddock rise when inside the trawl, while Nephrops and cod remain near the bottom. Separating cod, and other groundfish, from Nephrops remains the most challenging task for gear technologists. Designs involving square mesh panels, constructed with differing mesh sizes, materials, and positioning within the trawl have been tested extensively (see Section 4.3.4.2). Modified selective trawl designs incorporating escape panels or separator panels as well as rigid sorting grids have also been trialled. Despite this research, very few of these designs have been adopted into legislation and voluntary uptake remains low in the absence of real incentives. Nevertheless, with the recent adoption of effort restriction management in the North Sea by the EU as a way to maintain or increase fishing opportunities, fishers have increasingly moved to selective gears. In Sweden, for instance, a result of the extra effort and also national legislation requiring the use of species-selective Nephrops trawls has been a steady increase in the use of a rigid Nordmore grid in the Nephrops fisheries in the Skagerrak and Kattegat areas.

A number of gear modifications have been tested to improve fish selectivity in flatfish beam trawls, aimed at reducing demersal fish discards in the flatfish beam trawl fisheries. In general it was found that species selectivity of beam trawls could be improved with respect to whiting and haddock, but much less so for cod. In the framework of the Council Regulation laying down certain technical measures for the conservation of fisheries resources (850/98), a general increase in mesh size and the use of square mesh panels in towed gears was suggested to improve the selectivity of towed fishing gears. On the 19th of October 2001, EU Regulation 2056/2001 was adopted, establishing additional technical measures for the recovery of the stocks of cod in the North Sea and to the west of Scotland. It included a provision that the minimum codend mesh size of beam trawls in the North Sea must be 80 mm south of 56°N, and 120 mm north of 56°N (with a restricted area in the western part of the central North Sea, where codends of 100 mm mesh size were made compulsory). However, a general increase in mesh size as first suggested in earlier drafts of the regulations, was firmly rejected due to perceived losses of sole catches. These regulations also included the mandatory insertion of a panel of no less than 180 mm in the top panel of all beam trawls. The effects of the top panel have not been assessed. Mitigating the effects of flatfish beam trawls on benthic invertebrates has also been investigated by the Dutch, Belgian, and UK fleets. Bycatch mortality of benthic organisms accounts for 5–10% of the total benthic mortality caused by beam trawling. Commercially acceptable technical modifications have also been developed for the
catch mortality. The benthos release panel tested in UK, the Netherlands, and Belgium seems to be a simple and practical solution to release bycaught benthic invertebrates from a flatfish beam trawl without substantial loss of commercial fish species. The mesh size used needs to balance the need to reduce the benthos catch against the loss of commercial fish species through the panel. Based on the research work carried out with this gear modification, a mesh size of 150 mm seems to be the best compromise. The benthos release panel has been used voluntarily by some beam trawlers since 2005. In January 2003, legislation was introduced requiring all fishers in the EU *Crangon crangon* (brown shrimp) beam trawl fisheries to use selective gear (sieve net or a selection grid) that reduces the incidental bycatch of juvenile commercial fish species (see Section 4.3.4.3). Compliance is reportedly to be reasonably high and the discard problem in this fishery has been partially negated; however, issues regarding 0-age plaice and the introduction of derogations allowing vessels to fish without the sieve net are identified as problems in such fisheries in the North Sea.

Due to the bycatch of harbour porpoises, the use of acoustic devices, or ‘pingers’, was made mandatory for gillnet fisheries from June 2005 in the North Sea and western Channel, and in the eastern Channel in 2007, for all vessels over 12 m (see Section 4.5.3.). Since its inception a number of practical, technical, and economic issues have arisen that have largely negated effectiveness of this regulation. According to ICES (2008a) only Denmark and Sweden have fully implemented this regulation in the North Sea. There is ongoing German research to develop a device for monitoring acoustic deterrent devices at sea on patrol vessels.

Bycatch of common dolphins has also continued in the Channel bass fishery prosecuted by French and Scottish pelagic trawlers. Research into possible mitigation measures is ongoing and looking mainly at acoustic deterrent devices and excluder grids or panels. Some promising results have been found, but the work remains in a developmental phase.

The insertion of a square-mesh panel into the topsheet of single-rigged *Nephrops* trawls has been mandatory since 1991/92 and an additional 140 mm diamond mesh panel inserted behind the headline since January 2002. Furthermore, prior to 2002 the minimum legal codend mesh size was 70 mm for single-rigged trawls, but since January 2002, this has been increased to 80 mm. The threat of severe restrictions to fishing opportunities or closure of the English *Nephrops* fishery in 2002 in conjunction with the new regulations imposed on other fisheries provided the incentive to implement these gear changes.

The composition of catches was monitored just before and after these regulatory changes. The trawl modifications demonstrated a reduction in discard rate for whiting of 11%. A second more recent study, utilising observer data to compare a longer period before and after the introduction of these changes has also shown that whiting selectivity has improved.

It is apparent that technical measures, i.e. the gear modifications highlighted can in this case provide a partial solution to discarding problems in the North Sea *Nephrops* fisheries.

In January 2003, legislation was introduced requiring all fishers in the European *Crangon crangon* (brown shrimp) fisheries to use selective gear (sieve net or a selection grid) that reduces the incidental bycatch of juvenile commercial fish species. Each member state was responsible for implementing their own legislation enforceable within their national waters. The efficacy of the UK legislation (The Shrimp Fishing Nets Order) was formally evaluated in a multi-disciplinary study using social, biological, and economic methods. The analysis of the societal aspects of the changes seen after the introduction of the legislation was used to identify the changes in fleet structure and fishing patterns and the extent of compliance and enforcement. The biological analysis evaluated the performance of commercially used selective gear and also identified changes in fish stocks of bycatch species. The economic analysis assessed the economic implications of the legislation. The retrospective change in productivity of the brown shrimp fleet as a consequence of the use of sieve nets was estimated using a production function approach. The analysis utilized vessel logbook data, detailing brown shrimp landings by individual trip during the period January 1999 to August 2006. The analysis showed a reduction in fleet productivity of 14% following the introduction of the legislation.

The gear measures introduced into the *Crangon* beam trawl fisheries have largely been effective although the introduction of derogations for some fleets has reduced the effectiveness. This has been a weakness in a number of technical measures regulations.

**Fishing activities in OSPAR Region II – Greater North Sea**

The amount of fishing effort, expressed in terms of kW days-at-sea and total hours fished, has declined by around 25% from 2000 to 2006 (Figures 1.5.5.9.3.2, 1.5.5.9.3.3, and 1.5.5.9.3.4). Both otter and beam trawling show similar patterns of decline, the greatest change occurring from 2002 to 2003 with the measures, particularly effort control (days-at-sea limits), introduced as part of the CFP reform. In part this reduction in vessel effort may be offset by increases in the fishing efficiency through improved gear design and use (technical creep), hence changes in effort are not directly related to changes in mortality.
Figure 1.5.5.9.3.2. Trends in nominal fishing effort (kW*days-at-sea) in the Skagerrak, North Sea, & Eastern Channel by gear type. Gear codes are 4a: demersal trawl, 4b: beam trawl, 4c: gillnet, 4d: trammelnet, 4e: longline, none: unidentified (STECF, 2007).

Roundfish are caught in otter trawl and seine fisheries, with a 120 mm minimum mesh size. This is a mixed demersal fishery with more specific targeting of individual species in some areas and/or seasons. Cod, haddock, and whiting form the predominant roundfish catch in the mixed fisheries, although there can be important bycatches of other species, notably saithe and anglerfish in the northern and eastern North Sea and of Nephrops in the more offshore Nephrops grounds.

Beam trawling takes place predominantly in the southern North Sea. As total beam trawl effort has declined, effort has reduced more or less evenly across the entire impacted area (Figure 1.5.5.9.3.3). Otter trawling targeting fish takes place across the entire North Sea, but with activity levels highest in the north. As total effort has declined the greatest reductions have occurred in this northern region (Figure 1.5.5.9.3.4). Otter trawling targeting Nephrops is generally restricted to specific muddy areas of the North Sea that are the preferred habitat of the target species. Effort levels by this gear increased over the period for which spatial information was available, and this has been associated with an expansion of this fishing activity into new areas (Figure 1.5.5.9.3.5). Seine nets are mainly used in the northern North Sea with little or no use of this gear in the extreme south. As total seine effort has declined, marked reductions in activity have occurred in the northern North Sea, but the extent of the area impacted has also declined (Figure 1.5.5.9.3.6).

STECF (2007) concluded that there had been no large-scale and consistent changes in the recent geographical distribution patterns of demersal trawl effort, although local variations in the intensity and distribution of fishing effort have been observed and there was a consistent shift in the distribution of beam trawlers using 70–89 mm and ≥120 mm mesh. These beam trawlers, from Belgium, Germany, and UK, fish more frequently in the southern North Sea (Figure 1.5.5.9.3.3). It remains unclear whether the observed changes in the distribution of beam trawling effort are due to changes in the abundance of target stocks, economic considerations, or effort regulations.
Figure 1.5.5.9.3.3 Spatial distributions of fishing effort (hours-fishing) using beam trawl by the nine major fishing nations operating in the North Sea in each of the years between 1997 and 2004. Greenstreet et al., 2007.

Figure 1.5.5.9.3.4 Spatial distributions of fishing effort (hours-fishing) using otter trawl directed at fish for human consumption by the nine major fishing nations operating in the North Sea in each of the years between 1997 and 2004. Greenstreet et al., 2007.
Figure 1.5.5.9.3.5 Spatial distributions of fishing effort (hours-fishing) using otter trawl directed at *Nephrops* by the nine major fishing nations operating in the North Sea in each of the years between 1997 and 2004. Greenstreet *et al.*, 2007.

Figure 1.5.5.9.3.6 Spatial distributions of fishing effort (hours-fishing) using seine gear by the nine major fishing nations operating in the North Sea in each of the years between 1997 and 2004. Greenstreet *et al.*, 2007.
Impacts of fisheries on the ecosystem

Commercial fishing has direct and indirect effects on the marine ecosystem, which can be summarized as effects on:

1. commercial fish stocks;
2. non-target species, including birds, marine mammals, and discarded fish;
3. the seabed and associated benthic communities and habitats;
4. community structure and food webs.

Effects on commercial fish stocks

Biomass and fishing mortality limit reference points have only been defined for nine of the stocks assessed by ICES and allocated to Region II. Total landings from these stocks accounted for 13.11 million tonnes, or 20.5% of the total reported landings of 64.02 million tonnes of fish and shellfish from this region in the period 1986 to 2006. Temporal trends in the spawning-stock biomass (SSB) and fishing mortality (F) of these stocks in relation to their limit reference points are shown in Figure 1.5.5.9.3.7.

ICES prefers to give precedence to an analysis based on stocks for which limit reference points have been defined as the main indicator of fishing impacts on commercial stocks, because it is not straightforward to define stock status when limit reference points have not been defined. For demersal stocks, significant fishing impacts on assessed species are often indicative of significant fishing impacts on larger, more vulnerable species that are not assessed, but are taken as bycatch.

To determine the status of assessed stocks in relation to reference points we used 2005 rather than 2007 estimates of F and SSB. This is because the 2006 and 2007 estimates are less precise due to the so-called “convergence” feature of the methods used in fish stock assessment. The overall status of assessed stocks for which all reference points have been defined is shown in Figure 1.5.5.9.3.8. Thus in 2005, the reference year, five of the nine stocks were harvested unsustainably and/or suffering reduced reproductive capacity.

When considering the historical state of fish stocks and their management, Fpa and Bpa are not as relevant as Flim and Blim. For this reason the analyses focused only on the limit reference points. This means that no distinction was made between stocks that are harvested sustainably and those at risk of being harvested unsustainably (since in both cases F < Flim), and no distinction was made between stocks at risk of suffering reduced reproductive capacity and those at full reproductive capacity (in both cases B > Blim). This is unfortunate, but is also consistent with the focus of current ICES advice on the avoidance of limits rather than the achievement of targets.

Fishing mortality is generally high for several demersal stocks in the North Sea, but there are indications that fishing mortality on some stocks has been decreasing in recent years (Figure 1.5.5.9.3.7). This is consistent with the observed decrease in fishing effort due to days-at-sea regulations and decommissioning in the major fleets. Assessments of cod Gadus morhua, in the North Sea, Skagerrak, and eastern English Channel (North Sea cod), show trends in spawning-stock biomass (SSB), the mature component of the stock, declining from a peak of 250 000 t in the early 1970s to around 40 000 t. The stock is below the limit reference point of 70 000 t, indicative of a stock that is suffering reduced reproductive capacity.

The centre of the distribution of cod in the North Sea has moved north, associated with the different sub-population responses to both warming and differing spatial fishing pressures. Although cod remain widely dispersed, survey data have shown a contraction of distribution within the range so that most young cod are now found in just 40–50% of the North Sea, compared with 90% when cod were at their most abundant. There appears to have been a particular reduction in the spawning intensity in the Southern Bight, but other spawning locations have remained unchanged.
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Cod in Sub-area IV, Division VIIId & Division IIIa (Skagerrak)

Cod in the Kattegat (part of Division IIIa). Data from the 2006 assessment

Haddock in Sub-area IV (North Sea) and Division IIIa
Plaice in Division VIIId (Eastern Channel)

Plaice Sub-area IV (North Sea)

Saithe in Sub-area IV, Division IIIa (Skagerrak) & Sub-area VI
Figure 1.5.5.9.3.7 Trends in fishing mortality (F) and spawning-stock biomass (SSB) of assessed stocks allocated to OSPAR Region II and for which fishing mortality and biomass reference points have been defined. Continuous red horizontal lines show the limit reference points (F lim and B lim, respectively) while broken red horizontal lines show the precautionary reference points (F pa and B pa, respectively, when defined). The age classes for which values of F were calculated are shown in parentheses.

Figure 1.5.5.9.3.8 Summary of the status of assessed fish stocks in OSPAR Region II in 2005. Only those stocks for which F lim and B lim have been defined are included. Numbers in boxes refer to numbers of assessed stocks in each category.

Advice on status in relation to limit reference points is available for a relatively small proportion of the fish stocks that are fished in the North Sea, and for none of the invertebrate stocks. This reflects the considerable data demands necessary to support the assessment methods used by ICES.
Effects on non-target species, including birds, marine mammals, and discarded fish

Extensive discarding occurs in most fisheries on roundfish, flatfish, and *Nephrops* in the North Sea. These discards consist of predominantly small and juvenile fish below or close to the minimum landing size and of larger individuals of species without a reliable market.

The exploitation of sole and plaice are closely connected as they are caught together in fisheries mainly targeting sole, which are more valuable. This means that the minimum mesh size is decided on the basis of the more valuable species, resulting in substantial discards of undersized plaice. The mixed fisheries for flatfish are dominated by a mixed beam trawl fishery in the southern North Sea where up to 80% in number of all plaice caught are being discarded.

Based on the estimates of STECF (2007) the range of mean discard rates in the North Sea and eastern Channel flatfish fisheries by number by trip for drift netters is 29–63% for plaice (France and Germany), 61–100% for whiting (UK and Germany), 65–99% for dab, and 5–16% for sole (UK, France, and Germany). For the demersal trawlers, the range of mean discard rates (by trip and by number) for UK, France, Germany, and Denmark was 13–61% for plaice, 36–75% for whiting, and 65–94% for dab. For beam trawlers mean discard rates ranged from 13–81% for plaice, 78–98% for whiting, 65–98% for dab, and 11–27% for sole. In general, large numbers of whiting and dab above the Minimum Landing Size were discarded; this may have been due to the absence of a market for these fish.

The discard rate (by weight) in the English *Nephrops* fishery off the northeast coast of England was estimated at 4890 tonnes in the 2001/2002 season, equating to a discard rate of 57%. Discards in this fishery are dominated by whiting; other significant components of the discards include haddock, *Nephrops*, and commercial flatfish species. In 2001/2002 whiting discards from this fishery were thought to account for 16% of the estimated whiting discards for the entire North Sea. The weight of discarded whiting was estimated at six times that of the landed weight of whiting. Effort in the *Nephrops* fishery increased and then decreased in the period 1998 to 2006, and regulations have changed, so the discard rate reported in 2001/2 may not be representative of rates in other years.

The insertion of a square-mesh panel into the topsheet of single-rigged trawls used in the *Nephrops* fishery has been mandatory since 1991/92 and an additional 140 mm diamond mesh panel inserted behind the headline since January 2002. Furthermore, prior to 2002 the minimum legal codend mesh size was 70 mm for single-rigged trawls, but since January 2002, this has been increased to 80 mm. The threat of severe restrictions to fishing opportunities or closure of the English *Nephrops* fishery in 2002, in conjunction with the new regulations imposed on other fisheries provided the incentive to implement these gear changes.

The composition of catches has been monitored before and after these regulatory changes. The trawl modifications led to a reduction in discard rate for whiting of 11%. A second more recent study, utilising observer data to compare a longer period before and after the introduction of these changes, has also shown that whiting selectivity has improved.

The discard mortality on small commercial fish in the North Sea has contributed to the decline of stocks and consequent reduction in yields. Moreover, changes in community structure through discarding, either directly through discard mortality or indirectly, modify the energy flow through food webs.

Effects on the seabed and associated benthic communities and habitats

International beam and otter trawl effort, expressed as hours fished, declined by 31% and 44% respectively from 1997 to 2004 (Greenstreet et al., 2007; however, otter trawl effort directed at *Nephrops* increased by 65%. Given that *Nephrops* are restricted to a narrow range of seaboards the total spatial footprint of bottom fishing activity in the North Sea is expected to have declined since 1997, although this cannot be tested explicitly because satellite Vessel Monitoring System coverage was not available throughout this period. However, the spatial distribution of effort has increased in some areas as a result of the relocation of bottom fishing activity and thus previously lightly impacted areas may now be subjected to high intensities of physical disturbance. Such changes are inevitable when fishing fleets can operate on large spatial scales and drivers such as regulation and oil prices affect their behaviour. For example, the cod box closure of 2001 led to the beam trawl vessels fishing in previously unimpacted areas and the increased physical disturbance may have led to a greater reduction in the total productivity of benthic communities (Rijnsdorp et al., 2001; Dinmore et al., 2003). Changes in effort distribution can have significant effects on the overall impact of disturbance in the North Sea since there are considerable local variations in the sensitivity of seaboards to trawling disturbance (Figure 1.5.5.9.3.9).

Analysis of beam trawling impacts in the southern and central North Sea has shown that the impacts of trawling were greatest in areas with low levels of natural disturbance, while the impact of trawling was relatively small in areas with high rates of natural disturbance. Over the entire area, beam trawl fishing is reported to have reduced total benthic biomass and production by 56% and 21%, respectively, compared with an unfished situation. In 2003, the biomass of benthic invertibrates was less than 90% of the predicted biomass in the absence of fishing over 56% of the area of the southern and central North Sea and production was less than 90% of the predicted production in the absence of fishing.
over 27% of the area. Despite these changes in biomass and production, the spatial distribution of the macrofaunal communities as described using multivariate methods that focus on species identity and distribution was largely unchanged between 1986 and 2000.

Figure 1.5.5.9.3.9  Estimated recovery time (years) for southern North Sea benthic communities following one pass of a beam trawl. Recovery is a measure of the time required for benthic production to return to 90% of the production in the absence of trawling disturbance. Hiddink et al. (2006).

Effects on community structure and food webs

In addition to the changes in benthic communities that result from physical impacts on the seabed described in the previous section, fishing has led to changes in fish community structure. These are manifest as reductions in the relative abundance of larger individuals and species and the effective loss of species such as common skate *Dipturus batis* from Region II (ICES, 2008b). Mortality rates on thornback ray, cuckoo ray, and spotted ray were thought to exceed sustainable levels in the early part of the period (Walker and Hislop, 1998), but it is unclear whether the reductions in average *F* on demersal species have been sufficient to change this situation.

Analyses of data from national and international fish surveys in the North Sea show that the mean size of individuals in the demersal fish community has decreased, as well as the proportion of species with larger body sizes (Figure 1.5.5.9.3.10). Since larger individuals generally feed at higher trophic levels, the decreases in the abundance of larger individuals has paralleled a decline in the trophic level of the community. The declining trend in larger species and individuals is less pronounced from 1998 to 2007, with some data sources indicating a slowing and even some reversal of the long-term trend. This may be indicative of recent reductions in fishing effort which have led to reductions in the average mortality on demersal species (Figure 1.5.5.9.3.11), but given the expected interannual variability in these size-based metrics an assessment of the longer-term significance of these trends will be contingent on evidence for the persistence of the recent changes.
Figure 1.5.5.9.3.10 Trend in the proportion of large fish (the ratio between the weight of fish larger than 40 cm relative to the weight of fish larger than 10 cm). The metric is calculated for the North Sea demersal fish assemblage as sampled by the International Bottom Trawl Survey in the first quarter. From ICES (2008c).

Figure 1.5.5.9.3.11 Trends in average fishing mortality on North Sea demersal species. Source: ICES (2007).

Fishing-induced depletions in the abundance of large predatory fish species have had an indirect effect on community structure (ICES 2008b, c). Absolute numbers of both small fish belonging to all species and of demersal species with a low maximum length have steadily and significantly increased over large parts of the area during the last 30 years, while the abundance of large fish has decreased. These changes in the size composition of the demersal fish community sampled during fish surveys are reflected in the steeper slopes of size spectra (relationships between the abundance of fish in body-size classes and body size), which are driven both by decreases in the abundance of large individuals and absolute increases in the abundance of small individuals. The best available explanation for this shift is the reduction of the predation pressure on juveniles of large species and small species. This is an indirect effect of overexploitation of the larger predators. Changes in the size-composition of the community are expected to be more closely linked to fishing impacts than climate changes since climate has a greater influence on species composition than size composition.

The overall decline in fishing activity and in fish discards in particular may have impacted seabird communities directly through food subsidies and indirectly through the food web. Over the past decade, 12 out of 28 seabird species in the Region show an increasing trend, 4 others including the northern fulmar and black-legged kittiwake show a decreasing trend, while another 4 appeared stable. Effects on the food web have been suggested due to removal of sandeels by the industrial fishery. Sandeels are an essential component of the diet of many fish species as well as seabirds and marine mammals and their low abundance is therefore expected to have severe implications for the whole North Sea ecosystem. Low breeding success for some seabird species in some areas has been attributed to sandeel removals by fishing, or the effects of fishing on sandeel recruitment. However, it is difficult to establish causality and to distinguish between fishing and environmental effects.
Conclusions

Fishing effort and mortality rates have started to fall in the period 1998 to 2007 and there are tentative signs of increases in the abundance of some fish stocks and the proportion of larger individuals and species in the fish community. The species that are most vulnerable to fishing in Region II, especially skates and rays, continue to be impacted by unsustainable rates of fishing. Despite recent reductions in effort and smaller reductions in mortality, Region II is still heavily modified by fishing and both fish stock abundance and the state of some other components of the marine environment are not consistent with management objectives. Even for a ‘data-rich’ region, a relatively small proportion of species impacted by fishing are quantitatively assessed and reference points have only been determined for a small number of these. Further, for those stocks with reference points, the assessments still focus on advice relating to the avoidance of limits rather than the attainment of targets that are more consistent with commitments to achieving MSY.

References


1.5.5.9.d Regional QSR III: Celtic Seas

Introduction

Traditionally the coastal shelf seas to the west of the UK and France and surrounding Ireland have supported demersal fisheries for whitefish and flatfish, and in some locations for Nephrops and scallops. There were also large seasonal pelagic fisheries for mackerel, horse mackerel, and herring while the inshore grounds have supported crab, lobster, and other shellfish fisheries. The main fishing nations operating in Region III are Ireland and Scotland (UK) along with France and Spain.

The development of fisheries management and policy since 1998, and an assessment of their effectiveness

Major changes in the management of the fisheries are described in the QSR NE Atlantic Overview section. In this section, we consider those measures from a regional (OSPAR Region III – Celtic Seas) perspective.

In the Celtic Sea since 1998, there have been changes in the gear types being used, the introduction of new techniques or new fisheries, evidence of technological creep, and new legislation which has either shifted fishing effort into other fisheries or encouraged fishers to adopt new gears. For example, over this period economics, and in particular with low fuel prices in the late 1990s followed by a sharp increase in recent years, as well as the introduction of considerable regulation have been the main drivers for the changes observed. As a consequence, some beam trawlers have switched to otter trawl gear. This has led to increased catches of skates and rays and seasonally increased catches of other species such as bass. In addition, beam trawlers have changed over to scallop fishing which is highly unregulated. Accordingly, scallops are coming under increasing pressure due to the displacement of effort from other fisheries. In the west of Scotland TAC availability is a major driver of effort switching between areas – largely driven by the significant increase in fishing opportunities in adjacent areas.

In the demersal trawl fisheries there was widespread use of twin-rig trawls for species such as Nephrops and monkfish. The primary motivation for the adoption of this gear has been better ground contact that can be generated with this gear compared to standard single rigs. The move to twin rigging has been accompanied by an improvement in available gear monitoring equipment, which allows fishers to control the spread and symmetry of their trawls. Demersal trawl design has also concentrated on increased spreads and vertical opening to increase catching efficiency. Double bosom trawls with two mouths and double bag trawls with extra wide mouths to accommodate the two codends are now being used. However, recent increases in fuel prices has halted this trend and, as apparent in Ireland, Scotland, and France, fishers have begun to return to single rig trawls, using trawls constructed in low diameter, high tenacity materials. There is also a move towards more fuel-efficient methods such as Scottish seineing or gillnetting. Also of note is the change in use of technology to deliver better performance. In demersal fisheries this has included the testing of square mesh panels, selective codends, trawls with reduced top sheet sections, grids, and separator trawls (Section 4.4.4.2). Some of these developments in pelagic net design and sophisticated fish finding equipment. Trawls are now constructed with very large meshes in their fore parts (anything up to 128 mm meshes) and constructed using low drag materials. There has also been a shift to using hexagonal meshes in the front section to increase vertical and horizontal opening, while pelagic codends are now commonly constructed with the mesh orientated at 90° to that in the body of the net and with the inclusion of square mesh netting to improve water flow and reduce meshing. One of the latest developments in pelagic trawl design is the manufacture of so-called “self-spreading” trawls, which utilises the force of the water current through the net to spread the trawl without increasing towing resistance. Such trawls have been found to give the same effective horizontal and vertical openings for approximately 20% the twine surface area.

In static net fisheries there has been less development. Gear design has remained fairly similar with the only significant changes being a general increase in the amount of gear being used per vessel and lengthy soak times adopted in some fisheries, with subsequent increased discarding.

In the past decade, legislation in conjunction with the necessity for increased efficiency of gear (in order to reduce operating costs) and also lately, market pressures for fishers to act responsibly, has driven the development of gear technology to deliver better performance. In demersal fisheries this has including the testing of square mesh panels, selective codends, trawls with reduced top sheet sections, grids, and separator trawls (Section 4.4.4.2). Some of these modifications have found their way into legislation while others have seen limited voluntary adoption. Formal assessment of these measures remains incomplete with only limited data being available on the benefit to stocks of commercial fish species.

In order to reduce bycatch of harbour porpoises, the use of acoustic devices or ‘pingers’, was made mandatory for gillnet fisheries from January 2006 in the Celtic Sea and the western Channel and in 2007 in the eastern Channel for all
vessels over 12 m. Since its inception a number of practical, technical, and economic issues have arisen that have largely negated effectiveness of this regulation and it is doubtful whether any meaningful reduction in harbour porpoise bycatch has been achieved by these measures in the Celtic Sea area.

Recovery plans exist within the ‘Celtic Seas’ area for cod and hake. The EC regulation for cod has recently been amended (amending Regulation (EC) No. 423/2004 as regards the recovery of cod stocks and amending Regulation (EEC) No. 2847/93) in an attempt to speed the recovery of cod in community waters. Celtic Sea (VIIg) cod was previously excluded from the 2004 cod recovery plan on the basis of its better conservation status. Seasonal restrictions also exist on the fishing of herring off the south coast of Ireland, in parts of the Irish Sea, and north and east of the outer Hebrides. In an area surrounding Cornwall (ICES Division VIIf in its entirety and part of the adjoining VIIg,h,e), no directed fishing on mackerel is allowed, except with gillnets and handlines. The fishery for Celtic Sea sole (ICES Division VIIIf,g) is concentrated on the north Cornish coast and an average landing of 1000 tonnes is taken mainly by beam trawlers. Since 2003, fishing mortality has dropped substantially so that current fishing mortality is considered sustainable. Council Regulation (EC) No. 41/2007, Annex III, part A 7.2 prohibited fishing between the Cornish and the Welsh coasts (ICES rectangles 30E4, 31E4, and 32E3) during February and March 2007 with some gear-specific derogations. Lobster v-notching is a technical conservation measure, applied to the Irish lobster stock, which ensures that marked female lobsters have an opportunity to breed at least once before they are harvested. While stocks in Ireland appear to be depleted there is some evidence to suggest that, in some areas, v-notching in conjunction with reduced fishing effort has resulted in a positive response in terms of lobster stocks (BIM, 2008).
Figure 1.5.5.9.4.1 Areas closed to fishing for cod and hake in 2007 with insert showing the ‘windsock area’ north of Scotland which is included in the ‘cod recovery plan’.

Fishing activities in the OSPAR Region III (Celtic Seas)

Landings of the main species exploited for human consumption in the Celtic Seas Region have declined in recent years. In contrast, the industrial fishery for blue whiting, most of which occurs in Region V, has developed in recent years and showed an increase in landings since the late 1990s (Figure 1.5.5.9.4.4).
Overall, the fishing effort employed in the Celtic Seas, excluding the Irish Sea had an increasing tendency up to 2002 and subsequently declined (Figure 1.5.5.9.4.2a), with little difference in effort between the start and end of the decade. In contrast in the Irish Sea effort has generally been declining, slightly, each year. The apparent increases in both otter and beam trawling in this area between 2002 and 2003 and the mostly downward trend in ‘other’ is a reflection of the ‘other’ category including fishing for which the details of the gear were not known. As data capture has improved so has the other category been resolved into either otter or beam trawling. Although spatially the general decrease is apparent in this area, there is some evidence of an increase in effort off the coast of Brittany (Figure 1.5.5.9.4.3).

**Figure 1.5.5.9.4.2** Trends in nominal fishing effort (kW*days at sea) in (a) the Celtic Seas excluding the Irish Sea and (b) the Irish Sea by major gear type (from STECF, 2006).
Mackerel range from north of the Arctic Circle to Portugal and Spain in the south and is mainly exploited in a directed fishery for human consumption. This fishery tends to target bigger fish and there is evidence that this does cause the discarding of smaller, yet marketable, fish. Mackerel are generally caught near the shelf edge, particularly in the central area of the fishes range. In recent years (2005–2006) there has been an overall reduction in catches, but on a smaller scale there appears to have been a relative increase in catches near the shelf edge, with other areas showing only minor variation (Figure 1.5.5.9.4.4).

Western horse mackerel is taken in a variety of fisheries exploiting juvenile fish for the human consumption market (with mid-aged fish mostly for the Japanese market), and older fish either for human consumption purposes (mostly for the African market) or for industrial purposes. From about 1994 onwards the fishery on juveniles expanded, resulting in

Figure 1.5.5.9.4.3 Demersal effort (kW*days) by three main gear types (otter trawl, beam trawl, and demersal seine) and by ICES statistical rectangle. Left column: mean effort 2003–2006 and Right column: recent change in effort (2005–2006 effort minus 2003–2004 effort) (note: no Spanish effort data supplied).
a change in exploitation pattern for the stock. This may be due to the lack of older fish (decline of the 1982 year class) and the development of a market for juveniles. The percentage of catch (in weight) in the juvenile areas increased gradually from about 40% in 1997 to about 65% in 2003, dropping again to 40% in 2005 and 2006. Landings have generally been declining. Spatially the picture is mixed with the greatest reductions appearing at the entrance to the western English Channel and to the southwest of Ireland, with some suggestion that catches have increased further into the English Channel and also to the south of the Celtic Sea (Figure 1.5.5.9.4.4).

High landings of blue whiting from Region III over the last decade, which peaked in 2003–2004, were supported by enhanced recruitments. Spatially there appears to have been an increase in catches in deeper waters just west of the shelf edge (Figure 1.5.5.9.4.4), probably due to movement in fishing effort between these areas. The blue whiting stock is vulnerable to overexploitation because fishing mortality has remained high while recruitment has been consistently falling since 2003. The knowledge of the factors which drive blue whiting recruitment is very limited. It is not known if the poor 2005 and 2006 year classes are an anomaly or if it is a shift towards the low recruitment regime, as observed in the period before the mid-1990s.
Belgium, the Netherlands, and the United Kingdom (UK) are the main nations with beam trawl fisheries in Region III. These fleets target species such as flatfish, mainly sole (*Solea solea*) and plaice (*Pleuronectes platessa*), and groundfish species such as cod (*Gadus morhua*).

The following case-study focuses on the technical alterations to beam trawls that can reduce the direct ecosystem effects of this fishing method.

In the framework of the Council Regulation laying down certain technical measures for the conservation of fisheries resources (850/98), a general increase in mesh size and the use of square mesh panels in towed gears was suggested to improve the selectivity of towed fishing gears. On the 19th of October 2001, EU Regulation 2056/2001 was adopted,
establishing additional technical measures for the recovery of the stocks of cod in the North Sea and to the west of Scotland. It included as a provision that the minimum codend mesh size of beam trawls in the North Sea must be 80 mm south of 56°N, and 120 mm north of 56°N (with a restricted area in the western part of the central North Sea, where codends of 100 mm mesh size were made compulsory). However, a general increase in mesh size as first suggested in earlier drafts of the regulations, was firmly rejected due to perceived losses of sole catches. These regulations also included the mandatory insertion of a panel of no less than 180 mm in the top panel of all beam trawls.

There are a number of other discard (fish and benthos) reduction devices such as benthic release panels that are not currently included in technical measures legislation; however, there is evidence of increasing voluntary use of some of them.

The use of more selective beam trawl gear is being driven by the market place as well. Public perception of beam trawl-caught fish has become increasingly negative, putting pressure on fishers to adopt more responsible fishing practices. More importantly, some multiple retailers have publically stated a desire to move away from sourcing beam trawl-captured fish, or have executed this policy already. This move has gained increasing momentum worldwide with the advent of certification schemes such as MSC and Seafish Responsible Fishing Scheme, and also through competitions such as the WWF Smart Gear competition or the Responsible Fishing Gear competition in the UK.

The effect of the existing regulations under 850/98 and the additional requirements included in 2056/2001 designed to improve species selectivity have not been properly evaluated. Enever et al. (submitted) has showed a significant reduction in fish discards by number by increasing mesh sizes from 80–89 mm to 90–110 mm and 110–120 mm.

**Figure 1.5.5.9.4.5** Proportion of catch discarded (all finfish numbers combined) by English and Welsh registered beam trawlers in the North Sea between 1999 and 2006, fitted for varying codend mesh size groups (Modified from Enever et al., submitted).

**Impacts of fisheries on the ecosystem**

Commercial fishing has direct and indirect effects on the marine ecosystem, which can be summarized as effects on:

1. commercial fish stocks;
2. non-target species, including birds, marine mammals, and discarded fish;
3. the seabed and associated benthic communities and habitats;
4. community structure and food webs.

**Effects on commercial fish stocks**

Biomass and fishing mortality limit reference points have only been defined for four of the stocks assessed by ICES and allocated to Region III. Total landings from these stocks accounted for 1.8 million tonnes or 7.3% of the total reported landings of 24.7 million tonnes of fish and shellfish from this region in the period 1986 to 2006. Temporal trends in the spawning-stock biomass (SSB) and fishing mortality (F) of these stocks in relation to their limit reference points are shown in Figure 1.5.5.9.4.6.
ICES prefers to give precedence to an analysis based on stocks for which reference points have been defined as the main indicator of fishing impacts on commercial stocks because it is not straightforward to define stock status in relation to a management objective when reference points have not been defined. For demersal stocks, significant fishing impacts on assessed species are often indicative of significant fishing impacts on larger, more vulnerable species that are not assessed but taken as bycatch.

The overall status of assessed stocks for which all reference points have been defined is shown in Figure 1.5.5.9.4.7. It must be pointed out that the coding used in the summary assessment presented in Figure 1.5.5.9.4.7 might give a misleading impression regarding the status of the stock. Consequently, the status of the stock must also be considered in light of the time-series graphs presented in Figure 1.5.5.9.4.6.

Overall, there were four stocks considered for inclusion in this analysis, one stock (herring) was assessed using 2003 data as there were no assessments conducted after this date. Three other stocks (cod, hake, and sole) were analysed using 2005 data. The herring 2003 and sole 2005 stocks were both considered to be harvested unsustainably and suffering from reduced reproductive capacity. While the sole biomass and mortality values appear to be relatively close to the precautionary reference points, the herring values are considerably removed from the precautionary points, indicating a highly stressed stock. Cod in 2005 was considered to be harvested sustainably, yet suffering reduced reproductive capacity. Hake in 2005 was considered to be harvested sustainably and at full reproductive capacity; however, the values for biomass and mortality are still relatively close to the precautionary limits. This stock should continue to be assessed to validate the observed trends, which seem to demonstrate a gradual improvement in status.

To determine the status of assessed stocks in relation to reference points the 2005 (or earlier) estimates of \( F \) and \( SSB \) were used rather than the 2007 ones. This is because the 2006 and 2007 estimates are less precise due to the so-called “convergence” feature of the methods used in fish stock assessment.

The biological reference points \( F_{pa} \) and \( B_{pa} \) are developed to take the imprecision into account in the most recent estimates of \( F \) and \( SSB \) when developing fisheries management advice for fish quotas in the near future. Thus, when considering historical performance of fish stocks, \( F_{pa} \) and \( B_{pa} \) are not as relevant as \( F_{lim} \) and \( B_{lim} \) and focused only on the limit reference points. This means no distinction was made between the stocks that are harvested sustainably and those at risk of being harvested unsustainably (since in both cases \( F < F_{lim} \)), and no distinction was made between the stocks at risk of suffering reduced reproductive capacity and those at full reproductive capacity (in both cases \( B > B_{lim} \)). This is unfortunate, but does reflect the focus of current ICES advice on the avoidance of limits rather than the achievement of targets.
Figure 1.5.5.9.4.6  Trends in fishing mortality (F) and spawning stock-biomass (SSB) in assessed stocks allocated to OSPAR Region III and for which fishing mortality and biomass reference points have been defined. Continuous red horizontal lines show the limit reference points (\(F_{lim}\) and \(B_{lim}\), respectively) while broken red horizontal lines show the precautionary reference points (\(F_{pa}\) and \(B_{pa}\), respectively, where defined). The age classes for which values of F were calculated are shown in parentheses.
Figure 1.5.5.9.4.7  Summary of the status of assessed fish stocks in OSPAR Region 3 in 2005. Only those stocks for which Flim and Blim have been defined are included.

Landings of rays appear as a series of peaks and troughs, with lows of approximately 14 000 t in the mid-1970s and 1990s, and highs of just over 20 000 t in the early and late 1980s and late 1990s (Figure 1.5.5.9.4.8). While landings have fluctuated considerably over the time-series, they have been in a constant decline since 2003, and the 2006 landings of approximately 10 000 t are the lowest in the time-series. This decline in landings is thought to be due to a combination of increased regulation and changes in consumption. Fishery-independent data recording the landings of specimen rays by recreational anglers in the Irish Sea reported a linear decrease in the mean size of thornback rays landed between 1974 and 2002 (Richardson et al., 2006). This highlights a major deficiency in the manner in which landings of skates and rays are currently reported. No distinction is made between landings of different species of skates and rays. These species have widely contrasting life histories that make them more or less vulnerable to over-exploitation.

Figure 1.5.5.9.4.8  Total landings (tonnes) of Rajidae by nation in the Celtic Seas from 1973–2006 (Source: ICES).

Effects on non-target species, including birds, marine mammals, and discarded fish

The removal of the target fish and the incidental catch of small fish have had a widespread effect on the groundfish communities throughout the region. Scottish and Irish groundfish surveys (1997–2000 and 1993–2000, respectively) show declines in the biomass and abundance of cod, whiting, and hake, amongst others, which were more pronounced in the latter part of the time-series. In some cases these have translated to changes in the ecosystem structure. For example, in the Celtic Sea, the capture and discarding of large numbers of immature fish has significantly altered the
size structure of a number of commercial species. Discarding levels differ between the different fleets but can be as high as two thirds of the total catch. In addition, increased discarding rates have also been attributed to the exhaustion of single-species quotas in multi-species fisheries. Celtic Sea cod and Irish Sea haddock are two cases in point.

Analysis of discarding levels of the demersal fleet around Ireland has shown that a significant proportion of the catch is discarded (Borges et al., 2005). Discarding levels differ between the different fleets but have shown to be up to two thirds of the total catch. In this study, whiting, haddock, megrim, and dogfish are the main species discarded by otter trawlers, while the Scottish seiners discard mostly whiting, haddock, and grey gurnard and beam trawlers discard mostly dab and plaice. The majority of these discard species consist of immature fish and discarding appears to be increasing in recent years.

Cetacean bycatch occurs in this Region, mainly affecting small cetaceans – i.e. dolphins, porpoises, and the smaller toothed whales. Bycatch of common dolphins in fisheries in the northeast Atlantic have been reported for several decades, but only since the 1990s have large numbers of dead dolphins that had evidently died in fishing gear, washed ashore. Two types of fishery are considered to pose a particular threat to common dolphins, pelagic trawls and bottom-set nets. The pelagic trawl fisheries in the northeast Atlantic are complex and varied, with over twelve species targeted by vessels from six EU member states (with maybe further non-EU nations operating in international waters) using at least three major gear types. An even greater complexity applies to the bottom-set net fisheries. Some of these fisheries have relatively low or non-existent cetacean bycatches, others apparently have relatively high bycatches (e.g. the fishery for hake/pollock). For most fisheries, however, there is insufficient information to assess total cetacean bycatch at present.

Information from the Petracet Project (EU) and national programmes suggests that the total mortality of common dolphins in European pelagic trawl fisheries in the ICES area is currently probably around 800 animals per year, though large interannual variation in bycatch is known to occur in some fisheries, such as in the bass and tuna fisheries. Bycatch of common dolphins, though limited in numbers are also known to occur in other fisheries, including VHVO (Very High Vertical Opening) trawls, bottom trawls, and static nets (ICES, 2007). However, there is considerable variability in the estimated total bycatch in fisheries for which several years of data are available. This implies that there are dangers in taking (or not taking) measures based on only one or two years of bycatch data and that observation will need to continue in several fisheries where programmes appear to have finished (ICES, 2007).

**Effects on the seabed and associated benthic communities and habitats**

The effect of fisheries on habitat structure is not routinely monitored in this region. In addition, there have been no large-scale (1000s km²) studies of the aggregate effects of bottom fishing activity in this region, but the known distribution of bottom fishing effort and knowledge of the local impacts of fishing suggests that there would be detectable decreases in benthic biomass and production at larger spatial scales. Locally, assessment of the impacts of scallop dredging in the Irish Sea has shown that scallop dredging causes a shift from communities dominated by relatively sessile, emergent, high biomass species to communities dominated by infaunal, smaller-bodied fauna. Removal of emergent fauna also reduced the topographic complexity of the habitat (Kaiser et al., 2000). Based on studies in other regions beam trawls are expected to have similar effects.

Inshore fisheries for mollusc species can have major effects on habitat structure and associated infaunal and epifaunal communities with an associated decrease in biomass and production similar to that which has been quantified for the North Sea. Hydraulic dredges for cockles, razor clams, and surf clams (*Spisula sp.*) are considered destructive to benthic habitats, but are relatively restricted in their overall extent.

**Effects on community structure and food webs**

The Celtic Sea groundfish community consists of over a hundred species and the most abundant 25 make up 99 percent of the total estimated biomass and around 93 percent of total estimated numbers (Trenkel and Rochet, 2003). Population and community analyses have shown that fishing has impacted a number of commercial species, primarily because individuals of too small a size have been caught and discarded in the past (Trenkel and Rochet, 2003; Rochet et al., 2002).

The size and trophic structure of the fish community has changed over time, and a decrease in the relative abundance of larger (piscivorous) fish has been accompanied by an increase in smaller pelagic fish which feed at lower trophic levels (Blanchard et al., 2005; Pinnegar et al., 2003; Trenkel et al., 2005). Temporal analyses of the effects of fishing and climate variation suggest that fishing has had a stronger effect on size-structure than changes in temperature. While the bulk of the blue whiting fishery is carried out in Region V, Heath (2005) contends that there is no foodweb connection between the blue whiting catch and the other landed species from the Celtic Sea and west of Scotland. However, both Pinnegar et al. (2003) and Trenkel et al. (2005) have both highlighted the importance of blue whiting as a prey for fish on the shelf-edge, within Region III, most notably for hake and megrim.
Interactions of the fishery with other parts of the marine community are patchily described. Zooplankton abundance (estimated by CPR) has declined in recent years and the overall substantial decline in *Calanus* abundance in this region, which is currently below the long-term mean, may have longer term consequences. There is some evidence suggesting that the decline in *Calanus* may be due to increased feeding pressure of these smaller fish and hence an indirect effect of fishing; however, climate change factors are also implicated (Nash and Geffen, 2004).

**Conclusions and priorities for action**

The fisheries of Region III are economically important to the large coastal population of the region. They continue to evolve taking on technical developments, exploiting new fishing opportunities, responding to regulation, and increasingly being constrained by economic forces such as the fuel price and consumer preferences, although the effect of the latter has yet to be fully evaluated. The fisheries resources in the region are heavily exploited and the level of fishing mortality remains high on most species. There is good evidence of impacts of the fishery extending across the ecosystem of the region and to date mitigation measures and regulations do not appear to have reduced the levels of fishing mortality.

From the review it is apparent that formal assessment of regulatory measures remains incomplete, with only limited data available on the benefit to stocks of commercial fish species. It would be useful to derive new measures (metrics) or continue to develop/apply existing ones (e.g. EcoQOs) in order to distinguish between different forces acting on the communities (i.e. partition effects between environmental, economic, and regulatory forces). Ultimately the goal would be to assess the effectiveness of existing management measures (through legislation and/or voluntary measures) to improve stocks and mitigate against detrimental environmental impacts. In addition, it would be informative, as new mitigation or conservation measures are implemented, to recommend or develop appropriate metrics (that can be easily monitored and reported) in order to measure the success of such measures.

Of particular note is that in the Celtic Seas Region III, there is increasing effort on non-quota species such as scallops, and that these are currently fully or over-exploited. As other fishing opportunities decline many fishers are turning to these fisheries. It would be prudent to introduce quotas or a limited license entry scheme for scallops to regulate this fishery before the situation deteriorates further.

**References**


1.5.5.9.e  Regional QSR IV: Bay of Biscay and Iberia

Introduction

The region extends from west of Brittany (48°N) to the Gibraltar Strait (36°N). A large shelf extends west of France. The southern part of the Bay of Biscay, along the northern Spanish coast is known as the Cantabrian Sea and is characterized by a narrow shelf. Further south a narrow shelf continues west off Portugal. Lastly, to the south, the Gulf of Cadiz has a wider shelf strongly influenced by the Mediterranean Sea. Within these zones the topographic diversity and the wide range of substrates result in many different types of coastal habitat.

In addition, typical temperate-water species occur together with both sub-tropical and more boreal species. Consequently, species diversity is high. The exploited living resources consist of more than 100 species, including fish, cephalopods, and crustaceans. Many of these resources are exploited by a large variety of fleets from France, Portugal, and Spain, and also from other nations (e.g. Belgium and the Netherlands); however, the data presented are largely based on French sources and consequently do not cover the whole region.

In coastal areas, demersal and benthic resources are exploited using a wide range of fishing gears, including trawls and dredges, gillnets and trammel nets, seines, lines, traps, etc. In the offshore zone, trawling is the major activity, and fixed gears are also extensively and increasingly used. Most fisheries are multi-species.

With the exception of local stocks exploited in coastal areas (i.e. large crustaceans, scallops, small bivalve clams), few of the resources exploited are confined to the Bay of Biscay. Sole, anchovy, sea bass, *Nephrops*, and cuttlefish stocks are considered to be geographically limited to the Bay of Biscay. Most of the other resources are widely distributed and therefore part of the stock is exploited outside the Bay of Biscay. In contrast, the megrim, anglerfish, anchovy, and *Nephrops* stocks belong to the southernmost area.

The development of fisheries management and policy since 1998, and an assessment of their effectiveness

As a consequence of the depleted status of the stocks in Region IV, several recovery plans have been adopted since 2004. All aim at restoring spawning-stock biomass to a precautionary level by gradually reducing fishing mortality (TAC variations between years are to be kept below 15%). These plans involve various technical measures in addition to TAC reduction, including seasonal closures, protected areas, minimum landing size, and mesh size regulations (Table 1.5.5.9.5.1).

Although there is no recovery plan for *Nephrops* in the Bay of Biscay, a diversity of measures have been adopted either by the French administration or by the Producers’ organizations (POs) themselves. A 9 cm minimum landing size regulation was established in December 2005, together with a 70 mm codend mesh size since 2000. A license system was adopted in 2004 resulting in a cap on the number of *Nephrops* trawlers operating in this area; in addition, trawling is prohibited during week-ends, and individual quotas have been imposed by the French POs since 2006. Since April 2008 selective devices have been introduced into the *Nephrops* fishery.

The major management measure taken in this area, however, is the closure of the anchovy fishery in the Bay of Biscay in June 2005 following a recruitment failure. Although slight signs of improvement were seen in 2006 and 2007, the fishery will not be reopened until the end of 2008. The only fishing allowed in 2007 has been experimental fishing with scientific observers on board, representing 20% of French and Spanish effort.
Table 1.5.5.9.5.1 Ongoing recovery plans for the stocks in the Biscay and Iberia region. All plans aim at restoring SSB at a precautionary level by a gradual decrease in fishing mortality, and also include technical measures.

<table>
<thead>
<tr>
<th>Stock</th>
<th>Year adopted</th>
<th>Technical measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern hake</td>
<td>2004</td>
<td>100 mm minimum mesh size for large trawlers. 100 mm minimum mesh size OR square mesh panel for all trawlers in specified areas. Seasonal closures (2 months 2001–3, 1 month 2004–6).</td>
</tr>
<tr>
<td>Southern hake</td>
<td>2006</td>
<td>Minimum landing size. Protected areas. Minimum mesh size.</td>
</tr>
<tr>
<td>Bay of Biscay sole</td>
<td>2006</td>
<td>Minimum landing size; Minimum mesh size in the directed fishery.</td>
</tr>
<tr>
<td>Cantabrian Sea Nephrops</td>
<td>2006</td>
<td>Minimum landing size.</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>Selective device.</td>
</tr>
<tr>
<td>West of Portugal and Gulf of Cadiz Nephrops</td>
<td>2006</td>
<td>Minimum landing size. Minimum mesh size. Closed areas (3 months Galicia West; 4 months SW Portugal). Seasonal closure (1 month, Portuguese waters).</td>
</tr>
</tbody>
</table>

Drivers of fishing activities in OSPAR Region IV

The main economic forces acting on the fishers are the price of fish and the fuel prices, which have increased. The number of French vessels fishing in the Bay of Biscay decreased from 2000 to 2006 (Figure 1.5.5.9.5.1), except for liners and gillnetters. However, fishing effort in power × days fished increased or remained stable for each sector, except for the small pelagic fishery as the anchovy fishery was closed in 2005 (Figure 1.5.5.9.5.2). The paradoxical discrepancy between increasing fishing effort and decreasing fishing mortality on most stocks in the Bay of Biscay might be explained by i) effort targeting other stocks not presented here (e.g. cuttlefish and squid, sardine, sea bass) or ii) loss in fishing power owing to implementation of more selective fishing gears, e.g. in the Nephrops fishery. There has been no marked change in the spatial distribution of fishing activities of the French fleet between 2000 and 2005.

Figure 1.5.5.9.5.1 Number of French vessels fishing in the Bay of Biscay 2000–2006.
The last decade has also seen the introduction of a number of gear modification programmes aimed at reducing environmental impact, including the use of pingers in the set net fishery, modifications to demersal *Nephrops* trawls, and changes in the beam trawl fishery.

**Impacts of fisheries on the ecosystem**

Commercial fishing has direct and indirect effects on the marine ecosystem, which can be summarized as:

1. trends in commercial fish stocks;
2. bycatch of target and non-target species, including birds and marine mammals;
3. physical disturbance of the sea bottom and related impacts on benthic communities and habitats;
4. shifts in community structure; and
5. indirect effects on the food web.

**Effects on commercial fish stocks**

Landings of most species in the Iberian region have declined in recent decades. In the Bay of Biscay landings from most stocks have been maintained, with fluctuations of varying amplitudes; the exceptions to this being landings of sole which have decreased markedly since 1995, and landings of anchovy which declined severely from 2001 until the fishery was closed in 2005. In contrast, landings of the northern stock of hake started to recover in 2002 after a long period of decline.

In most cases, declines in landings were accompanied by declines in fishing mortality; southern hake and Biscay sole are the two stocks undergoing increasing fishing mortality.

Up to 90% of French landings from the Bay of Biscay are composed of 34 stocks (Forest, 2001; Forest, 2005). Reliable assessments are only available for a limited number of stocks. However, evidence of impacts of fishing on fish populations is provided by ICES (2007). Stocks which are harvested unsustainably and for which reduction in exploitation is required are Northeast Atlantic (NEA) mackerel, NEA blue whiting, southern hake, and sole on the Bay of Biscay continental shelf (ICES Divisions VIIIab). As the status of these stocks has not improved since 1998, and the status of the Bay of Biscay anchovy deteriorated, the fishery has been closed since July 2005. In contrast, landings of the northern stock of hake started to recover in 2002 after a long period of decline.

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The largest catch of albacore tuna in the North Atlantic is taken in Area IV. Since the 1960s, stock sizes in the North Atlantic have varied around the target that provides the maximum sustainable yield level. Catches have been around 30,000 tonnes per year over the past decade (Figure 1.5.9.5.3) (ICCAT, 2007).

### Figure 1.5.9.5.3

Biomass and fishing mortality limit reference points have only been defined for three of the ICES assessed stocks allocated to Region IV, i.e. southern hake (VIIIc and IXa), sole (VIII), and anchovy (VIII). Prior to 2004, southern horse mackerel had also biomass and fishing limit reference points. These data were used to plot Figure 1.5.9.5.4 for the state of this stock in 2002. Temporal trends in the spawning-stock biomass (SSB) and fishing mortality (F) of this stock in relation to its limit reference points are shown in Figure 1.5.9.5.4. In 2002, the horse mackerel stock was at risk of being harvested unsustainably and at risk of suffering reduced reproductive capacity. In 2004, this stock was redefined as covering only Division IXa and the Division VIIIc stock was included in the western horse mackerel stock, based on new scientific evidence, with no limit reference points having been set so far (ICES, 2007a).

ICES prefers to give precedence to an analysis based on stocks for which reference points have been defined as the main indicator of fishing impacts on commercial stocks because it is not straightforward to define stock status in relation to a management objective when reference points have not been defined. For demersal stocks, significant fishing impacts on assessed species are often indicative of significant fishing impacts on larger, more vulnerable species that are not assessed, but taken as bycatch. This summary excludes the ICCAT assessments. We have presented the results of those separately above.

The biological reference points $F_{pa}$ and $B_{pa}$ are developed to take the imprecision into account in the most recent estimates of $F$ and SSB when developing fisheries management advice for fish quotas in the near future. Thus, when considering historical performance of fish stocks, $F_{pa}$ and $B_{pa}$ are not as relevant as $F_{lim}$ and $B_{lim}$ and are focused only on the limit reference points. This means that no distinction was made between stocks that are harvested sustainably and those at risk of being harvested unsustainably (since in both cases $F < F_{lim}$), and no distinction was made between stocks at risk of suffering reduced reproductive capacity and those at full reproductive capacity (in both cases $B > B_{lim}$). While this is unfortunate, it does reflect the focus of current ICES advice on the avoidance of limits rather than on the achievement of targets.
Figure 1.5.5.9.5.4  Trends in fishing mortality (F) and spawning-stock biomass (SSB) in assessed stocks allocated to OSPAR Region IV and for which fishing mortality and biomass reference points have been defined. Continuous red horizontal lines show the limit reference points (F_{lim} and B_{lim}, respectively) while broken red horizontal lines show the precautionary reference points (F_{pa} and B_{pa}, respectively, where defined). The age classes for which values of F were calculated are shown in parentheses.

Effects on non-target species, including birds, marine mammals, and discarded fish

In the trawl fishery, trawls with small mesh sizes have long been used, catching large amounts of small fish. Even if this exploitation pattern improved over the years, large amounts of undersized catch and non-target fish species are currently being discarded in the Nephrops fishery and in the other French trawl fisheries in the Bay of Biscay (unpublished on-board observer data, 2002–2006). In the southern Bay of Biscay, the Spanish mixed-species fishery has increased its level of discards to the highest yet reported (ICES, 2008). The main fish species discarded are the small-sized snipe-fish Macrorramphosus scolopax and silver pout Gadicus argenteus and the medium-sized blue whiting Micromesistius poutassou. None of these species survive (Pérez et al., 1996).

Effects on the seabed and associated benthic communities and habitats

As a consequence of heavy trawling in the Bay of Biscay, especially in the Nephrops fishery, the benthic community structure is significantly altered in terms of species composition and size structure. In heavily exploited stations, the benthic community is dominated by opportunistic carnivorous species of minor or no commercial interest (Blanchard et al., 2004).

The Great Mud Bank (Grande Vasière), stretching from north to south in the center of the Bay of Biscay is heavily trawled, especially by the Nephrops trawler fleet. On average, the northern part is swept six times a year and this is suspected to have changed the sediment grain size through resuspension of fine materials, causing a decrease in the proportion of muds found on the “Grande Vasiere” grounds (Bourillet et al., 2004).

Effects on community structure and food webs

The Bay of Biscay fish community is recognised to have been strongly affected by fishing for a long time. A number of top predator species have been depleted in the early to mid-20th century. Red seabream, for example, used to be one of the dominant large fish species, and its collapse in the mid-1980s generated a major change in the community structure. The fish community in the Bay of Biscay is therefore dominated by small-sized species. Over the last ten years few changes have occurred at the community level. There are, however, recent signs of increase in total biomass of both small and large species after a year of sharp declines (Figure 1.5.5.9.5.5).

An analysis of demersal trawl survey-based indicators for the whole community of 51 target and non-target populations off the French coast demonstrated no overall changes in community structure in the period 1987–2002 (Rochet et al., 2005).

In the Cantabrian Sea, the mean trophic level of the demersal and benthic fisheries has declined. Most of this change occurred from 1983 through to 1993 and has since varied without a clear trend (Sánchez and Olaso, 2004). The fish communities are now largely dominated by lower trophic level planktivorous fish (blue whiting, horse mackerel).
Fisheries have a considerable influence on the distribution of seabirds at sea due to the supply of discard that serve as food for scavenging species. Studies of offshore seabirds in the Gulf of Cadiz, Galicia, and the Cantabrian Sea report a strong correlation between the spatial distribution of the scavengers and that of the demersal trawl fleet (Valeiras et al., 2007).

Conclusions and priorities for action

Despite a decrease in the number of fishing vessels in the French fleet, fishing effort has increased and, under this continuing pressure, the impact of fishing cannot be said to have decreased over the last ten years. Although some management measures have proven efficient like the northern hake recovery plan, in general there has been low or no improvement in the status of target species and in the impact of fishing on the community, and the anchovy fishery had to be closed in 2005. Moreover, undersized individuals and bycatch species continue to be caught and discarded in large amounts. Recent changes in fishing gears for example, in the Nephrops fishery, have not yet proven efficient.

References


1.5.5.9.f Regional QSR V: Wider Atlantic

Introduction

The majority of Region V is deep water, greater than 3000 m in depth. The exceptions are the continental slope, some banks to the west of Scotland and Ireland and southwest of the Faroes, and the narrow areas of shallow water around the Azores. The major topographic feature is the northern part of the mid-Atlantic Ridge, located between Iceland and the Azores. Numerous seamounts of variable heights occur all long this ridge along with isolated seamounts in other areas such as Altair and Antialtair. The physical structure of seamounts often amplify water currents and create unique hard substrata environments that are densely populated by filter-feeding epifauna such as sponges, bivalves, brittle stars, sea lilies, and a variety of corals.

The fisheries on the shallower banks (e.g. Rockall) are similar to those in the more offshore parts of Region III, targeting for instance haddock. On the continental slopes and deeper banks, there are bottom trawl and set-net fisheries for species such as monkfish Lophius spp., hake Merluccius merluccius, and deep-water species such as blue ling, roundnose grenadier, black scabbard fish and deep-water sharks. Bottom-fisheries for deep-water species such as redfish Sebastes spp., orange roughy Hoplostethus atlanticus, and roundnose grenadier Coryphaenoides rupestris also occur along the mid-Atlantic Ridge and over seamounts using trawls, set nets, and longlines.

There are two fisheries for small pelagic species in the area: the large pelagic fishery for blue whiting Micromesistius poutassou on the western European continental margin extends into parts of Regions I, III, and IV, while the greater silver smelt Argentina silus fishery is more localised. Fisheries for large pelagic species, tuna, billfish, and some sharks extend across much of the region.

Management of fisheries for large pelagic species in Region V is carried out through the International Commission for the Conservation of Atlantic Tuna (ICCAT). Management of demersal fishing in the high seas of Area V is through the North-East Atlantic Fisheries Commission or the relevant authority for areas inside exclusive fishing zones (European Union, Faroe Islands, Iceland).

The development of fisheries management and policy since 1998, and an assessment of their effectiveness

Major changes in the management of fisheries in the northeast Atlantic are described in the Quality Status Report (QSR) NE Atlantic Overview volume. In this section we consider only measures with a purely regional basis.

Deep-water fisheries in the European waters of Region V are regulated under the Common Fisheries Policy (CFP). Under Council Regulation (European Commission (EC) No. 2347/2002), member states must ensure that fishing activities which lead to catches and retention on board of more than 10 tonnes each calendar year of deep-sea species by vessels flying their flag and registered in their territory are subject to a deep-sea fishing permit. Member states are obliged to calculate the aggregate power and the aggregate volume of their vessels which, in any one of the years 1998, 1999, or 2000, landed more than 10 tonnes of any mixture of the deep-sea species. The aggregate volume of vessels holding deep-sea fishing permits may not exceed this figure.

Council Regulation (EC) No. 27/2005 obliged member states to ensure that, for 2005, the fishing effort levels, measured in kilowatt days absent from port, by vessels holding deep-sea fishing permits did not exceed 90% of the average annual fishing effort deployed by that member state’s vessels in 2003 on trips when deep-sea fishing permits were held and deep-sea species were caught. For 2006 this limit was further reduced to 80% of 2003 levels.

Council Regulation (EC) No. 51/2006 banned the use of gillnets by Community vessels at depths greater than 200 m in ICES Divisions VIa, b and VII b, c, j, k. This was intended as an emergency measure for a duration of one year, and it was replaced in 2006 with a ban on gillnetting at depths greater than 600 m. In 2008, this measure is still a “transitional measure(s) to allow these fisheries to take place under certain conditions [...] until more permanent measures are adopted” included in the general TAC regulation (Council regulation (EC) No. 40/2008 of the Council of 16/01/2008).

Since 2003, black scabbardfish Aphanopus carbo, blue ling Molva dypterygia, greater silver smelt Argentina silus, ling Molva molva, orange roughy Hoplostethus atlanticus, red seabream Pagellus bogaraveo, roundnose grenadier Coryphaenoides rupestris, and tusk Brosme brosme have been subject to TACs and quotas in EC waters and for Community vessels fishing elsewhere. In 2005, the list of species managed by quota was increased by the addition of deep-water sharks.

Closed areas have been established in ICES Subarea VII to protect aggregations of orange roughy and in Division VIa to protect cold-water corals.
The only deep-water fisheries in ICES Subarea Xa are those from the Azores. Fisheries management is based on regulations issued by the European Community, by the Portuguese government, and by the Azores regional government. Fishing with trawl gears is forbidden in the Azores region. A box of 100 miles limiting the deep-water fishing to vessels registered in the Azores was created in 2003 under the management of fishing effort of the common fishery policy for deep-water species (EC Reg. 1954/2003). Some technical measures were also introduced by the Azores regional government in 1998 (including fishing restrictions by area, vessel type and gear, fishing licence based on landing threshold and minimum lengths). In order to reduce effort on traditional stocks, fishers are encouraged by local authorities to exploit the deeper strata (>700m), but the poor response of the market has been limiting the expansion of the fishery.

The Northeast Atlantic Fisheries Council (NEAFC) regulates effort in the fisheries for deep-water species in the NEAFC Regulatory area and has introduced some closed areas to protect vulnerable habitats and cold-water coral. These closures are on the Hecate, Faraday, Altair, and Antialtair seamounts, a section of the Reykjanes Ridge, Hatton Bank, and Rockall Bank.

Gillnets, entangling nets, and trammel nets have been banned from use in the NEAFC Regulatory Area since early 2006 in waters deeper than 200 m.

NEAFC introduced a system in 2007 to list vessels caught fishing illegally. This effectively bans such vessels from operating in ports of NEAFC Contracting Parties and thus helps curtail illegal, unreported, and unregulated (IUU) fishing.

Measures were introduced by ICCAT in 2004 to ban the “finning” of sharks caught in ICCAT waters. This measure was designed to reduce the incentive to target sharks for their fins alone (the remainder of the shark being discarded).

In 2007, ICCAT introduced measures to reduce seabird bycatch in tuna fisheries. The measures apply to vessels fishing south of 20°S. All vessels are required to carry and use bird-scare lines (tori poles) to specified design. Vessels are encouraged to use a second tori pole and bird-scare line at times of high bird abundance or activity. Longline vessels targeting swordfish using monofilament longline gear may be exempted on condition that these vessels set their longlines during the night, with night being defined as the period between nautical dusk/dawn as referenced in the nautical dusk/dawn almanac for the geographical position fished. In addition, these vessels are required to use a minimum swivel weight of 60 g placed not more than 3 m from the hook to achieve optimum sink rates.

There is no evidence of any gear-based mitigation measures being introduced into deep-water fisheries and given the species composition it is unlikely that any such measures would have much effect as most of the species are vulnerable deep-water species. A closure has been introduced on Rockall Bank to protect juvenile haddock, but there has been no formal assessment of the effectiveness of this closure. Vinnichenko and Khlinovoy (2008) indicated that at least part of the closed area contained few juvenile haddock.

The largest fishery in the northeast Atlantic is for blue whiting. This stock is present in waters of Regions I, III, and IV and straddles various fishery management zones, including portions of the high seas managed by NEAFC. Negotiations among coastal states failed to set a TAC in this fishery for many years, with coastal states subsequently setting quotas for themselves that totalled substantially more than was recommended in scientific advice. For example, in 2003, catches of blue whiting reached a peak of 2.3 million tonnes whereas the advice from ICES was not to exceed 600 thousand tonnes. In 2005, coastal states finally agreed a TAC, but this was set considerably in excess of the TAC recommended by ICES, with an agreement to reduce the TAC annually by 100 000 tonnes until a target fishing mortality rate was reached. ICES found that these management decisions were not consistent with the precautionary approach.

BOX Reducing bycatch in the pelagic trawl fishery for blue whiting around the Faroe Islands

As noted above, blue whiting is one of the major pelagic fish resources in the northeast Atlantic. The total blue whiting catch in the Faroese exclusive economic zone (EEZ) in 2004 was 426 000 t (http://www.neafc.org/fisheries/docs/final_catch_2004.pdf).

The last decade has seen huge technical developments in pelagic fishing, both in vessel size and design, as well as in development of trawl design. Today pelagic trawls used for blue whiting have horizontal openings 200 m wide, with vertical openings of 100 m encompassing meshes of 64 mm in the mouth of the trawl gradually tapering back to 32 mm in the codend. These trawls have the ability to catch several 100 tonnes in a few minutes towing time with a towing speed of 3–4 knots.

In recent years an increasing bycatch of demersal species, mainly saithe Pollachius virens and to a lesser degree cod Gadus morhua, have been observed in the blue whiting fishery, particularly in the Faroese area. The Faroese Fisheries
programmes have accompanied their introduction to advise fishers on correct installation and handling, as well as paralleled to the introduction of Turtle Excluder Devices in the US, southeast Asia, and Australia where education for back-up technical support and education of fishers to encourage acceptance. The adoption of this grid is perhaps parallel with the introduction of Turtle Excluder Devices in the US, southeast Asia, and Australia where education and installations have been instigated. This strong collaboration between the Faroese fisheries laboratory and the Faroese fishing industry, in parallel with the technical assistance provided has led to this high level of acceptance of adopting the sorting grid.

Monitoring of the use of the grid has been intense and, as part of the introduction of the regulation the Faroese authorities have sought to assess the effectiveness of this measure through monitoring catches at sea and landings ashore. The monitoring of the landings reflects whether bycatch levels have been reduced effectively and reports suggest this is the case.

The introduction of the flexible grid into the blue whiting fishery shows how gear measures properly researched with full industry support can work, and what is really interesting about this gear measure is that it took only a year or so from inception to regulation. The Faroese experience shows the importance of industry collaboration, but also the need for back-up technical support and education of fishers to encourage acceptance. The adoption of this grid is perhaps paralleled to the introduction of Turtle Excluder Devices in the US, southeast Asia, and Australia where education programmes have accompanied their introduction to advise fishers on correct installation and handling, as well as provision of back-up technical assistance to solve any rigging and handling problems that may have arisen.

**Fishing activities in OSPAR Region V; Wider Atlantic**

The Wider Atlantic region encompasses high seas fisheries and some fisheries in Exclusive Fisheries Zones from south of Iceland and the Faroe Islands to the Azores. The deep-water fisheries are relatively poorly described and the developments in gear and introduction of gear-based technical measures identified are fairly limited.

A demersal trawl fishery, primarily for haddock *Melanogrammus aeglefinus* occurs on Rockall Bank (primarily EU vessels) and in international waters to the west of Rockall (primarily Russian vessels). The fishery in international waters began in 1999. It uses rockhopper trawls with small mesh codends and has a high bycatch of blue whiting and grey gurnard *Eutrigla gurnardus*. Catches of undersize haddock in this fishery are high in some areas of waters less than 200 m in depth (Vinnichenko and Khlivnoy, 2008).

Bottom trawl fisheries in deep waters are mainly concentrated around the continental slope and offshore banks west of the British Isles, the mid-Atlantic Ridge, and to the west of the Azores. They target species such as redfish, orange roughy, roundnose grenadier, deep-water sharks, alfonsino *Beryx decadactylus*, and black scabbardfish. The gears used in these fisheries tend to be high opening rockhopper trawls with heavy groundgears made up of a combination of steel bobbins and rubber discs of 500 mm or more in diameter. The net designs used are broadly similar across fleets, generally quite simple 2-panel “Alfredo” trawls that are relatively cheap to construct and easy to repair given gear damage in many of these fisheries can be high.

The pelagic fishery for blue whiting off the west coast of Ireland and the UK extends into the wider Atlantic region. Large vessels from EU, Norway, Faroe Islands, and Iceland participate in this fishery using single-boat pelagic trawls. Trawl design in this fishery as with other pelagic fisheries has seen dramatic changes as net manufacturers have strived to improve the hydrodynamics of the trawls to reduce drag and improve water flow. This has included using self-spreading technology, which utilises the force of the water current through the net to spread the trawl without increasing towing resistance and also the use of hexagonal meshes at the mouth of the trawl, as well as using low drag materials such as dynex. Trawl door designs in this fishery have also developed in the last decade. Doors have become smaller and lighter but with the same spreading force, allowing vessels to tow faster without increasing fuel consumption.

Since the introduction of a ban on deep-water gillnets at depths greater than 600 m in EU waters of Subareas VI and VII, the directed gillnet fishery for deep-water sharks and deep-water red crab *Geryon affinis* that formerly took place in these subareas has now been displaced to Subareas IV, VIII, and IX. This fishery is very poorly documented, but there is a bycatch of mora *Mora moro* and greater forkbeard *Phycis blemnooides*. There are also directed gillnet fisheries for monkfish and hake at depths less than 600 m. Since 2005, vessels operating in the NEAFC Regulatory Area are not permitted to deploy gillnets, entangling nets, or trammel nets at any position where the charted depth is greater than 200 metres. In recent years a directed fishery for deep-water red crab, using pots, has also taken place in this area. Effort

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levels in this fishery are not known, but vessels are reportedly fishing upwards of 1000 pots per vessel. A similar pot fishery exists off the Azores.

As in the OSPAR Regions III and IV a major development within the static net fisheries was the development and subsequent banning of a driftnet fishery for albacore tuna *Thunnus alalunga*. This fishery straddled the wider Atlantic region. This fishery developed in the early 1990s and at its peak involved around 120 Irish and French vessels working 5–10 km of gear in line with the UN resolution 44/225 of 22 December 1989, which called for a moratorium on the use of large-scale driftnets to protect cetacean species. Following protracted negotiations this fishery was closed in 2002 on the basis of reported marine mammal bycatches. Following these measures, Irish and French fishers converted to other forms of fishing, including the use of pair pelagic trawls. Research trials with this method showed that bycatch of marine mammals was as high as in the driftnet fisheries, although in later years this bycatch has reduced considerably. Anecdotally this has been put down to the fact that fishers have tended to drop the headline of these trawls to well below the surface to target bigger tuna.

The Norwegian longline fleet described in Region I also fishes in Region V for blue ling *Molva dypterygia*, tusk *Brosme brosme*, and deep-water sharks. These vessels all fish with automatic longline systems and in the deeper waters in this region can work around 20 000–25 000 hooks a day. A directed fishery for Greenland halibut *Reinhardtius hippoglossoides* with a bycatch of deep-water shark species, mora, and blue ling was developed in 2000/2001 at Hatton Bank, yielding very high catch rates. However, this fishery has declined in recent years with only limited catches reported, and effort has been reduced.

In the south of the OSPAR Region V, there are traditional handline and longline fisheries near the Azores, targeting red seabream, wreckfish *Polyprion americanus*, conger eel *Conger conger*, bluemouth *Helicolenus dactylopterus*, golden eye perch *Beryx splendens*, and alfonsonio. The gear used in this fishery is artisanal with only 30–60 hooks shot per set. Hooks are attached to 1.1 m gangions spaced every 1.2 m along a monofilament leader which is connected to a steel wire that runs to the surface. The fishery predominantly targets red seabream. Since the mid-1990s, the landings of other deep-water species have decreased (Figure 1.5.5.9.6.1.). Since 2000, the use of bottom longline in the coastal areas has been significantly reduced, as a result of a ban on the use of longlines within 3 miles of the islands. As a consequence, the smaller boats operating in this area have changed their gears to several types of handlines, which may have increased the pressure on some species. The deep-water bottom longline is at present mostly a seamount fishery.

![Figure 1.5.5.9.6.1](image)

**Figure 1.5.5.9.6.1** Annual landings of major deep-water species in Azores from the hook and line fishery (1980–2007).

A number of surface longline fisheries in this area target tuna and billfish species with high bycatches of pelagic sharks. Approximately 150 active Japanese pelagic longline vessels operating over the wider Atlantic Ocean target species such as bluefin tuna *Thunnus thynnus* and bigeye tuna *Thunnus obesus* in the remaining regions. The gear used has not changed recently and the longline systems used by these vessels are still labour intensive. Up to 50 km of 2500 hooks is shot and hauled per day.

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The Spanish surface longline fishery in the North Atlantic primarily targets swordfish *Xiphias gladius*, sharks, and tuna over a variety of years, areas, and seasons (Mejuto and de la Serna, 2000). The gear used is the standard Spanish surface longline for swordfish (using a mean number of 1100–1500 hooks per set), although some technological improvements have been documented over time (e.g. the introduction of light sticks and changing from a multifilament to a monofilament line) (Mejuto and de la Serna, 1997; Mejuto et al., 2002). It can be considered a multi-species fishery because the gear can be modified (e.g. by switching configurations such as the depth of set or hook type) to target swordfish, tuna, or sharks. Blue shark *Prionace glauca* has become a target species in recent years for some sets, trips and areas due to the recent increase in price of this species on the international market (Mejuto and García-Cortés, 2004) and the ability of modern vessels to freeze their catch and therefore to retain sharks caught without any deterioration of the meat and cross-contamination of other more valuable species.

There are also Portuguese surface longline fisheries targeting swordfish around the Azorean EEZ. An artisanal fleet fishes 800–1200 hooks on a daily or weekly basis. This is still essentially manual fishery with little mechanization other than limited haulers. Larger sized longline vessels from the Azores and Portugal also target swordfish in waters outside the Azorean EEZ. These vessels have freezing capabilities and conduct trips lasting a month or more, working an average of 2500 hooks per set. These vessels are much more sophisticated, tending to work with line hauling and line setting equipment and using also chemical lightsticks to attract swordfish.

Another major development within static net fisheries was the development and subsequent banning of a driftnet fishery for albacore tuna. This fishery developed in the early 1990s and at its peak involved around 120 Irish and French vessels working 5–10 km of gear in waters to the west of France and Ireland. In line with the UN resolution 44/225 of 22 December 1989, which called for a moratorium on the use of large-scale driftnets to protect cetacean species, this fishery was closed in 2002 (see Section 4.6.4.2 for reported marine mammal bycatches). Following these measures, Irish and French fishers converted to other forms of fishing, including the use of pair pelagic trawls.

Another fishery that was developed during the period from 1998 and then subsequently declined is the orange roughy fishery on seamounts off the west and southwest coast of Ireland. French vessels had been exploiting this fishery on a limited basis since the early 1990s, although landings had declined markedly in Area VI by 1995. These vessels continued to land orange roughy from Area VII. Following a fleet renewal programme in Ireland, which saw the introduction of a number of new and efficient whitefish trawlers the fishery in Area VII expanded rapidly around 2000–2001. The vessels worked around a limited number of seamounts at depths up to 1200 m. In 2003 following concerns about the state of deep-water species, including orange roughy, the EU introduced TACs and quotas into these fisheries, thereby restricting fishing opportunities. Prompted by concerns over damage to sensitive habitats, further restrictions were introduced in 2005, preventing fishing on seamounts. This effectively curtailed the orange roughy fishery and has forced the vessels involved to divert effort to other areas, e.g., Rockall, or concentrate on species such as black scabbard, grenadier, and saithe.

**Impacts of fisheries on the ecosystem**

Commercial fishing has direct and indirect effects on the marine ecosystem, which can be summarized as effects on:

1. commercial fish stocks;
2. non-target species, including birds, marine mammals, and discarded fish;
3. the seabed and associated benthic communities and habitats; and
4. community structure and food webs.

**Effects on commercial fish stocks**

There is clear evidence that some deep-water fish (500–1800 m) have been severely depleted in Region V by the deep-water fisheries. Many of these species have attributes which make them particularly vulnerable to overfishing such as slow growth rates, late age of maturity, low or unpredictable recruitment, and long life spans. Examples include the roundnose grenadier, orange roughy, and deep-sea sharks. Other deep-water species such as black scabbard fish and blue ling have higher productivity and are believed to be more similar to typical gadoids.

Populations of fish that aggregate on oceanic bathymetric features such as seamounts are particularly sensitive to overfishing, due to low productivity and high catchability. On the southern part of the mid-Atlantic Ridge and adjacent seamounts, populations of alfonsinos were depleted also in the 1970s. More recently, longline fisheries appear to have depleted seamount populations of “giant” redfish on seamounts of the northern mid-Atlantic Ridge (Hareide and Garnes, 2001).

Modern fishing fleets are capable of causing a very significant reduction in demersal deep-water fish biomass in just a few years; a consequence of this has been the collapse of several fisheries (Koslow et al., 2000). Exploitation of orange roughy on a single seamount in Subarea VI began in 1989. Catches peaked in 1991 at 3500 t, then dropped to less than 100 t by 1995. It is presumed that the aggregation was fished out and no subsequent recovery has been observed.
Landings are a particularly poor indicator of the state of deep-water species in Region V because sequential depletion of local stocks has occurred in this fishery (ICES, 2008). Moreover, increases in landings reflect increased effort in this fishery. In cases where landings data are known to apply to a single stock or location, they may provide a better proxy for the status of the resource. However, biological reference points have not been set for any of the assessed species in this region, and therefore only landings data are presented.

Landings of blue ling, tusk, and haddock have declined over the past decade, all continuing long-term declines (Figure 1.5.5.9.6.3). Fishing mortality on haddock at Rockall has declined (Figure 1.5.5.9.6.4). The blue whiting fishery grew greatly in the past decade and has since declined; fishing mortality paralleled this increase, but has remained high (Figure 1.5.5.9.6.4). Much of this growth of the fishery has occurred in OSPAR Region 1.

Bluefin tuna are caught throughout Region V (Figure 1.5.5.9.6.2). The stocks in the North Atlantic and Mediterranean are related. Spawning biomass fell in the 1950s and has remained at a relatively low level ever since. In 2004 the reported catch was about 32 500 tonnes for the east Atlantic and Mediterranean, of which about 25 000 t were reported for the Mediterranean. It is likely that catches of bluefin tuna from the eastern Atlantic and Mediterranean have been seriously under-reported in recent years. This indicates the probability that the volume of catch taken in recent years significantly exceeded TAC levels and is about 7000 tonnes in the east Atlantic (ICCAT, 2006). The ICCAT assessment results show that the spawning-stock biomass continues to decline while fishing mortality is increasing rapidly, especially for large fish. ICCAT (2006) mentioned the possibility of a collapse in the near future, given the estimation of the fishing capacity of all fleets combined and current fishing mortality rates, unless adequate management measures are implemented.

![Figure 1.5.5.9.6.2](image)

Results of three runs of VPA models of east Atlantic and Mediterranean bluefin tuna. Top figures show average fishing mortality for ages 1 to 5, and 8 and older. The bottom figures show trends in recruitment and spawning-stock biomass. These figures are based on analyses which assume there was no underreporting of catches (From ICCAT, 2006).
Figure 1.5.5.9.6.3  Landings of selected species of commercial importance from parts of OSPAR Region V. Data from ICES.

a) Blue whiting combined stock (Sub-areas I-IX, XII & XIV)

b) Blue ling *Molva dypterygia* (All relevant ICES sub-areas including some outside Region V)

c) Haddock in Division VIIb (Rockall)

d) Tusk *Brosme brosme* (All relevant ICES sub-areas including some outside Region V)

e) Red (=blackspot) seabream (All relevant ICES sub-areas including some outside Region V)

Figure 1.5.5.9.6.4  Fishing mortality on selected stocks of importance in Region V.

Blue whiting combined stock (Sub-areas I-IX, XII & XIV)

Haddock in Division VIIb (Rockall)
Effects on non-target species, including birds, marine mammals, and discarded fish

The majority of fish and invertebrates living in the deep waters of OSPAR Region V are poorly known, and consequently the impacts of fishing on these communities have not been clearly demonstrated.

In order to reduce bycatch in lost and abandoned deep-water gillnet fisheries, Ireland and the UK have completed a number of net retrieval surveys and recovered substantial amounts of lost or abandoned gear in certain areas. These retrieval surveys are continuing in 2008.

An observer programme on an albacore tuna driftnet fishery in Region V has provided some data on bycatch. A minimum of seven fish species were caught and landed. Eleven fish species were discarded, of which blue shark Prionace glauca was the most frequently recorded representing 68% of all fish discarded by number. At least four species of seabird (northern gannet Morus bassanus, northern fulmar Fulmarus glacialis, Manx shearwater Puffinus puffinus, Atlantic puffin Fratercula arctica) and two species of turtle, including the leatherback turtle Dermochelys coriacea, were also entangled. Eight species of cetacea were recorded as bycatch during these fishing operations, including common dolphins Delphinus delphis and striped dolphins Stenella coeruleoalba. Using landings of albacore tuna as an indicator of effort, the extrapolated decadal scale data from Irish and other driftnet fleets operating in this area suggest that during the period 1990–2000, a minimum of about 778 000 blue sharks were caught, with a substantial proportion discarded. An estimated 24 300 dolphins were killed during these years by these fleets, of which 11 700 were common dolphins and 12 600 were striped dolphins.

There are indications that the bycatch of marine mammals in the pelagic trawl fishery for albacore was as high as in the driftnet fishery it replaced, although in later years this bycatch appears to have reduced considerably.

There are some detailed data available for the fleet of about 20 Spanish demersal longliners targeting hake in the Gran Sol area (which straddles the boundary of OSPAR Regions III and V) off western Ireland. This information indicates a relatively large bycatch of northern fulmar and great shearwater Puffinus gravis.

A programme to monitor demersal longline fisheries around the Azores placed three observers on-board vessels in 2005–2007 over periods between 6 and 9 months, during which time no seabirds were recorded as bycatch.

Figure 1.5.5.9.6.5 Landings of three species of tuna, 1950–2007 in the northeast Atlantic (Data from ICCAT).

- a) Albacore tuna
- b) Bigeye tuna
- c) Northern bluefin tuna
Surface longline fisheries for tunas, swordfish, and others often have a bycatch of sea turtle, pelagic sharks, and seabirds. ICCAT is currently engaged in assessing all of the fisheries that it manages to determine the scale and significance of seabird bycatch.

In addition to catching target species, deep-water fisheries bycatch unwanted species that are either too small or unpalatable. Discarding rates are often high (in the order of 50%). The bulk of the discarded catch in deep-water trawl fisheries west of the British Isles consists of smoothheads (Alepocephalidae).

**Effects on the seabed and associated benthic communities and habitats**

Most attention has been directed towards the destruction of biogenic habitat by bottom tending gear. In particular, cold-water coral and sponge species have been recognized as vulnerable marine ecosystems warranting international protection. The main reef building species is *Lophelia pertusa*. This species forms large bioherms or reefs along the continental slope and on the offshore banks (Rockall and Hatton). Many areas remain to be surveyed for *Lophelia pertusa*. Some of these reefs are large, for instance, to the south and west of Ireland several reefs have built mounds at heights of 150–200 m and about 1 km wide.

Seamounts often have coral reefs, supporting aggregations of fish such as orange roughy and alfonsinos. Many seamounts have been targeted by commercial fleets. The habitats on seamounts are often highly susceptible to damage by mobile bottom fishing gear and the fish stocks can be rapidly depleted due to the life history traits of the species, which are slow-growing and longer-living than non-seamount species.

**Effects on community structure and food webs**

No available information directly describes changes in the community structure within Region V. Based on research elsewhere and given the depletion of some fish stocks, it is likely that such changes have occurred.

**Conclusions and priorities for action**

The effects of fishing in OSPAR Region V are relatively poorly studied. The high value of the large pelagic fish in the region has also led to depletion of their stocks. A number of the deep-water biogenic habitats in Region V are very susceptible to damage from seabed fisheries, particularly trawling, but also to the intense or prolonged use of other gears. Damage has been documented at a number of locations, but there is very likely to have been more damage than that documented. Fisheries managers have introduced closed areas to protect some of these habitats. Bycatch of birds, marine mammals, and sharks occurs, and in the case of sharks this is probably affecting stocks in an unsustainable manner.

Priorities in the region are primarily to continue to improve the management of fisheries. In general a reduction in fishing effort in deep-water trawl and pelagic long-lining (tuna) fleets will be effective, but other fisheries management tools are available. Further scientific surveys are required to identify habitats of particular importance, along with fisheries closures to protect vulnerable marine ecosystems. Bycatch can be reduced using technical measures, but these require dedicated development, usually best undertaken in association with relevant fishers.

**References**


Mejuto, J., and García-Cortés, B. 2004 Preliminary relationships between the wet fin weight and the body weight of some large pelagic sharks caught by the Spanish surface longline fleet. ICCAT Collective Volume of Science Papers, SCRS/03/085.

1.5.5.10 Assessment of data on fish diseases in the OSPAR maritime area

Request

An assessment of data on fish diseases in the OSPAR maritime area (OSPAR 13-2008)

To trial the fish disease index developed by ICES and reported at WKIMON III through application in an evaluation of data collected by OSPAR Contracting Parties with a view to providing an assessment of fish disease in the OSPAR maritime area for inclusion in the QSR 2010 to the extent possible. The assessment should consider the prevalence of externally visible fish diseases, macroscopic liver neoplasms and liver histopathology in common dab (Limanda limanda).

Summary

This trial application of the Fish Disease Index (FDI) to the ICES fish disease data demonstrates that the FDI approach is appropriate for the analysis and assessment of fish disease data generated within monitoring programmes according to established ICES guidelines. However, a considerable amount of disease data available in national databanks is still missing in the ICES fish disease database. The fish disease data submitted to the ICES Data Centre so far were not sufficient to conduct an overall assessment of levels and trends as planned by using the full FDI approach with all of its components. With a technical modification of the FDI with respect to a number of parameters, e.g. the suite of diseases considered, an analysis and assessment was carried out with the data available. The preliminary results of this assessment clearly show that it is advisable to include as many diseases as possible in the FDI. Only then is a comprehensive assessment of the overall disease status possible. A decision on the most appropriate FDI approach and a more comprehensive assessment of the fish disease data will only be possible once all data available in national databanks have been submitted to the ICES Data Centre and have been analysed.

ICES also undertook an independent peer review of the technical aspects of the FDI. The review concluded that the FDI is technically sound and is a promising tool for assessing various aspects of ecosystem function, including general ecosystem health and environmental quality. Several proposals for improvements in the assessment methodology have been made and these may be applied before the final assessment is provided in 2009.

ICES Response

Introduction

In 2006 and 2007, ICES reviewed progress made in the development of a Fish Disease Index (FDI), a tool designed to be used for the assessment of data on diseases of wild fish in the ICES area (ICES 2006, 2007).

The FDI was constructed mainly for data obtained from regular disease surveys in dab (Limanda limanda) on externally visible diseases, macroscopic liver neoplasms, and liver histopathology. Such studies have been carried out by Denmark, Germany, the Netherlands, and the UK in the North Sea and adjacent areas. In order to meet the OSPAR request, ICES member countries running regular fish disease surveys in the OSPAR area or those that hold historic data generated according to the ICES standard guidelines were requested in 2007 to submit their complete set of fish disease data to the fish disease database of the ICES Environmental Data Centre by using the new ICES Integrated Environmental Reporting Format Version 3.2.3 (http://www.ices.dk/env/repfor/ERF323.doc).

The FDI is also applicable to other species and geographical areas after modification. It consists of the following components:

- data on the presence or absence of a range of externally visible diseases and parasites, macroscopic liver neoplasms, and liver histopathology;
- data on the severity of the diseases (disease grades);
- disease-specific weighting factors assigned by expert judgment on the basis of the effects of the diseases on the host; and
- adjustment factors for confounding entities or variables (length, sex, and season).

The calculations involved results in scores for each of the diseases considered which are summarized into the final FDI for an individual fish. This FDI for individual fish already contains adjustments for length and sex as well as a disease-specific weighting scheme. From the individual FDIs, mean values in a population for a given time period in a given sampling area can be calculated and appropriate statistical analyses can be conducted.
In 2007, the FDI was applied using empirical data derived from fish disease surveys carried out by Germany in the North Sea and adjacent areas. Using the common dab in the North Sea as a model, the externally visible lesions of the following diseases were used to characterize the FDI: lymphocystis, epidermal hyperplasia/papilloma, acute/healing ulceration, x-cell gill disease, hyperpigmentation, acute/healing fin rot/erosion, and the parasites *Stephanostomum baccatum*, *Acanthochondria cornuta*, and *Lepeophtheirus pectoralis*. Because of the lack of availability of data macroscopic liver neoplasms and histopathological liver lesions were not considered at this stage but are intended to be added at a later stage.

For trend assessment, mean FDI values were adjusted for the season of data collection, additionally to the previous adjustment for sex and length. From these values an assessment statistic was calculated, which jointly accounts for the FDI level and trend. The “level” component of the statistic was obtained by dividing the FDI range, for data from 1991 to 2000, into three equally sized intervals using tertiles (the 33% and 66% percentile) as cut-points. FDI means, after 2000, were weighted by -1, 0, and +1, according to their position in the lower, middle, and upper interval, respectively. The sum of these weights, scaled to lie in the range (-1, +1), served as the “level” component of the test statistic. For the “trend” component of the statistic, after 2000, a scaled version of the Mann-Kendall trend test statistic was used. The scaled version has values in the range (-1, +1), as the level component. Then the FDI assessment statistic was calculated as (0.5*level component + 0.5*trend component). For aesthetical reasons a scaling factor of 0.5 was used in order to have a test statistic with values in the interval (-1, +1).

According to the resulting statistic, different “smiley faces” were assigned to individual geographical regions (ICES statistical rectangles) with a sufficient amount of disease data. A p <0.025 resulted in a “green smiley face”; 0.025 <p <0.975 in a “yellow indifferent face”; and p >0.975, in a “red frowny face”. These icons, placed on a chart of the ICES statistical rectangles in the North Sea, provided a general visual assessment of levels and trends in overall disease status.

### Diseases to be included in the construction of the Fish Disease Index (FDI)

According to its original construction (ICES, 2006), the Fish Disease Index includes the disease categories and key diseases shown in Table 1.5.5.10.1. Ideally, the data used should not only include information on the presence or absence of the key diseases but also on their severity (according to three defined grades). Such data, however, only exist for certain diseases (see below).

| Disease categories and key diseases for constructing the Fish Disease Index (FDI) |
|---------------------------------|---------------------------------|---------------------------------|
| Externally visible diseases     | Macroscopic liver neoplasms     | Liver histopathology            |
| Lymphocystis                   | Benign neoplasms                | Non-specific lesions            |
| Epidermal hyperplasia/papilloma| Malignant neoplasms             | Early non-neoplastic toxicopathic lesions |
| Acute/healing ulceration,      |                                 | Pre-neoplastic lesions (FCA)    |
| X-cell gill disease,           |                                 | Benign neoplasms                |
| Hyperpigmentation              |                                 | Malignant neoplasms             |
| Acute/healing fin rot/erosion   |                                 |                                 |
| *Stephanostomum baccatum*      |                                 |                                 |
| *Acanthochondria cornuta*      |                                 |                                 |
| *Lepeophtheirus pectoralis*    |                                 |                                 |

### ICES fish disease data available for the assessment

In contrast to the previous fish disease assessment in 2007 that was done using only data on externally visible fish diseases from the German fish disease monitoring programme (ICES, 2007), the goal for the present assessment was to include data from all countries on externally visible disease, as well as data on macroscopic liver neoplasms and liver histopathology.

After all data had been submitted to ICES as requested (final submissions in mid-January 2008), the fish disease databank was checked for data available for the assessment. The majority of information covers disease data generated in studies on dab from the North Sea and adjacent areas. The time span covered is from 1981 until 2007. Disease data are also available for flounder (*Platichthys flesus*), cod (*Gadus morhua*), and whiting (*Merlangius merlangus*), however, to a much lesser extent. These were not considered in the analysis and assessment.

Table 1.5.5.10.2 provides details on the total number of dab examined per year, submitting labs, the time spans covered by individual data sets, disease categories monitored (externally visible diseases, macroscopic liver neoplasms, liver...
histopathology), and as to whether the data submitted meet the original criteria defined for calculating the FDI and for the assessment (ICES, 2007).

As can be seen from Table 1.5.5.10.2, the data are fragmented in that:

- The time spans covered differ considerably and, thus, there is no period of time with data from all submitting labs.
- There is only a limited amount of most recent data (2006–2007).
- The majority of data submitted only concerns externally visible diseases. Relatively few data are available on macroscopic liver neoplasms and data on liver histopathology are completely lacking in the ICES fish disease database.
- The majority of data sets do not meet the original criteria defined for the FDI calculation, because either data do not cover all of the diseases/parasites meant to be included or data on severity grades are lacking.

Furthermore, there is indication that the data submitted to ICES using the Environmental Data Reporting Format 3.2.2 do not comprise all the data that had earlier been submitted in other formats. This must be concluded from comparing the counts from earlier analyses to the counts presently.
Table 1.5.5.10.2  Data on externally visible diseases (EVD), macroscopic liver neoplasms (MLN), and liver histopathology (LH) in dab (*Limanda limanda*) submitted by laboratories in ICES member countries to the ICES Data Centre (green: full set of diseases for FDI; yellow: only selected set of diseases).

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**BFCG**: Federal Research Centre for Fisheries, Cuxhaven, Germany; **ALUK**: FRS Marine Laboratory, Aberdeen, UK; **DOUK**: Cefas, Weymouth, UK; **BODC**: British Oceanographic Data Centre; **DGWN**: National Institute for Coastal and Marine Management, The Netherlands; **RIVO**: The Netherlands Institute for Fisheries Research; **DFHU**: Danish Institute for Fisheries and Marine Research; **n ex**: number of fish examined.
Modification of the Fish Disease Index construction

It became obvious that the findings from the screening of the ICES fish disease database have had an impact on the assessment requested by OSPAR when it was discovered that, because of the lack of data, the FDI as originally constructed could not be used given the data available. Based on this, the following modifications were made to the construction of the FDI in order to use as many fish disease data submitted as possible:

Three different FDIs based on different sets of diseases were calculated:

- FDI-EVD3, using the externally visible diseases (EVD) lymphocystis, epidermal hyperplasia/papilloma, and acute/healing skin ulcers. This definition was chosen to allow an FDI calculation for as many ICES rectangles as possible.
- FDI-EVD9, using all 9 externally visible diseases given in Table 1.5.5.10.2. This is the set of diseases used in previous FDI calculations.
- FDI-EVD4, using the same externally visible diseases as FDI-EVD3 plus data on macroscopic liver neoplasms (MLN). This definition combined liver data, as requested by OSPAR, and the set of EVDs which otherwise allowed an FDI calculation for as many ICES rectangles as possible. These four diseases also represent the combination that allows an FDI calculation for as many rectangles as possible under the condition that macroscopic liver neoplasms are included.

All diseases entered the FDI calculation as ungraded (presence/absence) data because of the lack of disease grades in a large part of the data. Data that had been reported as graded data was transformed to ungraded information.

Strategy for FDI calculation and assessment

The criteria for data to be used in this trial assessment were set as follows:

- Only samplings between 1 January 1991 (starting point) and 31 December 2007 were included. A sampling is defined as “all catching done on one day in one ICES rectangle”.
- For each FDI, only ICES rectangles with at least 10 samplings since the starting point and with determination of all the diseases used in that FDI were considered.

With these settings, FDI calculations and assessments were possible for 17 (FDI-EVD3), 10 (FDI-EVD9), and 6 (FDI-EVD4) ICES rectangles, respectively.

Disease-specific weighting factors were obtained from expert judgements on disease severity, using the Bradley-Terry approach to derive the weighting factors from the pair-wise comparisons provided by the experts. Judgements from 5 experts were available and used for this calculation. The MLN data does not differentiate between benign and malignant tumours, but as the large majority of MLN cases consists of benign tumours, all reported MLN observations were considered as benign and associated with the corresponding disease severity weight. Adjustment factors for confounding entities (length, sex, and season) were computed as reported previously (ICES, 2007, pp. 71–77). Also the p level for the assessment statistic and the resulting “smiley category” (green, yellow, red) were calculated as described there and summarized in the introduction above.

Results of the assessment of the ICES fish disease data using the Fish Disease Index (FDI) approach

The results of the application of the Fish Disease Index approach can be seen in Figures 1.5.5.10.1a–c and 1.5.5.10.2a–c. Note that the choice of the colours for the “tertiles”, red, yellow, and green, is arbitrary and should not be equated to the meaning of these colours as used in the “traffic light approach” to integrated assessments.

Figures 1.5.5.10.1a–c illustrate the results regarding the temporal changes in the FDI as well as the assessment of the levels and changes recorded since 1 January 1991. Figure 1.5.5.10.1a shows the results for the approach including only data on the full set of 9 externally visible diseases (FDI-EVD9), Figure 1.5.5.10.1b for the set of only 3 externally visible diseases (FDI-EVD3), and Figure 1.5.5.10.1c for the combination of 3 externally visible diseases and macroscopic liver neoplasms (FDI-EVD4).

Figures 1.5.5.10.2a–c provides the maps showing the assessment results for the 3 approaches above on a geographical basis.

Some major differences can be deduced from the results shown:

- By using the approach with only 3 externally visible diseases, an assessment could be made for 17 ICES statistical rectangles. Some major fluctuations in the FDI values were observed in single ICES rectangles, but in most ICES rectangles (15 out of 17) no upward or downward trend occurred (Figure 1.5.5.10.1a),
Downward trends were only observed in two areas. Consequently, yellow smilies indicating no trends were assigned to 15 and green smilies indicating a significant downward trend to 2 rectangles (Figure 1.5.5.10.2a). From this model, there is no indication for major regional differences or trends between ICES statistical rectangles.

- The approach using the full set of 9 externally visible diseases resulted in an assessment for 10 ICES statistical rectangles (Figure 1.5.5.10.1b). Again, some strong fluctuations were observed in single rectangles. In contrast to the approach with only 3 externally visible diseases, the majority of rectangles (7) were characterized by a significant upward trend in FDI, resulting in the assignment of red smilies (Figure 1.5.5.10.2b). From this model, there is indication for both regional differences between ICES statistical rectangles and for trends.

- The third approach with the same 3 externally visible diseases as above in combination with macroscopic liver neoplasms resulted in an assessment for only 6 rectangles (Figure 1.5.5.10.1c). Four out of these showed no trend (yellow smilies) and two a downward trend (green smilies) (Figure 1.5.5.10.2c). Due to the low number of rectangles no conclusions about regional or temporal patterns can be drawn.

**Conclusions**

From the application of the Fish Disease Index (FDI) to the ICES fish disease data there is evidence that the FDI approach is an appropriate tool for the analysis and assessment of fish disease data generated within monitoring programmes according to established ICES guidelines.

There is evidence that a considerable amount of disease data available in national databanks is still missing in the ICES fish disease databank This is partly due to the fact that data have not yet been submitted (e.g., data on liver histopathology) or due to problems related to conversion or submission of data using the ICES Environmental Data Reporting Format 3.2.

The fish disease data submitted to the ICES Data Centre so far were not sufficient to conduct an overall assessment of levels and trends as planned by using the full FDI approach with all of its components. Reasons were: national data cover different time periods and different sets of diseases, lack of data on severity grades, and patchy regional coverage. However, since the FDI can technically be modified in a way that still enables an assessment (i.e., by reducing the number of diseases considered, neglecting disease severity grades, and considering the three disease categories (i.e. externally visible diseases, macroscopic liver neoplasms, and liver histopathology separately), an analysis and assessment was carried out with the data available, the results of which have to be considered as preliminary, however.

The results of the assessment using different approaches (set of diseases included in the construction of the FDI) clearly show that the temporal changes in the FDI and the resulting assessment of the disease status strongly depend on the set of diseases included in the construction of the FDI, because the 3 assessments using the different FDI calculations have a different behaviour in terms of levels and trends. Therefore, it is not sufficient to consider only few diseases. On the contrary, it is advisable to include as many diseases as possible in the FDI because only then can a comprehensive assessment of the overall disease status be performed.

A decision on the most appropriate FDI approach and a more comprehensive assessment of the fish disease data will only be possible once all data available in national databanks have been submitted to the ICES Data Centre and have been analysed. Ways will be explored with data originators and the ICES Data Centre as to how this can be achieved in a timely fashion in order to meet the OSPAR requirements for the QSR 2010.

**Sources of information**

Figure 1.5.10.1a Temporal changes in the FDI and assessment of levels and trends in ICES statistical rectangles (based on 3 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing skin ulcerations)) Note: data set is incomplete!
Figure 1.5.10.1a (cont.). Temporal changes in the FDI and assessment of levels and trends in ICES statistical rectangles (based on 3 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing skin ulcerations)). Note: data set is incomplete!
Figure 1.5.5.10.1a (cont.). Temporal changes in the FDI and assessment of levels and trends in ICES statistical rectangles (based on 3 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing skin ulcerations)). Note: data set is incomplete!
Figure 1.5.10.1b Temporal changes in the FDI and assessment of levels and trends in ICES statistical rectangles (based on 9 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing ulceration, X-cell gill disease, hyperpigmentation, acute/healing fin rot/erosion, *Stephanostomum baccatum*, *Acanthochondria cornuta*, *Lepeophtheirus pectoralis*)). **Note: data set is incomplete!**
Figure 1.5.10.1b (cont.). Temporal changes in the FDI and assessment of levels and trends in ICES statistical rectangles (based on 9 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing ulceration, X-cell gill disease, hyperpigmentation, acute/healing fin rot/erosion, *Stephanostomum baccatum*, *Acanthochondria cornuta*, *Lepeophtheirus pectoralis*). Note: data set is incomplete!
Figure 1.5.5.10.1c Temporal changes in the FDI and assessment of levels and trends in ICES statistical rectangles (based on the combination of 3 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing skin ulcerations) and macroscopic liver neoplasms). **Note: data set is incomplete!**
Figure 1.5.5.10.2a  Assessment of levels and trends in ICES statistical rectangles (based on 3 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing skin ulcerations)).

Note: data set is incomplete!
Figure 1.5.5.10.2b  Assessment of FDI levels and trends in ICES statistical rectangles (based on 9 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing ulceration, X-cell gill disease, hyperpigmentation, acute/healing fin rot/erosion, *Stephanostomum baccatum*, *Acanthochondria cornuta*, *Lepeophtheirus pectoralis*)). Note: data set is incomplete!
Figure 1.5.5.10.2c Assessment of FDI levels and trends in ICES statistical rectangles (based on the combination of 3 externally visible diseases (lymphocystis, epidermal hyperplasia/papilloma, acute/healing skin ulcerations) and macroscopic liver neoplasms). Note: data set is incomplete!
1.5.5.11 Answer to request from OSPAR for a scoping report on summaries of the status of biodiversity

Request

“To contribute to the development of a possible request for the 2008 ICES work programme, through the preparation of an initial scoping report on the possible contents and methods that ICES would use to prepare a set of concise expert summaries of the quality status of the main components of biodiversity in each of the OSPAR Regions (seabed habitats and their associated communities; plankton, fish communities, marine mammals, seabirds and reptiles) (no more than 1 page per Region) as a contribution to the QSR 2010, if this request was included in the 2009 ICES Work Programme.”

(2008 ICES Work programme, request no. 14)

Source of information

The chairs of the ICES Working Groups on Benthic Ecology, Deepwater Ecology, Zooplankton Ecology, Fish Ecology, Marine Mammal Ecology, Seabird Ecology and two Planning Groups were asked to provide written input, if possible after consultation with Working Group members.

ICES Response

Summary of available information

Seabed habitats and their associated communities

The status of benthos populations is relatively well-known throughout the OSPAR area, although there are some gaps in knowledge for some regions. For the OSPAR Region II (the Greater North Sea), ICES would need to base its summary on the results of a common North Sea Benthos Survey that integrated recent macro-benthic infaunal and environmental data from various national sources over the years 1999–2002. These results can be compared with those from the 1986 ICES North Sea Benthos Survey and any significant changes (and their likely causes) may possibly be identified.

Within the North Sea, the structure and distribution of benthic communities can be explained largely by measured (or modelled) natural environmental variables. These include temperature, salinity, tidal/wave-induced bed stress, stratification, depth, and sediment type. The relative importance of these variables varies spatially, and many are correlated.

Information on the quality status of seabed habitats and their associated communities in other OSPAR regions is patchy and relies on regional studies and monitoring programmes.

Information on the state of harvested stocks of *Nephrops norvegica* may be included here, based on ICES stock assessment processes.

Plankton

Information on trends in phytoplankton communities is available from several national long-term monitoring programmes. National programmes are active in OSPAR Regions I, II, III, and IV. A forthcoming academic publication describing several EU series of long-term plankton observations will also be used.

Biomass/chlorophyll-a trends are available from a selected number of stations and from Continuous Plankton Recorder (CPR) data in the North Sea (OSPAR Regions II, III, and V, with limited coverage in Regions I and IV). Trends of certain algal groups can be estimated through data sets from annual updates of toxic species and occurrence in OSPAR Regions I to IV.

For zooplankton most information may be derived from the CPR data (collected monthly, mainly in OSPAR Regions II, III, and V), but important information may also be derived from national monitoring programmes. Indicator species of particular water masses are known to exist, and species are now appearing that were not present 30 years ago. The indicator species for each OSPAR region will be determined and trends in the indicators described.
Fish communities

Summaries of the status of fish communities are available from a variety of sources, as detailed in Table 1.

Table 1  Sources of data for demersal fish communities

<table>
<thead>
<tr>
<th>OSPAR REGION</th>
<th>SURVEYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region I</td>
<td>Icelandic, Russian, and Norwegian surveys</td>
</tr>
<tr>
<td>Region II</td>
<td>IBTS surveys, beam trawl surveys (plus some Scottish west coast info for areas west of the Shetland Islands)</td>
</tr>
<tr>
<td>Region III</td>
<td>Scottish west coast surveys, SWIBTS (Scotland, Ireland, England, France, Spain), beam trawl surveys, Old Cefas PHHT survey</td>
</tr>
<tr>
<td>Region IV</td>
<td>Biscay/Iberian, French/Spanish/Portuguese SWIBTS surveys</td>
</tr>
<tr>
<td>Region V</td>
<td>Potentially an Azores survey, to be considered in terms of deepwater and pelagic fish communities</td>
</tr>
</tbody>
</table>

Additionally, catch statistics exist for all of these regions, as compiled by ICES and FAO. Most of the ICES fish community analyses have been focused on the state of demersal fish communities, with the status of pelagic fish usually being described by stock rather than by community.

Further descriptions, from detailed species biology to broadscale community analyses, could also involve, for example:

i) Fish community indicators of state (e.g. size spectra, diversity), based on survey time-series;
ii) Species inventories by region and potential habitat dependencies; and
iii) Identification of potentially vulnerable species based on life-history characteristics and susceptibility to human activities.

Marine mammals

The general lack of reliable baseline information on distribution, abundance, and condition of marine mammals within the OSPAR area inhibits consistent assessment of the quality status of marine mammals. In general only a few datasets are available on a regular basis (e.g. annually) and these cover a large spatial area.

For cetaceans, limited trend information is available and could be used for OSPAR Regions I (NASS and TNASS), II (SCANS and SCANS II), and the northern part of V (NASS and TNASS). Some baseline information has also been collected recently for Regions III and IV, and for NW Region V (SCANS II and CODA). Some local datasets could be used when these are believed to mirror wider trends. Examples of distributional changes that could be used include those pertaining to harbour porpoises in the North Sea, bottlenose dolphins off the Scottish coast, killer whales off Norway, minke whales in the North Sea, and common dolphins.

Information on seal abundance trends could be used to describe changes in OSPAR Region II and part of Region III. Some information also exists for OSPAR Region I (and very few seals are present in OSPAR Regions IV and V).

Seabirds

The status of seabird populations is relatively well-known throughout the OSPAR area, although there are some gaps in knowledge for some species and regions.

OSPAR Region I is large and rather heterogeneous and the population status of seabirds here has been less well studied than in other regions. Robust data exist on population sizes and recent (last two–three decades) trends for many species especially in mainland Norway, but there are information gaps for several species (notably the auklets and the northern fulmar) in parts of Iceland, Greenland, and northern Russia. ICES could summarize trends in breeding success for representative species, mainly in the Norwegian parts of the region.

Particularly good information exists on the sizes of the breeding populations of most seabird species over at least three decades in OSPAR Regions II and III, especially in the former. ICES could provide actual/estimated annual trends in breeding abundance in these two regions for most species. Breeding success data are also available for some species such as the black-legged kittiwake and common guillemot. Indicators of the health of individual seabird breeding populations, as well as for some feeding guilds based on population size and breeding success, exist for several species in parts of these regions. ICES could supply information on seasonal patterns, actual and modelled, of seabird dispersion at sea over the last two-three decades in OSPAR Regions I, II, and III, although there is a degree of spatial and temporal heterogeneity in the data sets.
OSPAR Region IV has been less well studied than Regions II and III, but ICES has available data on breeding abundance of seabird populations in recent years as well as some information on at-sea dispersion, especially of Cory’s shearwater. OSPAR Region V hosts some important populations of breeding seabirds, notably petrels and terns. Limited information exists on the movements and at-sea distribution of these species, but better information is available on population sizes, especially of the terns.

Reptiles

ICES has no information on trends throughout the OSPAR area in marine reptiles. Some information of unknown reliability exists to describe local trends.

Methods

ICES would use its existing Expert Group structure to initially provide short summaries, by OSPAR Region, of the quality status of the main components of biodiversity (seabed habitats and their associated communities, plankton, fish communities, marine mammals, seabirds). These summaries would be further distilled to provide concise summaries of the status of biodiversity in each region and would be peer-reviewed before being provided to OSPAR. For the North Sea (OSPAR Region II), ICES could provide information based on a pilot Regional Ecosystem Assessment conducted during the past few years.
1.5.5.12 Answer to request from OSPAR for scientific review of the WWF proposal for a Marine Protected Area for the Mid Atlantic Ridge/the Charlie Gibbs Fracture Zone

Request

A proposal to establish a Marine Protected Area on the mid-Atlantic ridge was presented by WWF to the meeting of OSPAR’s Working Group on Marine Protected Areas, Species and Habitats (MASH) at its meeting in November 2007. Annex 11 of the summary record of MASH 2007, requests that ICES:

- review the information provided in Section A of the WWF proposal and provide any relevant data that is available to ICES.
- a review of whether information provided in Section B meets the ecological criteria and considerations set out in appendix 1 of the OSPAR guidelines on identification and selection of MPAs in the OSPAR maritime area (OSPAR agreement 2003-17), focussing on the following:
  - (i) reviewing and adding to the information provided in relation to ecological criteria and considerations.
  - (ii) commenting on which of the selection criteria are fulfilled taking into account all available information.
  - (iii) reviewing and if possible, adding to the information provided on possible damage by human activities.
  - (iv) commenting on the value of the site for scientific research.
- commenting on the appropriateness of the proposed boundaries and suggest alternative boundary options.
- identify and delineate, when known by the reviewers, the key locations of ecologically significant and/or vulnerable (i) habitats, (ii) species and (iii) ecological processes within the area identified in the WWF proposal, taking into account available data.

ICES was requested to provide this review by fast track procedure by 29 January 2008.

Source of information

The ICES Working Groups on Deep-water Ecology (WGDEC) and Seabird Ecology (WGSE) were asked for their comments by correspondence.

ICES Response

Further relevant data

Information on the ecology of this area is scarce and dispersed. The data from two projects (MarEco and EcoMar) conducted in the Mid-Atlantic Ridge region are currently being analyzed, and the results (which will start to become available in published form later in 2008) should contribute to an enhanced understanding of the Mid-Atlantic Ridge ecosystem.

For marine mammals and seabirds, as for the other taxa covered, the report provides an inadequate summary of the known status of marine mammals and seabirds from MarEco and other projects. A plethora of scientific information on the distribution of biodiversity at the Mid Atlantic Ridge has been published or is in press from the MarEco project. In particular, the nomination document should be updated by the wealth of information, including on cetaceans, to become available in the special issue of Deep Sea Research (2) (to be published early 2008) on the results of the G.O. Sars cruise in 2004. It should however be noted that the MarEco study focused on describing the meso-scale variability of biodiversity along and across the Ridge, and no specific research has been made by this project to address the conservation status and management requirements in relation to seabirds and marine mammals.

ICES provides some information on fishing on the Mid-Atlantic Ridge in its Advice for 2006, (Book 9, Section 11.1.2. available at www.ices.dk)
1.5.5.12 Application of OSPAR MPA identification guidelines

Ecological criteria

Criterion 1. Threatened or declining species and habitats/ biotopes

ICES notes that the ecological criteria state that an area should be “important” for a threatened or declining species to be used. ICES has no evidence that the proposed area is important for either loggerhead turtles or leatherback turtles. ICES considers that it is likely that the area is important for the other species and habitats listed, but notes that the evidence for this is not presented.

Criterion 2. Important species and habitats/biotopes

ICES is not aware of any further “other” species that might qualify in the ongoing OSPAR selection process qualify.

Criterion 3. Ecological significance

ICES found no evidence in the application to support:

- a high proportion of a habitat/biotope type or a biogeographic population of a species at any stage in its life cycle;
- important feeding, breeding, moultiing, wintering or resting areas;
- important nursery, juvenile or spawning areas; or
- a high natural biological productivity of the species or features being represented.

ICES notes, contrary to the proposal, that OSPAR has not at any stage categorised the Mid-Atlantic Ridge as a “habitat” nor that the sub-polar front at 52°N is particularly productive in this area.

Criterion 4. High natural biological diversity

ICES found no comparison of this area with other parts of the North Atlantic to demonstrate that this area has a higher natural variety of species than exists elsewhere.

Criterion 5. Representativity

ICES is certain that the proposed area is representative of part of the northern Mid Atlantic Ridge.

Criterion 6. Sensitivity

ICES found no evidence in the proposal that the area contains a high proportion of very sensitive or sensitive habitats or species compared to elsewhere. However, ICES acknowledges that any area that has not been subjected to anthropogenic impacts is likely to be more sensitive than areas that have been impacted.

Criterion 7. Naturalness

It is likely that much of this area is in a natural state, but that past and present fisheries have had impacts within the depth zones fished.

ICES notes that an MPA can be designated by OSPAR whether or not it meets all selection criteria.

Practical criteria

ICES has no information available to comment on management aspects of the proposed area (practical criteria 1-5). In the time available, ICES has been unable to undertake any further specific analysis of fishing activity within the proposed area. As with many other deep water areas, this area is comparatively under-researched.

Appropriateness of boundaries

ICES is unable to comment on the appropriateness of the proposed boundaries due to insufficient data. ICES notes that “WWF met serious impediments as the steering committee of the Mar-Eco project did not feel to be in a position to make an expert judgment yet” (MASH 07/6/7-E Agenda Item 6). Several of the scientists associated with the ICES
working groups that were asked to review the WWF proposal are also members of the steering committee and, as such, reiterated the same advice they had provided as committee members.

**Key locations**

As there is presently insufficient information available to delineate key features within the proposed area. ICES advises to await the publication, in late 2008, of the Mar-Eco and Eco-Mar results before any further actions are envisaged or taken in establishing an MPA in the region. This new information on the Mid-Atlantic Ridge ecosystem should be indispensable in providing a more comprehensive and knowledgeable basis for evaluating the ecological merits of any subsequent proposal for an MPA in the region.
1.5.5.13 Update of proposed background concentrations for alkylated PAHs in sediments and biota

Request

ICES has received the following request from OSPAR:

Development of Background Concentrations (OSPAR 3-2007)

a. To revisit the current accepted background concentrations for biota (OSPAR agreement 2005-6) and the values for background concentrations for biota that were proposed following the 2004 OSPAR/ICES workshop and to evaluate the methodology that was used to derive them with the aim of:

(i) developing proposals for deriving BCs in biota, with priority given to metals in fish and shellfish, bearing in mind that a pragmatic approach has to be identified that will be applicable for the wider OSPAR area;

(ii) identify those parts of the OSPAR maritime area for which the proposed BCs in biota may not be applicable so that this can be taken into account during the assessments, and;

(iii) for the parts of the OSPAR maritime area identified, determine how assessments of whether concentrations are of at or near background should be prepared.

b. To develop background concentrations for the following alkylated PAHs in sediments and biota:

(i) C1-, C2- and C3-naphthalenes;

(ii) C1-, C2- and C3-phenanthrenes; and

(iii) C1-, C2- and C3-dibenzothiophenes, as well as the parent compound dibenzothiophene;

In 2007 ICES provided preliminary recommendations for background concentrations of alkylated PAHs in sediments in response to the request (b). Those recommendations are replaced by this advice.

Summary

Due to the fact that BCs for alkylated PAHs in sediments and biota vary across the convention area ICES is not able to develop the requested BCs. However, recommendations for “low concentrations” are provided for alkylated PAHs in those areas where data are available. The recommendations for sediments in this document are based on the analysis of deep-core samples and replace the previous recommendations. The development of these recommendations is partly hampered by the limited available data for alkylated PAHs in biota and sediments. ICES therefore recommends that work be undertaken to extend the dataset on alkylated PAHs.

ICES Response

OSPAR has requested ICES to develop background concentrations (BCs) for a number of alkylated PAHs in biota and sediments. There is a basic difficulty with the concept of a specific natural background concentration for contaminants in biota for the entire OSPAR convention area. This is caused by differences across the convention area due to, e.g. geological and geochemical differences. Hydrocarbons like alkylated PAHs occur naturally at high concentrations in sediments in some geological provinces, while the natural background concentrations in sediments in other provinces can be very low. Other factors also influence the concentration levels found for PAHs, such as oceanographic conditions and different sedimentation/erosion conditions. In addition different anthropogenic inputs of hydrocarbons can be spread over wide distances.

The ICES response is hampered by the lack of data on alkylated PAH in sediment and biota; with limited data available for only a few locations in the OSPAR area. In order to refine the recommendations in this document more information on alkylated PAHs in sediments and biota will have to be made available.

a. Background concentrations in biota

The approach that has been taken to determine background concentrations (BCs) of contaminants has been to use results from biota samples collected from relatively “remote” and “pristine” areas. However, data for alkylated PAHs in biota are limited in both number and quality.

ICES therefore recommends the use of “low concentrations” based on available data (Table 1.5.5.13.1). Available data included mussel data for “remote” areas from Scotland and Spain (parent PAH only) and a large dataset from France for mussel and oyster. However, this latter dataset was not screened to select remote areas. These datasets were used to estimate “low concentrations” using the median of the 10th percentile of the data for the different datasets (Scotland,
Spain, and France). For most substances there was good agreement for the values from the different areas. The median of the 10th percentile for the different datasets is proposed as a “low concentration”. ICES was not in a position to propose low concentrations for all target PAHs identified in OSPAR’s CEMP due to the proportion of concentrations below the limits of quantification for some PAHs. Consequently, “low concentrations” are not proposed for anthracene, dibenzothiophene, and C1- to C3-napthalenes. Natural background concentrations in some parts of the OSPAR area could be lower than the proposed “low concentrations.” Due to the limited data available it is not possible to extrapolate these “low concentrations” to other parts of the OSPAR area. This information is provided to assist OSPAR with the JAMP.

Table 1.5.13.1  Proposed “low concentrations” (µg kg⁻¹ wet weight) of some parent and alkylated PAHs in shellfish (mussels & oysters).

<table>
<thead>
<tr>
<th>Compound</th>
<th>Proposed low concentrations¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent PAH</td>
<td></td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>0.8</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>1.1</td>
</tr>
<tr>
<td>Pyrene</td>
<td>0.8</td>
</tr>
<tr>
<td>Benzo(a)anthracene</td>
<td>0.2</td>
</tr>
<tr>
<td>Chrysene/Triphenylene²</td>
<td>0.8</td>
</tr>
<tr>
<td>Benzo(bj)fluoranthene³</td>
<td>0.6</td>
</tr>
<tr>
<td>Benzo(k)fluoranthene</td>
<td>0.2</td>
</tr>
<tr>
<td>Benzo(e)pyrene</td>
<td>0.5</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>0.1</td>
</tr>
<tr>
<td>Indeno(1,2,3-cd)Pyrene</td>
<td>0.2</td>
</tr>
<tr>
<td>Benzo(g,h,i)perylene</td>
<td>0.3</td>
</tr>
<tr>
<td>Alkyl-PAH</td>
<td></td>
</tr>
<tr>
<td>C1-phenanthrenes/anthracenes</td>
<td>1.4</td>
</tr>
<tr>
<td>C2-phenanthrenes/anthracenes</td>
<td>1.4</td>
</tr>
<tr>
<td>C3-phenanthrenes/anthracenes</td>
<td>1.3</td>
</tr>
<tr>
<td>Sulfur heterocyles</td>
<td></td>
</tr>
<tr>
<td>C1-dibenzothiophenes</td>
<td>0.2</td>
</tr>
<tr>
<td>C2-dibenzothiophenes</td>
<td>0.7</td>
</tr>
<tr>
<td>C3-dibenzothiophenes</td>
<td>0.7</td>
</tr>
</tbody>
</table>

1. Low concentrations are proposed for use by OSPAR in lieu of “Background Concentrations” in OSPAR CEMP assessments and not for other purposes. These concentrations are based on 10th percentiles of datasets from Scotland, Spain (parent PAH only), and France. Proposed “low concentrations” do not reflect true natural background concentrations and MCWG considers that true natural background concentrations may be lower.
2. Chrysene/triphenylene are generally reported as summed compounds, particularly if analysed by GCMS.
3. Benzo(bj)fluoranthene and benzo(j)fluoranthene generally reported as summed compounds, particularly if analysed by GCMS.
Sediments

Previously ICES had examined the data on alkylated PAHs held in the database of sediment analyses from areas considered to represent background conditions. Initially this database had been created at the 2004 ICES Workshop on BCs and EACs and additional data had been added over the years. However, the database still contains relatively few data on alkylated PAHs covering only a limited parts of the OSPAR area, i.e. France, Norway, and Scotland. Some of the contaminant data were not accompanied by analyses of appropriate cofactors and there appeared to be inconsistencies in some of the data. ICES undertook a re-evaluation of its previous recommendations based on the availability of data from cores (i.e. deep cores referring to pre-industrial times). Such data was only available for a few core samples from France (Bay of Biscay), Norway (Oslofjord), and Scotland (Loch Etive). For each dataset, results were normalized to 2.5% organic carbon and a median value was calculated for each (if applicable) sampling station.

Figure 1.5.5.13.1 compares the medians of the different locations with the overall median and the background values previously recommended by ICES. With the exception of dimethylnaphthalenes, the core data yields similar, but generally lower, background values than those previously recommended by ICES. Furthermore, a deep core from the Baltic, outside the OSPAR area, yielded a concentration of methylphenanthrenes that was of the same order of magnitude as the other values from the cores. Given their origin, these values are probably more indicative of background conditions than values previously recommended. ICES therefore proposes to update its previous recommendations to those given in Table 1.5.5.13.2. ICES also recommends that further work be undertaken to extend the data set underlying these estimations, to include data from more areas and add more data to the database.

Figure 1.5.5.13.1  Median concentrations of alkylated PAH in deep-core samples from France, Norway, and Scotland. Also included are the median for all samples, the values recommended previously by ICES, and the concentration of C2-naphthalene in a core from the Baltic.
Table 1.5.5.13.2  “Low concentrations” for alkylated PAHs in sediments normalized to 2.5% organic carbon, based on the median concentration of a few deep-core samples from France, Norway, and Scotland.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2007 values (µg/kg dry weight)</th>
<th>2008 values (µg/kg dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1- naphthalene</td>
<td>1.7</td>
<td>2.7</td>
</tr>
<tr>
<td>C2- naphthalene</td>
<td>2.3</td>
<td>6.7</td>
</tr>
<tr>
<td>C3- naphthalene</td>
<td>5.0</td>
<td>3.3</td>
</tr>
<tr>
<td>C1-phenanthrenes/anthracenes</td>
<td>4.5</td>
<td>2.7</td>
</tr>
<tr>
<td>C2-phenanthrenes/anthracenes</td>
<td>8.3</td>
<td>3.7</td>
</tr>
<tr>
<td>C3-phenanthrenes/anthracenes</td>
<td>9.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Dibenzothiophene</td>
<td>1.3</td>
<td>0.6</td>
</tr>
<tr>
<td>C1-dibenzothiophenes</td>
<td>2.3</td>
<td>1.0</td>
</tr>
<tr>
<td>C2-dibenzothiophenes</td>
<td>5.0</td>
<td>0.7</td>
</tr>
<tr>
<td>C3-dibenzothiophenes</td>
<td>4.8</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Sources of information

1.5.5.14 Proposals for background concentrations in biota with priority to metals in fish and shellfish

Request

ICES has received the following request from OSPAR:

*Development of Background Concentrations (OSPAR 3-2007)*

a) To revisit the current accepted background concentrations for biota (OSPAR agreement 2005-6) and the values for background concentrations for biota that were proposed following the 2004 OSPAR/ICES workshop and to evaluate the methodology that was used to derive them with the aim of:

i. developing proposals for deriving BCs in biota, with priority given to metals in fish and shellfish, bearing in mind that a pragmatic approach has to be identified that will be applicable for the wider OSPAR area;

ii. identify those parts of the OSPAR maritime area for which the proposed BCs in biota may not be applicable so that this can be taken into account during the assessments, and;

iii. for the parts of the OSPAR maritime area identified, determine how assessments of whether concentrations are of at or near background should be prepared.

b) To develop background concentrations for the following alkylated PAHs in sediments and biota:

i. C1-, C2- and C3-naphthalenes;

ii. C1-, C2- and C3-phenanthrenes, and;

iii. C1-, C2- and C3-dibenzothiophenes, as well as the parent compound dibenzothiophene;

ICES has previously provided advice for this request with the exception of the advice for metals under bullet (i). Updated advice on point b) is provided in Section 1.5.5.13.

**ICES Response**

**Summary**

Background Concentrations (BCs) are required for use in OSPAR’s Coordinated Environmental Monitoring Programme (CEMP) assessment of temporal trends. The OSPAR strategy for hazardous substances (OSPAR, 1998) sets an “ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances.” However, there is a difficulty with the concept of a unique natural background concentration for individual contaminants in biota for the entire OSPAR convention area due to the differences across the convention area (for example due to geochemical differences, oceanographic factors such as upwelling, and different transport pathways). Furthermore, no sound methodology exists to determine natural background (pre-industrial) concentrations for these contaminants in biota. In order to expedite the OSPAR assessment, ICES proposes “low concentrations” for selected metals in mussels for those parts of the OSPAR region where this data is available. The high variability in the limited data for these metals in fish precludes making any recommendation for low or background concentrations.

**Background**

ICES examined the available data for metals in biota in the OSPAR area. Recognizing OSPAR’s urgent need for background concentrations for use in the 2008 CEMP assessment, ICES makes the following recommendations subject to the following considerations:

- Concentrations presented for use by OSPAR as BCs are concentrations that ICES considers as “low concentrations.” They are not proposed as natural background concentrations.
- These background concentrations are proposed to assist OSPAR with the 2008 CEMP assessment and should not be used for other purposes.

**Low concentrations of metals in mussels**

Data from areas generally fulfilling the criteria for remote areas from Spain, Greenland (2 datasets), Shetland/Faroe, Norway, and the west coast of Ireland were reviewed. The datasets varied in size, and while the Norwegian data were not screened to identify and remove specific areas that might not fit the remote area criteria, it was a large dataset (>1000 samples) and the majority of the data clearly represented low concentrations.
Ideally, area-specific concentrations should be derived to account for the geochemical and oceanographic variability between regions. However, for pragmatic reasons, low concentrations for the entire convention area, based on the median of medians (rounded up) for these individual regions, are presented for trace metals in mussel (Table 1.5.5.14.1). For some metals, most notably cadmium, the spatial variability across these regions is high and in such cases concentration ranges for these remote areas are also presented. In the specific case of cadmium the proposed low concentration reflects a median value for background areas for Ireland, Shetland/Faroe, and Norway and excludes higher concentrations from Spain (due to upwelling) and Greenland\(^1\). Therefore, the proposed “low concentration” is not appropriate for these areas. As oysters exhibit higher concentrations of certain metals than mussels (e.g. cadmium, copper, silver, zinc) the values cannot be directly used for these elements to assess oyster concentrations.

Table 1.5.5.14.1 Proposed concentration ranges for metals in mussels from remote areas and proposed “low concentrations” of metals in mussels (mg kg\(^{-1}\) wet weight).

<table>
<thead>
<tr>
<th>Metal</th>
<th>Range(^1)</th>
<th>Proposed low concentrations(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadmium</td>
<td>0.045–0.73</td>
<td>0.12(^3)</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>0.07–0.28</td>
<td>0.16(^4)</td>
</tr>
<tr>
<td>Copper</td>
<td>0.91–1.50</td>
<td>1.1</td>
</tr>
</tbody>
</table>

1. Range of median concentrations for datasets from different regions (Spain, Greenland, Norway, Faroe Islands/Shetland Islands, west coast of Ireland).
2. Low concentrations proposed for use by OSPAR in lieu of “Background Concentrations” in OSPAR 2008 CEMP assessments and not for other purposes. These concentrations do not necessarily reflect true natural background concentrations and may not be applicable across the entire convention area.
3. Low concentration is not applicable for entire convention area, e.g. Iberian coast and Greenland.
4. Low concentration may not applicable for entire convention area.
5. Limited data, therefore it is not possible to provide a “meaningful” range.

Low concentrations of metals in fish

The variability of concentrations in the dataset available for trace metals in finfish can be quite pronounced as biological factors, for example diet and size/age, play an important role in determining tissue concentrations. This variability was reflected in the limited data examined. Few records had appropriate metadata to enable further analysis of the role of such factors. Due to this ICES is unable to recommend BCs or low concentrations for fish and suggests that for fish, a statistical approach to derive BACs such as that illustrated in the MON 2007 report should be used.

References


Source of information


\(^1\) The high concentrations in Greenland of many contaminants, including some metals, observed in biota are presumably due to long-range transport.
1.5.5.15 Development of background concentrations for dioxins in biota and sediment

Request

ICES has received the following request from OSPAR:

Tools for coordinated monitoring of dioxins, planar CBs and PFOS (OSPAR 4-2008)

To prepare the following tools to support the coordinated monitoring of dioxins, planar CBs and PFOS under the OSPAR CEMP:

a) technical annexes to the JAMP Guidelines for monitoring Contaminants in Sediments (OSPAR agreement 2002-16) and JAMP Guidelines for monitoring Contaminants in Biota (OSPAR agreement 1992-2) according to the structure of the existing technical annexes covering the following:

i. monitoring of dioxins in biota in sediments, taking into account advice from SIME 2007 that monitoring of dioxins in sediments should only be carried out in specific areas (such as sedimentation areas or estuaries) because of time lag (10 – 12 years) in deposition of quantities required for sampling;
ii. monitoring of PFOS in sediments, biota and water;

b) to review the existing technical annexes on monitoring of chlorinated biphenyls in biota and sediment and propose revisions so that they are adequate for monitoring of planar CBs in these compartments, taking into account advice from SIME that monitoring in sediments should be undertaken only if levels of marker PCBs are e.g. 100 times higher than the BACs and that for biota monitoring of concentrations in seabird eggs could provide an alternative matrix;

c) to develop background concentrations for dioxins.

The response below refers to item (c) in the request from OSPAR. The response to items a) and b) is found in Section 1.5.5.4 of this report.

ICES Response

Summary

Presently the primary source of dioxins in the environment is human activity. However, in the past, as today, natural events such as forest fires produce some of these compounds. The background concentration for dioxins is therefore low, but not zero. A preliminary assessment of the data available for dioxins in marine sediments and biota indicate that it will be a considerable challenge to define these background concentrations with any degree of rigor. ICES will continue to seek more environmental data and explore alternate approaches to determining the background concentrations, with the aim of providing additional advice in 2009.

Explanation

OSPAR has included dioxins in their voluntary monitoring programme, i.e. pre-CEMP, and therefore background concentrations (BCs) will be needed for the assessment of monitoring data.

Background concentrations for dioxins are not necessarily zero. Although they may be predominantly of anthropogenic origin today, these compounds would also have been formed in the past through natural processes, for example in forest fires.

Background concentrations of dioxins in sediments

ICES examined a number of scientific papers in relation to concentrations of dioxins in sediments from different areas. Difficulties were encountered with the relative paucity of data from potential pristine areas and differences in the units in reporting (see Annex 1 for preliminary list of data. It is important to note that these values are not considered to be background concentrations; they are only a summary of dioxin concentrations reported for individual areas.).
ICES found:

- That a very limited geographical area was covered by the available data;
- That some of the contaminant data were not accompanied by appropriate data on cofactors;
- That the data collected so far are not sufficient to allow a reliable evaluation of background conditions;
- That work needs to be undertaken to collect data from other areas in order to
  - identify sources of data from areas considered to represent background conditions, and
  - to collate data on contaminants and appropriate cofactors from these areas.

**Background concentrations of dioxins in biota**

ICES also found that very limited data were available to support derivation of BCs for PCDD/PCDFs in biota. The development of recommendations of BCs for dioxins in biota will be a difficult task which will be revisited in 2009.

**Sources of information**

### Annex 1. Preliminary list of data available for determining background concentrations of dioxins in sediments.

#### Preliminary table of concentrations of dioxins in sediment

<table>
<thead>
<tr>
<th>Author</th>
<th>Reference</th>
<th>Site</th>
<th>Sediment depth cm</th>
<th>Sediment age</th>
<th>pg/g PCDD</th>
<th>pg/g PCDF</th>
<th>pg/g PCDD/F</th>
<th>pg/g TE-PCDD</th>
<th>pg/g TE-PCDF</th>
<th>pg/g TOC</th>
<th>% TOC</th>
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<td>Gauss</td>
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<td>&lt;10</td>
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<td>National marine sediment criteria, mud</td>
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<td>Jonsson</td>
<td>Ambio, 22, 1933</td>
<td>Baltic</td>
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<td></td>
<td></td>
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<td>Frignani</td>
<td>Environ. Int., 31,2005</td>
<td>Venice</td>
<td>40</td>
<td></td>
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<td></td>
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<td>Isosaari</td>
<td>Chemosf,47, 2002</td>
<td>Finland</td>
<td>0-11</td>
<td>1999-1790</td>
<td>84</td>
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<td>1.18</td>
<td></td>
<td>Freshwater, average value?</td>
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<td>Okumura</td>
<td>Water Res., 38, 2004</td>
<td>Japan</td>
<td>28-30</td>
<td>1934</td>
<td>377</td>
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<td>0.73</td>
<td>0.28</td>
<td></td>
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</table>
1.5.5.16  JAMP Guidelines for monitoring contaminants in biota and sediments

Request

ICES has received the following request from OSPAR:

**Development of JAMP monitoring guidelines** (OSPAR no. 2-2007)

To carry out the following development work with regard to the JAMP Guidelines for monitoring Contaminants in Sediments (OSPAR agreement 2002-16) and JAMP Guidelines for monitoring Contaminants in Biota (OSPAR agreement 1999-2) to ensure that monitoring guidance is in place to support a revised Co-ordinated Environmental Monitoring Programme.

- develop draft technical annexes on monitoring of polybrominated diphenyl ethers and hexabromocyclododecane in sediments and biota following the structure of the existing technical annexes. SIME 2007 will be invited to clarify the congeners and compartments that are relevant for the development of monitoring guidance for brominated flame retardants.
- review the existing technical annexes on PAHs to see whether they are adequate for monitoring of the alkylated PAHs and, as appropriate, prepare advice on any revisions that are necessary.
- to develop a draft technical annex on monitoring of TBT and its breakdown products in biota

Advice on point (a) has been provided previously.

Summary

**Alkyl PAH in sediment and biota**

The current OSPAR technical annex for PAH analyses required updating as clear guidance was required to ensure quantification of alkyl homologues of PAHs and alkyl substituted sulphur-heterocyclic PAHs in biota and sediment. The proposed updated technical guidelines are presented in annexes 1 and 2 and are recommended to OSPAR for adoption as part of their JAMP guidelines for monitoring contaminants.

The technical annex for the analyses of parent and alkylated PAHs in biota contains information for the selection of species, sampling techniques, sample transport, conservation, and sample treatment (including extractions, clean-up, and pre-concentration).

The analytical protocol follows the same technical principles as for the analysis of unsubstituted, parent PAHs. However, HPLC with fluorescence detection (HPLC-UVF) cannot be used for the detailed analysis of individual alkylated PAHs. Gas chromatography with mass spectrometry (GC-MS) is presently the preferred analytical technique for the analysis of both parent and alkylated PAHs.

**Organotins in biota**

The technical annex for organotins in biota, as appended at annex 3 is proposed for adoption by OSPAR as part of the Joint Monitoring and Assessment Programme (JAMP) Guidelines for Monitoring Contaminants in Biota.

**Explanation**

The full text of the response is found in the attached technical annexes.

**Sources of information**

ANNEX 1: Polyaromatic hydrocarbons in biota

Determination of parent and alkylated PAHs in biological materials

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) consist of a variable number of fused benzene rings. By definition, PAHs contain at least two fused rings. PAHs arise from incomplete combustion processes and from both natural and anthropogenic sources, although the latter generally predominate. PAHs are also found in oil and oil products, and these include a wide range of alkylated PAHs formed as a result of diagenetic processes, whereas PAHs from combustion sources comprise mainly parent (non-alkylated) compounds. PAHs are of concern in the marine environment for two main reasons: firstly, low molecular weight (MW) PAHs can cause tainting of fish and shellfish and render them unfit for sale; secondly, metabolites of some of the high MW PAHs are potent animal and human carcinogens — benzo[α]pyrene is the prime example. Carcinogenic activity is closely related to structure. Benzo[e]pyrene and the four benzo[a]fluoranthene isomers all have a molecular weight of 252 Da; however, they are much less potent than benzo[a]pyrene. Less is known about toxicity of alkylated PAHs. However, one study has demonstrated that alkylated PAHs may have increased toxicity compared to the parent compound (Marvanova et al., 2008).

PAHs are readily taken up by marine animals both across gill surfaces (lower MW PAHs) and from their diet. They may bioaccumulate, particularly in shellfish. Filter-feeding organisms such as bivalve molluscs can accumulate high concentrations of PAHs, both from chronic discharges to the sea (e.g., of sewage) and following oil spills. Fish are exposed to PAHs both via uptake across gill surfaces and from their diet, but do not generally accumulate high concentrations of PAHs as they possess an effective mixed-function oxygenase (MFO) system which allows them to metabolise PAHs and to excrete them in bile. Other marine vertebrate and marine mammals also metabolise PAHs efficiently. An assessment of the exposure of fish to PAHs therefore requires the determination of PAH metabolite concentrations in bile, as turnover times can be extremely rapid.

There are marked differences in the behaviour of PAHs in the aquatic environment between the low MW compounds (such as naphthalene; 128 Da) and the high MW compounds (such as benzo[ghi]perylene; 276 Da) as a consequence of their differing physico-chemical properties. The low MW compounds are appreciably water soluble (e.g. naphthalene) and can be bioaccumulated from the dissolved phase by transfer across gill surfaces, whereas the high MW compounds are relatively insoluble and hydrophobic, and can attach to both organic and inorganic particulates within the water column. PAHs derived from combustion sources may actually be deposited to the sea already adsorbed to atmospheric particulates, such as soot particles. The sediment will act as a sink for PAHs in the marine environment.

2. Appropriate species for analysis of parent and alkylated PAHs

2.1 Benthic fish and shellfish

Guidance on the selection of appropriate species for contaminant monitoring is given in the OSPAR Joint Assessment and Monitoring Programme guidelines. All teleost fish have the capacity for rapid metabolism of PAHs, thereby limiting their usefulness for monitoring temporal or spatial trends of PAHs. Shellfish (particularly molluscs) generally have a lesser metabolic capacity towards PAHs, and so they are preferred because PAH concentrations are generally higher in their tissues. The blue mussel (Mytilus edulis) occurs in shallow waters along almost all coasts of the Northeast Atlantic. It is therefore suitable for monitoring in near shore waters. No distinction is made between M. galloprovincialis because the latter species, which may occur along Spanish and Portuguese coasts, fills a similar ecological niche. A sampling size range of 30–70 mm shell length is specified to ensure availability throughout the whole maritime area. In some areas (e.g., the Barents Sea), other species may be considered. Recent monitoring studies have indicated a seasonal cycle in PAH concentrations (particularly for combustion-derived PAHs) in mussels, with maximum concentrations in the winter prior to spawning and minimum concentrations in the summer. It is particularly important, therefore, that samples selected for trend monitoring and spatial comparisons are collected at the same time of year, and preferably in the first months of the year prior to spawning.

For the purposes of temporal trend monitoring, it is essential that long time-series with either a single species or a limited number of species be obtained. Care should be taken that the sample is representative of the population and that it can be sampled annually. There are advantages in the use of molluscs for this purpose as they are sessile, and so reflect the degree of contamination in the local area to a greater degree than fish which are mobile and metabolise PAHs relatively efficiently. The analysis of fish tissues is often undertaken in conjunction with biomarker and disease studies, and associations have been shown between the incidence of some diseases (e.g., liver neoplasia) in flatfish and the concentrations of PAHs in the sediments over which they live and feed (Malins et al., 1988; Vethaak and Rheinallt, 1992). The exposure of fish to PAHs can be assessed by the analysis of PAH metabolites in bile, and by measuring the induction of mixed-function oxygenase enzymes which catalyse the formation of these metabolites.
3. Transportation

Live biota should be transported in closed containers at temperatures between 5°C and 10°C. For live animals it is important that the transport time is short and controlled (e.g., maximum of 24 hours). If biomarker determinations are to be made, then it will be necessary to store tissue samples at lower temperatures, for example, in liquid nitrogen at −196°C.

4. Pre-treatment and storage

4.1 Contamination

Sample contamination may occur during sampling, sample handling, pre-treatment, and analysis, due to the environment, the containers or packing materials used, the instruments used during sample preparation, and from the solvents and reagents used during the analytical procedures. Controlled conditions are therefore required for all procedures. In the case of PAHs, particular care must be taken to avoid contamination at sea. On ships there are multiple sources of PAHs, such as the oils used for fuel and lubrication, and the exhaust from the ship’s engines. It is important that the likely sources of contamination are identified and steps taken to preclude sample handling in areas where contamination can occur. A ship is a working vessel and there can always be procedures occurring as a result of the day-to-day operations (deck cleaning, automatic overboard bilge discharges, etc.) which could affect the sampling process. One way of minimizing the risk is to conduct dissection in a clean area, such as within a laminar-flow hood away from the deck areas of the vessel. It is also advisable to collect samples of the ship’s fuel, bilge water, and oils and greases used on winches, etc., which can be used as fingerprinting samples at a later date, if there are suspicions of contamination in particular instances.

Freeze-drying of tissue samples may be a source of contamination due to the back-streaming of oil vapours from the rotary vacuum pumps. Furthermore, drying the samples may result in losses of the lower molecular weight and more volatile PAHs through evaporation (Law and Biscaya, 1994).

4.2 Shellfish

4.2.1 Depuration

Depending upon the situation, it may be desirable to depurate shellfish so as to void the gut contents and any associated contaminants before freezing or sample preparation. This is usually applied close to point sources, where the gut contents may contain significant quantities of PAHs associated with food and sediment particles which are not truly assimilated into the tissues of the mussels. Depuration should be undertaken in controlled conditions and in clean seawater; depuration over a period of 24 hours is usually sufficient. The aquarium should be aerated and the temperature and salinity of the water should be similar to that from which the animals were removed.

4.2.2 Dissection and storage

Mussels should be shucked live and opened with minimal tissue damage by detaching the adductor muscles from the interior of at least one valve. The soft tissues should be removed and homogenised as soon as possible, and frozen in glass jars or aluminium cans at −20°C until analysis. Plastic materials must not be used for sampling and storage owing to possible adsorption of the PAHs onto the container material. As PAHs are sensitive to photo-degradation, exposure to direct sunlight or other strong light must be avoided during storage of the samples as well as during all steps of sample preparation, including extraction and storage of the extracts (Law and Biscaya, 1994). The use of amber glassware is strongly recommended.

When samples are processed, both at sea and onshore, the dissection must be undertaken by trained personnel on a clean bench wearing clean gloves and using PAH-free stainless steel knives and scalpels. Stainless steel tweezers are recommended for holding tissues during dissection. After each sample has been prepared, all tools and equipment (such as homogenisers) should be cleaned by wiping with tissue and rinsing with solvent.

5. Analysis

5.1 Preparation of materials

Solvents and adsorptive materials must all be checked for the presence of PAHs and other interfering compounds. If found then the solvents, reagents, and adsorptive materials must be purified or cleaned using appropriate methods. Absorptive materials should be cleaned by solvent extraction and/or by heating in a muffle oven as appropriate. Glass fibre materials (e.g. Soxhlet thimbles and filter papers used in pressurised liquid extraction (PLE)) should be cleaned by solvent extraction or pre-baked at 450°C overnight. It should be borne in mind that clean materials can be re-
contaminated by exposure to laboratory air, particularly in urban locations, and so the method of storage after cleaning is of critical importance. Ideally, materials should be prepared immediately before use, but if they are to be stored, then the conditions should be considered critically. All containers which come into contact with the sample should be made of glass or aluminium, and should be pre-cleaned before use. Appropriate cleaning methods would include washing with detergents, rinsing with water of known quality, and finally solvent rinsing immediately before use.

5.2 Lipid determination

Although PAH data are not usually expressed on a lipid basis, the determination of the lipid content of tissues can be of use in characterising the samples. This will enable reporting concentrations on a wet weight or lipid weight basis. The lipid content should be determined on a separate subsample of the tissue homogenate, as some of the extraction techniques used routinely for PAHs determination (e.g., PLE with fat retainers, alkaline saponification) destroy or remove lipid materials. The total lipid content of fish or shellfish should be determined using the method of Bligh and Dyer (1959) as modified by Hanson and Olley (1963) or an equivalent method such as Smedes (1999). Extractable lipid may be used, particularly if the sample size is small and lipid content is high. It has been shown that if the lipid content is high (>5%) then extractable lipid will be comparable to the total lipid.

5.3 Extraction

PAHs are lipophilic and so are concentrated in the lipids of an organism, and a number of methods have been described for PAH extraction (Ehrhardt et al., 1991). These methods generally utilise either Soxhlet extraction, or alkaline digestion followed by liquid-liquid extraction with an organic solvent. In the case of Soxhlet extraction, the wet tissue must be dried by mixing with a chemical drying agent (e.g., anhydrous sodium sulphate), in which case a time period of several hours is required between mixing and extraction in order to allow complete binding of the water in the sample. Samples are spiked with recovery standard and should be left overnight to equilibrate. Alkaline digestion is conducted on wet tissue samples, so this procedure is unnecessary.

Apolar solvents alone will not effectively extract all the PAHs from tissues when using Soxhlet extraction, and mixtures such as hexane/dichloromethane may be effective in place of solvents such as benzene and toluene, used historically for this purpose. Alkaline digestion has been extensively used in the determination of PAHs and hydrocarbons and is well documented. It is usually conducted in alcohol (methanol or ethanol), which should contain at least 10% water, and combines disruption of the cellular matrix, lipid extraction and saponification within a single procedure, thereby reducing sample handling and treatment. Solvents used for liquid-liquid extraction of the homogenate are usually apolar, such as pentane or hexane, and they will effectively extract all PAHs.

Alternatively extraction of wet or dry samples of biota may be carried out by pressurised liquid extraction (PLE). This is a more recent method, requiring less solvent and time for the extraction process. The wet biota sample is dried by mixing with sufficient anhydrous sodium sulphate to form a free flowing mixture and is packed into stainless steel extraction cells containing a glass fibre filter and sodium sulphate or glass powder to fill the cell. To ensure a better recovery samples may be extracted twice and extractions are performed at elevated temperatures and pressure.

5.4 Clean-up

Tissue extracts will always contain many compounds other than PAHs, and a suitable clean up is necessary to remove those compounds which may interfere with the subsequent analysis. Different techniques may be used, either singly or in combination, and the choice will be influenced by the selectivity and sensitivity of the final measurement technique and also by the extraction method employed. If Soxhlet extraction was used, then there is a much greater quantity of residual lipid to be removed before the analytical determination can be made than in the case of alkaline digestion. An additional clean-up stage may therefore be necessary. The most commonly used clean-up methods involve the use of deactivated alumina or silica adsorption chromatography. When applying fractionation, the elution pattern has to be checked frequently. This should be carried out in the presence of sample matrix, as that can partially deactivate the clean-up column, resulting in earlier elution of the PAHs than in a standard solution.

Gel permeation chromatography (GPC) and high performance liquid chromatography (HPLC) based methods are also employed (Nondek et al., 1993; Nyman et al., 1993; Perfetti et al., 1992). The major advantages of using HPLC-based clean-up methods are their ease of automation and reproducibility.

Isocratic HPLC fractionation of the extract can be used to give separate aliphatic and aromatic fractions (Webster et al., 2002). A metal-free silica column is used for the clean-up/fractionation as dibenzothiophene (DBT) can be retained on ordinary silica columns. The split time is determined by injection of a solution containing representative aliphatic and PAH standards. The silica column is regenerated by a cleaning cycle after a set number of samples. If PAHs are to be analysed by HPLC and there are significant amounts of alkylated PAHs present then the removal of the alkylated PAHs may be difficult.
5.5 Pre-concentration

In the methods suggested above, all result in an extract in which non-polar solvents are dominant. The sample volume should be 2 ml or greater to avoid errors when transferring solvents during the clean-up stages. Syncore parallel evaporators can be used with careful optimisation of the evaporation parameters. Evaporation of solvents using a rotary-film evaporator should be performed at low temperature (water bath temperature of 30°C or lower) and under controlled pressure conditions, in order to prevent losses of the more volatile PAHs such as naphthalenes. For the same reasons, evaporation to dryness must be avoided. When reducing the sample to final volume, solvents can be removed by a stream of clean nitrogen gas. Suitable solvents for injection into the GC-MS include pentane, hexane, heptane, iso-hexane and iso-octane.

5.6 Selection of PAHs to be determined

The choice of PAHs to be analysed is not straightforward, both because of differences in the range of PAH compounds resulting from combustion processes and from oil and oil products, and also because the aims of specific monitoring programmes can require the analysis of different representative groups of compounds. PAHs arising from combustion processes are predominantly parent (unsubstituted) compounds, whereas oil and its products contain a much wider range of alkylated compounds in addition to the parent PAHs. This has implications for the analytical determination, as both HPLC-based and GC-based techniques are adequate for the determination of a limited range of parent PAHs in samples influenced by combustion processes, whereas in areas of significant oil contamination and following oil spills only GC-MS has sufficient selectivity to determine the full range of PAHs present. The availability of pure individual PAHs for the preparation of standards is problematic and limits both the choice of determinands and, to some degree, the quantification procedures which can be used. The availability of reference materials certified for PAHs is also rather limited. A list of target parent and alkylated PAHs suitable for environmental monitoring is given in Table A1.1. This differs both from the list previously developed within ICES specifically for intercomparison purposes, and the historic list of Borneff. In both cases, the lists were concentrated on a subset of parent (predominantly combustion-derived) PAHs due to analytical limitations. This approach completely neglects the determination of alkylated PAHs, which allows the interpretation of PAH accumulation from multiple sources including those due to oil inputs. It will not be necessary for all of these PAH compounds and groups to be analysed in all cases, but an appropriate selection can be made from this list depending on the specific aims of the monitoring programme to be undertaken.

Table A1.1 Compounds of interest for environmental monitoring for which the guidelines apply. For compounds in italics standards are not available for any isomers in this group.

<table>
<thead>
<tr>
<th>Compound</th>
<th>MW</th>
<th>Compound</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>128</td>
<td>2, 3d-benzonapthothiophene</td>
<td>234</td>
</tr>
<tr>
<td>C1-Naphthalenes</td>
<td>142</td>
<td>C1-234</td>
<td>248</td>
</tr>
<tr>
<td>C2-Naphthalenes</td>
<td>156</td>
<td>C2-Fluoranthenes/Pyrenes</td>
<td>230</td>
</tr>
<tr>
<td>C3-Naphthalenes</td>
<td>170</td>
<td>Benz[a]anthracene</td>
<td>228</td>
</tr>
<tr>
<td>C4-Naphthalenes</td>
<td>184</td>
<td>Chrysene</td>
<td>228</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>152</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>154</td>
<td>C1-Benz[a]anthracene/ Chrysene</td>
<td>256</td>
</tr>
<tr>
<td>Biphenyl</td>
<td>154</td>
<td>C2-Benz[a]anthracene/ Chrysene</td>
<td>256</td>
</tr>
<tr>
<td>Fluorene</td>
<td>166</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1-Fluorenes</td>
<td>180</td>
<td>Benzo[a]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>C2-Fluorenes</td>
<td>194</td>
<td>Benzo[b]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>C3-Fluorenes</td>
<td>208</td>
<td>Benzo[k]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>Dibenzothiophene</td>
<td>184</td>
<td>Benzo[e]pyrene</td>
<td>252</td>
</tr>
<tr>
<td>C1-Dibenzothiophenes</td>
<td>198</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2-Dibenzothiophenes</td>
<td>212</td>
<td>Benzo[a]pyrene</td>
<td>252</td>
</tr>
<tr>
<td>C3-Dibenzothiophenes</td>
<td>226</td>
<td>Perylene</td>
<td>252</td>
</tr>
<tr>
<td>Phenanthenre</td>
<td>178</td>
<td>Indeno[1,2,3-cd]pyrene</td>
<td>276</td>
</tr>
<tr>
<td>Anthracene</td>
<td>178</td>
<td>Benzo[ghi]perylene</td>
<td>276</td>
</tr>
<tr>
<td>C1-Phenanthrenes/Anthracenes</td>
<td>192</td>
<td>Dibenzo[a,h]anthracene</td>
<td>278</td>
</tr>
<tr>
<td>C2-Phenanthrenes/Anthracenes</td>
<td>206</td>
<td>Benzo[k]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>C3-Phenanthrenes/Anthracenes</td>
<td>220</td>
<td>Cyclopenta[cd]pyrene</td>
<td>226</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>202</td>
<td>Naphtho[2,1-a]pyrene</td>
<td>302</td>
</tr>
<tr>
<td>Pyrene</td>
<td>202</td>
<td>Dibenzo[a,e]pyrene</td>
<td>302</td>
</tr>
<tr>
<td>C1-Fluoranthenes/Pyrenes</td>
<td>216</td>
<td>Dibenzo[a,l]pyrene</td>
<td>302</td>
</tr>
<tr>
<td>2, 1d-benzonapthothiophene</td>
<td>234</td>
<td>Dibenzo[a,l]pyrene</td>
<td>302</td>
</tr>
<tr>
<td>1,2d-benzonapthothiophene</td>
<td>234</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.7 Instrumental determination of PAHs

The greatest sensitivity and selectivity in routine analysis for parent PAH is achieved by combining HPLC with fluorescence detection (HPLC-UVF) or capillary gas chromatography with mass spectrometry (GC-MS). However, for the analysis of parent and alkylated PAHs GC-MS is the method of choice. In terms of flexibility, GC-MS is the most capable technique, as in principle it does not limit the selection of determinands in any way, while HPLC is suited only to the analysis of parent PAHs. In the past, analyses have also been conducted using HPLC with UV-absorption detection and GC with flame-ionisation detection, but neither can be recommended for alkylated PAHs because of their relatively poor selectivity. Both in terms of the initial capital cost of the instrumentation, and the cost per sample analysed, HPLC-UVF is cheaper than GC-MS. With the advent of high-sensitivity benchtop GC-MS systems, however, this cost advantage is now not as marked as in the past, and the additional information regarding sources available makes GC-MS the method of choice.

Limits of determination within the range of 0.05 to 0.5 µg kg⁻¹ wet weight for individual PAH compounds should be achievable by GC-MS. However this limit can be lowered in routine analysis.

5.7.1 GC-MS

The three injection modes commonly used are splitless, on-column and PTV (programmed temperature vaporiser). Automatic sample injection should be used wherever possible to improve the reproducibility of injection and the precision of the overall method. If splitless injection is used, the liner should be of sufficient capacity to contain the injected solvent volume after evaporation. For PAH analysis, the cleanliness of the liner is also very important if adsorption effects and discrimination are to be avoided, and the analytical column should not contain active sites to which PAHs can be adsorbed. Helium is the preferred carrier gas, and only capillary columns should be used. Because of the wide boiling range of the PAHs to be determined and the surface-active properties of the higher PAHs, the preferred column length is 25–50 m, with an internal diameter of 0.15 mm to 0.3 mm. Film thicknesses of 0.2 µm to 1 µm are generally used; this choice has little impact on critical resolution, but thicker films are often used when one-ring aromatic compounds are to be determined alongside PAHs, or where a high sample loading is needed. No stationary phase has been found on which all PAH isomers can be resolved; the most commonly used stationary phase for PAH analysis is 5% phenyl methylsilicone (DB-5 or equivalent). This will not, however, resolve critical isomers such as benzo[\(b\)], [\(j\)] and [\(k\)]fluoranthenes, or chrysene from triphenylene. Chrysene and triphenylene can be separated on other columns, if necessary such as a 60 m non polar column such a DB5MS. For PAHs there is no sensitivity gain from the use of chemical ionisation (either positive or negative ion), so analyses are usually conducted in electron-impact mode at 70eV. Quadrupole instruments are used in single ion monitoring to achieve greater sensitivity. The masses to be detected are programmed to change during the analysis as different PAHs elute from the capillary column. In SIM the molecular ion is used for quantification. Qualifier ions can be used to confirm identification but they are limited for PAHs. Triple quadrupole mass spectrometry can also be used and will give greater sensitivity. Some instruments such as ion-trap and time of flight mass spectrometers exhibit the same sensitivity in both modes, so full scan spectra can be used for quantification.

An example of mass spectrometer operating conditions in SIM mode is given in Table A1.2. The ions are grouped and screened within GC time windows of the compounds. In general the number of ions should not be greater than 20. The dwell time is important parameter and should be close for each ion. For GC capillary column analysis a dwell time should not be shorter than 20 ms, while a sum of a dwell in each retention time windows should not be greater than 500 ms. An example of conditions that can be used along with dwell times are shown in Table A1.2.
Table A.1.2: Example of operational conditions for the GC-MS analysis of parent and alkylated PAHs.

<table>
<thead>
<tr>
<th>Group No</th>
<th>Retention time (min)</th>
<th>Dwell time (ms)</th>
<th>Ions in group (AMU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.00</td>
<td>100</td>
<td>128 136 142</td>
</tr>
<tr>
<td>2</td>
<td>21.00</td>
<td>100</td>
<td>152 156 160</td>
</tr>
<tr>
<td>3</td>
<td>23.70</td>
<td>100</td>
<td>154 164 168 170</td>
</tr>
<tr>
<td>4</td>
<td>26.80</td>
<td>80</td>
<td>166 176 180 182 184</td>
</tr>
<tr>
<td>5</td>
<td>31.60</td>
<td>80</td>
<td>178 184 188 194 196 198</td>
</tr>
<tr>
<td>6</td>
<td>35.30</td>
<td>100</td>
<td>192 198</td>
</tr>
<tr>
<td>7</td>
<td>36.60</td>
<td>100</td>
<td>206 212</td>
</tr>
<tr>
<td>8</td>
<td>39.40</td>
<td>80</td>
<td>202 206 212 216 220 226</td>
</tr>
<tr>
<td>9</td>
<td>44.65</td>
<td>100</td>
<td>216 220</td>
</tr>
<tr>
<td>10</td>
<td>45.30</td>
<td>100</td>
<td>226 228 230 234 240</td>
</tr>
<tr>
<td>11</td>
<td>48.58</td>
<td>90</td>
<td>242 248</td>
</tr>
<tr>
<td>12</td>
<td>52.00</td>
<td>100</td>
<td>252 256 264 266</td>
</tr>
<tr>
<td>13</td>
<td>59.00</td>
<td>100</td>
<td>266 276 278 288</td>
</tr>
</tbody>
</table>

Alkylated homologues of PAHs (C1–C4), mainly associated with petrogenic sources, contain a number of different isomers that can give very complex but distinct distribution profiles when analysed by GC-MS. Integration of each isomer separately is difficult for most alkylated PAHs. 1- and 2-Methyl naphthalene give well resolved peaks that can be quantified separately. C1-Phenanthrene/anthracene gives five distinct peaks corresponding to 3-methyl phenanthrene, 2-methyl phenanthrene, 2-methyl anthracene, 4- and 9-methyl phenanthrene and 1-methyl phenanthrene. These may be integrated as a group or as separate isomers. For all other alkylated PAHs the area for all isomers may be summed and quantified against a single representative isomer. This method will lead, however, to an overestimation of the concentration as may include non alkylated PAHs. Examples of integrations of both parent and alkylated PAHs are shown in Appendix 1.

6. Calibration and quantification

6.1 Standards

The availability of pure PAH compounds are limited. Although most of the parent compounds can be purchased as pure compounds, the range of possible alkyl-substituted PAHs is vast and only a limited selection of them can be obtained. PAH standards are available for at least one isomer of most alkyl group listed in Table A1.1. A range of deuterated PAHs (normally 5 to 7) should be used as internal standards to cover the range of PAHs being analysed in samples. A range of fully-deuterated parent PAHs is available for use as standards in PAH analysis. Suitable standards could range from d8-naphthalene to d14-dibenzo[a,h]anthracene. Crystalline PAHs of known purity should be used for the preparation of calibration standards. If the quality of the standard materials is not guaranteed by the producer or supplier (as for certified reference materials), then it should be checked by GC-MS analysis. Solid standards should be weighed to a precision of 10−5 grams. Calibration standards should be stored in the dark because some PAHs are photosensitive, and ideally solutions to be stored should be sealed in amber glass ampoules or sealed GC vials. Otherwise, they can be stored in a refrigerator in stoppered measuring cylinders or flasks that are gas tight to avoid evaporation of the solvent during storage.

6.2 Calibration

Multilevel calibration with at least five calibration levels is preferred to adequately define the calibration curve. In general, GC-MS calibration is linear over a considerable concentration range but may exhibit a change of slope at very low concentrations. Quantification should be conducted in the linear region of the calibration curve. A separate calibration curve may be used where sample concentrations are very low. An internal standard method should be employed, using a range of deuterated PAHs as internal standards.

6.3 Recovery

The recovery of analytes should be checked and reported. Given the wide boiling range of the PAHs to be determined, the recovery may vary with compound group, from the volatile PAHs of low molecular weight to the larger compounds. Deuterated standards can be added in two groups: those to be used for quantification are added at the start of the analytical procedure, whilst those from which the absolute recovery will be assessed are added prior to GC-MS injection. This allows the recovery to be calculated.
7. Analytical Quality Control

Planners of monitoring programmes must decide on the accuracy, precision, repeatability, and limits of detection and determination which they consider acceptable. Achievable limits of determination for each individual component are as follows:

- for GC-MS measurements: \(0.05 \mu g \ kg^{-1} \) ww;

- Further information on analytical quality control procedures for PAHs can be found elsewhere (Law and de Boer, 1995). A procedural blank should be measured with each sample batch, and should be prepared simultaneously using the same chemical reagents and solvents as for the samples. Its purpose is to indicate sample contamination by interfering compounds, which will result in errors in quantification. The procedural blank is also very important in the calculation of limits of detection and limits of quantification for the analytical method. In addition, a laboratory reference material (LRM) should be analysed within each sample batch. The LRM must be homogeneous and well-characterised for the determinands of interest within the analytical laboratory. Ideally, stability tests should have been undertaken to show that the LRM yields consistent results over time. The LRM should be of the same matrix type (e.g. mussels) as the samples, and the determinand concentrations should be in the same range as those in the samples. Realistically, and given the wide range of PAH concentrations encountered, particularly in oil spill investigations, this is bound to involve some compromise. The data produced for the LRM in successive sample batches should be used to prepare control charts. It is also useful to analyse the LRM in duplicate from time to time to check within-batch analytical variability. The analysis of an LRM is primarily intended as a check that the analytical method is under control and yields acceptable precision, but a certified reference material (CRM) of a similar matrix should be analysed periodically in order to check the method bias. The availability of biota CRMs certified for PAHs is very limited, and in all cases the number of PAHs for which certified values are provided is small. At present, only NIST 1974a (a frozen wet mussel tissue) and NIST 2974 (a freeze-dried mussel tissue) are available. At regular intervals, the laboratory should participate in an intercomparison or proficiency exercise in which samples are circulated without knowledge of the determinand concentrations, in order to provide an independent check on performance.

8. Data reporting

The calculation of results and the reporting of data can represent major sources of error, as has been shown in intercomparison studies for PAHs. Control procedures should be established in order to ensure that data are correct and to obviate transcription errors. Data stored on databases should be checked and validated, and checks are also necessary when data are transferred between databases. Data should be reported in accordance with the latest ICES reporting formats.

9. References


Revision of the Nordtest Methodology for oil spill identification, http://www.nordicinnovation.net/nordtestfiler/tec499.pdf


ANNEX 1

Appendix 1

Examples of integration of parent and alkylated PAHs analysed by GC-MS. The standards used for the calibration of the alkylated PAHs are asterixed.
phenanthrene

anthracene

2-methylphenanthrene

C1-phenanthrenes/anthracenes

C2-phenanthrenes/anthracenes

2,6,9-trimethylphenanthrene

C3-phenanthrenes/anthracenes
Abundance

Ion 252.00 (251.70 to 252.70): QU576.D\textunderscore ms

- benzofluoranthenes
- benzo[e]pyrene
- benzo[a]pyrene
- perylene

Abundance

Ion 276.00 (275.70 to 276.70): QU576.D\textunderscore ms

- indeno[123-cd]pyrene
- benzo(ghi)perylene
ANNEX 2

Technical annex: Polyaromatic hydrocarbons in sediments

Determination of parent and alkylated PAHs in sediments

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) consist of a variable number of fused aromatic rings. By definition, PAHs contain at least two fused rings. PAHs arise from incomplete combustion processes and from both natural and anthropogenic sources, although the latter generally predominate. PAHs are also found in oil and oil products, and these include a wide range of alkylated PAHs formed as a result of diagenetic processes, whereas PAHs from combustion sources comprise mainly parent (non-alkylated) PAHs. Metabolites of some of the high MW PAHs are potent animal and human carcinogens – benzo[a]pyrene is the prime example. Carcinogenic activity is closely related to structure. Benzo[e]pyrene and the four benzofluoranthenne isomers all have a molecular weight of 252 Da, however they are much less potent than benzo[a]pyrene. Less is known about toxicity of alkylated PAHs. However, one study has demonstrated that alkylated PAHs may have increased toxicity compared to the parent compound (Marvanova et al., 2008).

This Technical Annex provides advice on the analysis of parent and alkylated polycyclic aromatic hydrocarbons (PAH) in total sediment, sieved fractions, and suspended particulate matter. The analysis of in sediments generally includes extraction with organic solvents, clean-up, high performance liquid chromatography (HPLC) with ultraviolet or fluorescence detection or gas chromatographic (GC) separation with flame ionisation (FID) or mass spectrometric (MS) detection (e.g., Fetzer and Vo-Dinh, 1989; Wise et al., 1995). All steps in the procedure are susceptible to insufficient recovery and/or contamination. Quality control procedures are recommended in order to check the performance of the method. These guidelines are intended to encourage and assist analytical chemists to critically reconsider their methods and to improve their procedures and/or the associated quality control measures, where necessary.

These guidelines are not intended as a complete laboratory manual. If necessary, guidance should be sought from highly specialised research laboratories. Whichever procedure is adopted, each laboratory must demonstrate the validity of each step of its procedure. In addition, the use of a second (and different method), carried out concurrently to the routine procedure, is recommended for validation. The analyses must be carried out by experienced staff.

2. Pre-treatment and Storage

2.1 Contamination

Sample contamination may occur during sampling, sample handling, pre-treatment and analysis, due to the environment, the containers or packing materials used, the instruments used during sample preparation, and from the solvents and reagents used during the analytical procedures. Controlled conditions are therefore required for all procedures. In the case of PAHs, particular care must be taken to avoid contamination at sea. On ships there are multiple sources of PAHs, such as the oils used for fuel and lubrication, and the exhaust from the ship’s engines. It is important that the likely sources of contamination are identified and steps taken to preclude sample handling in areas where contamination can occur. A ship is a working vessel and there can always be procedures occurring as a result of the day-to-day operations (deck cleaning, automatic overboard bilge discharges, etc.) that could affect the sampling process. It is advisable to collect samples of the ship’s fuel, bilge water, and oils and greases used on winches, etc., which can be used as fingerprinting samples at a later date, if there are suspicions of contamination in particular instances.

Freeze-drying of sediment samples may be a source of contamination due to the back-streaming of oil vapours from the rotary vacuum pumps. Furthermore drying the samples may result in losses of the lower molecular weight, more volatile PAHs through evaporation (Law et al., 1994).

Plastic materials must not be used for sampling and storage owing to possible adsorption of the PAHs onto the container material. Samples should be transported in closed containers; a temperature of 25°C should not be exceeded. If the samples are not analysed within 48 hours after sampling, they must be stored at 4°C (short-term storage). Storage over several months is only possible for frozen, (i.e., below −20°C) and/or dried samples (Law and de Boer, 1995).

As PAHs are sensitive to photo-degradation, exposure to direct sunlight or other strong light must be avoided during storage of the samples as well as during all steps of sample preparation, including extraction and storage of the extracts (Law and Biscaya, 1994). The use of amber glassware is strongly recommended.
2.3 Blanks

The procedural detection limit is determined by the blank value. In order to keep the blank value as low as possible, PAHs or other interfering compounds should be removed from all glassware, solvents, chemicals, adsorption materials, etc., that are used in the analysis. The following procedures should be used:

- glassware should be thoroughly washed with detergents and rinsed with an organic solvent prior to use. Further cleaning of the glassware, other than calibrated instruments, can be carried out by heating at temperatures >250°C;
- all solvents should be checked for impurities by concentrating the amount normally used to 10% of the normal end volume. This concentrate can then be analysed by GC and should not contain significant amounts of PAHs or other interfering compounds;
- all chemicals and adsorption materials should be checked for impurities and purified (e.g., by heating or extraction), if necessary. Soxhlet thimbles should be pre-extracted. Glassfibre thimbles are preferred over paper thimbles. Alternatively, full glass Soxhlet thimbles, with a G1 glass filter at the bottom, can be used. The storage of these supercleaned materials for a long period is not recommended, as laboratory air can contain PAHs that will be absorbed by these materials. Blank values occurring despite all the above-mentioned precautions may be due to contamination from the air. The most volatile compounds will usually show the highest blanks (Gremm and Frimmel, 1990);
- Glassfibre filters used for the PLE (pressurised liquid extraction) method should be heated at 450°C overnight.

3. Pre-treatment

Before taking a subsample for analysis, the samples should be sufficiently homogenised. The intake mass is dependent on the expected concentrations. For the marine environment, as a rule of thumb, the mass of sample taken for analysis can be equal to an amount representing 50–100 mg organic carbon. PAHs can be extracted from wet or dried samples. However, storage, homogenisation and extraction are much easier when the samples are dry. Care must be taken if freeze-drying samples for the reasons described in 2.1. Possible losses and contamination have to be checked. Contamination can be checked by exposing 1–2 g C18-bonded silica to drying conditions and analysing it as a sample (clean-up can be omitted) (Smedes and de Boer, 1997). Contamination during freeze-drying can be reduced by placing a lid, with a hole about 3 mm in diameter, on the sample container, while evaporation of the water is not hindered.

4. Extraction and clean-up

Exposure to light must be kept to a minimum during extraction and further handling of the extracts (Law and Biscaya, 1994). Since photo-degradation occurs more rapidly in the absence of a sample matrix, first of all the standard solution used for checking the recovery of the procedure will be affected, allowing a proper detection of the influence of light. The most photo-sensitive PAH is benzo[a]pyrene, followed by anthracene.

4.1 Wet sediments

Wet sediments should be extracted using a stepwise procedure by mixing with organic solvents. Extraction is enhanced by shaking, Ultra Turrax mixing, ball mill tumbling or ultrasonic treatment. Water-miscible solvents, such as acetone, methanol, or acetonitrile, are used in the first step. The extraction efficiency of the first step will be low as there is a considerable amount of water in the liquid phase. For sufficient extraction, at least three subsequent extractions are needed. The contact time with the solvent should be sufficient to complete the desorption of the PAHs out of the sediment pores. Heating by microwave or refluxing will accelerate this process.

When utilising a Soxhlet, the extraction of wet sediments should be conducted in two steps. First, a polar solvent, such as acetone, is used to extract the water from the sediment, then the flask is replaced and the extraction continued with a less polar solvent or solvent mixture (e.g., acetone/hexane). Thereafter, the extracts must be combined. For both batch and Soxhlet extraction, water must be added to the combined extracts and the PAHs must be extracted to a non-polar solvent.

Extraction of wet sediments by pressurised liquid extraction (PLE) is a more recent method, requiring less solvent and time for the extraction process. Wet sediment is dried by mixing with sufficient anhydrous sodium sulphate to form a free flowing mixture and is packed into stainless steel tubes for extraction. Extractions are performed at elevated temperatures and pressures. Various extracting solvents (DCM, acetone, methanol, acetonitrile, hexane, DCM: acetone [1:1], hexane:acetone [1:1] were investigated by Saim et al. (1998) and as long as the solvent polarity was >1.89 (i.e. all
except hexane) no significant differences were noted. Extraction temperatures can be manipulated to suit the analytical requirements.

4.2 Dry sediments

Although all the methods mentioned above can also be used for dried sediments, Soxhlet extraction is the most frequently applied technique to extract PAHs from dried sediments. Medium-polar solvents such as dichloromethane or toluene, or mixtures of polar and non-polar solvents can be used. When using dichloromethane, losses of PAHs have occasionally been observed (Baker, 1993). Although toluene is not favoured because of its high boiling point, it should be chosen as solvent when it is expected that sediment samples contain soot particles. For routine marine samples, the use of a mixture of a polar and a non-polar solvent (e.g., acetone/hexane (1/3, v/v)) is recommended.

The extraction can be carried out with a regular or a hot Soxhlet (Smedes and de Boer, 1997). A sufficient number of extraction cycles must be performed (approximately 8 hours for the hot Soxhlet and 12 to 24 hours for normal Soxhlet). The extraction efficiency has to be checked for different types of sediments by a second extraction step. These extracts should be analysed separately.

PLE can also be used for the extraction of freeze-dried sediments. Instead of anhydrous sodium sulphate to dry the sediment the sample is mixed with a clean sand or diatomaceous earth to increase the surface area of the sediment. The same solvent mixtures detailed above for wet sediment extraction can be used for the dry sediments. Supercritical fluid extraction (SFE) has also been used for the extraction of organic compounds. The optimum conditions may vary for specific sediments (e.g., Dean et al., 1995; Reimer and Suarez, 1995).

4.3 Clean-up

The crude extract requires a clean-up to remove the many other compounds which are co-extracted (e.g., Wise et al., 1995). Due to chlorophyll-like compounds extracted from the sediment, the raw extract will be coloured and also contain sulphur and sulphur-containing compounds, oil, and many other natural and anthropogenic compounds. Selection of the appropriate clean-up method depends on the subsequent instrumental method to be used for analysis. Prior to the clean-up, the sample must be concentrated and any polar solvents used in the extraction step should be removed. The recommended acetone/hexane mixture will end in hexane when evaporated because of the formation of an azeotrope. Evaporation can be done either using a rotary evaporator or parallel evaporating systems such as Syncore. Especially for the rotary evaporator, care should be taken to stop the evaporation in time at about 5 ml. For further reducing the volume, a gentle stream of nitrogen should be applied. The extract should never be evaporated to dryness. The drawback of the rotary evaporator is that more volatile components may be lost during the nitrogen drying stage whilst the heavier components stick to the glassware. The Buchi Syncore Analyst also uses glass tubes but the system is sealed, avoiding contamination from the lab air during evaporation. It does not use a nitrogen stream, thus reducing the loss of volatiles and if the flushback module is fitted the sides of the tubes are rinsed automatically thus reducing the loss of the heavier components.

For removing more polar interferences from the extract, deactivated aluminium oxide (10 % water), eluted with hexane, as well as silica or modified silica columns, e.g., aminopropylsilane, eluted with toluene or a semipolar solvent mixture such as hexane/acetone (95/5, v/v) or hexane/dichloromethane (98/2, v/v), can be used. Gel permeation chromatography (GPC) can be used to remove high molecular weight material and sulphur from the extracts.

For GC-MS analysis, sulphur should be removed from the extracts, in order to protect the detector. This can be achieved by the addition of copper powder, wire or gauze during or after Soxhlet extraction. Copper can also be added to the PLE cell, however, this is not always sufficient and further treatment with copper may be required following extraction. Ultrasonic treatment might improve the removal of sulphur. As an alternative to copper, other methods can be used (Smedes and de Boer, 1997).

Aliphatic hydrocarbons originating from mineral oil interfere with the flame ionisation detection. They can be removed from the extract by fractionation over columns filled with activated aluminium oxide or silica. The first fraction eluting with hexane is rejected. The PAHs elute in a second fraction with a more polar solvent, e.g., diethylether or acetone/hexane. When applying fractionation, the elution pattern has to be checked frequently. This should be carried out in the presence of sample matrix, as that can partially deactivate the clean-up column, resulting in earlier elution of the PAHs than in a standard solution.

Gel permeation chromatography (GPC) and high performance liquid chromatography (HPLC) based methods are also employed (Nondek et al., 1993; Nyman et al., 1993; Perfetti et al., 1992). The major advantages of using HPLC-based clean-up methods are their ease of automation and reproducibility.
Isocratic HPLC fractionation of the extract can be used to give separate aliphatic and aromatic fractions (Webster et al., 2002). A metal free silica column is used for the clean up/fractionation as dibenzothiophene (DBT) can be retained on ordinary silica columns. The split time is determined by injection of a solution containing representative aliphatic and PAH standards. The silica column is regenerated by a cleaning cycle after a set number of samples. If PAHs are to be analysed by HPLC and there are significant amounts of alkylated PAHs present then the removal of the alkylated PAHs may be difficult.

4.4 Pre-concentration

In the methods suggested above, all result in an extract in which non-polar solvents are dominant. The sample volume should be 2 ml or greater to avoid errors when transferring solvents during the clean-up stages. Syncore parallel evaporators can be used with careful optimisation of the evaporation parameters. Evaporation of solvents using a rotary-film evaporator should be performed at low temperature (water bath temperature of 30°C or lower) and under controlled pressure conditions, in order to prevent losses of the more volatile PAHs such as naphthalenes. For the same reasons, evaporation to dryness must be avoided. When reducing the sample to final volume, solvents can be removed by a stream of clean nitrogen gas. Suitable solvents for injection into the GC-MS include pentane, hexane, heptane, iso-hexane, and iso-octane.

5. Selection of PAHs to be determined

The choice of PAHs to be analysed is not straightforward, both because of differences in the range of PAH compounds resulting from combustion processes and from oil and oil products, and also because the aims of specific monitoring programmes can require the analysis of different representative groups of compounds. PAHs arising from combustion processes are predominantly parent (unsubstituted) compounds, whereas oil and its products contain a much wider range of alkylated compounds in addition to the parent PAHs. This has implications for the analytical determination, as both HPLC-based and GC-based techniques are adequate for the determination of a limited range of parent PAHs in samples influenced by combustion processes, whereas in areas of significant oil contamination and following oil spills only GC-MS has sufficient selectivity to determine the full range of PAHs present. The availability of pure individual PAHs for the preparation of standards is problematic and limits both the choice of determinands and, to some degree, the quantification procedures that can be used. The availability of reference materials certified for PAHs is also rather limited. A list of target parent and alkylated PAHs suitable for environmental monitoring is given in Table A2.1, and this differs both from the list previously developed within ICES specifically for intercomparison purposes, and the historic list of Borneff. In both cases, the lists were concentrated on a subset of parent (predominantly combustion-derived) PAHs due to analytical limitations. This approach completely neglects the determination of alkylated PAHs, which allows the interpretation of PAH accumulation from multiple sources including those due to oil inputs. It will not be necessary for all of these PAH compounds and groups to be analysed in all cases, but an appropriate selection can be made from this list depending on the specific aims of the monitoring programme to be undertaken.
Table A2.1  Compounds of interest for environmental monitoring for which the guidelines apply. For compounds in italics standards are not available for any isomers in this group.

<table>
<thead>
<tr>
<th>Compound</th>
<th>MW</th>
<th>Compound</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthalene</td>
<td>128</td>
<td>Benzo[b]naphtho[2,3-d]thiophene</td>
<td>234</td>
</tr>
<tr>
<td>C1-Naphthalenes</td>
<td>142</td>
<td>C1-benzonaphthothiophenes</td>
<td>248</td>
</tr>
<tr>
<td>C2-Naphthalenes</td>
<td>156</td>
<td>C2-Fluoranthenes/Pyrenes</td>
<td>230</td>
</tr>
<tr>
<td>C3-Naphthalenes</td>
<td>170</td>
<td>Benz[a]anthracene</td>
<td>228</td>
</tr>
<tr>
<td>C4-Naphthalenes</td>
<td>184</td>
<td>Chrysene</td>
<td>228</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>152</td>
<td>2,3-Benzanthracene</td>
<td>228</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>154</td>
<td>C1- Benz[a]anthracene/ Chrysene</td>
<td>242</td>
</tr>
<tr>
<td>Biphenyl</td>
<td>154</td>
<td>C2- Benz[a]anthracene/ Chrysene</td>
<td>256</td>
</tr>
<tr>
<td>Fluorene</td>
<td>166</td>
<td>C2- Benz[a]anthracene/ Chrysene</td>
<td>270</td>
</tr>
<tr>
<td>C1-Fluorenes</td>
<td>180</td>
<td>Benzo[a]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>C2-Fluorenes</td>
<td>194</td>
<td>Benzo[b]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>C3-Fluorenes</td>
<td>208</td>
<td>Benzo[j]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>Dibenzothiophenes</td>
<td>184</td>
<td>Benzo[k]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>C1-Dibenzothiophenes</td>
<td>198</td>
<td>Benzo[e]pyrene</td>
<td>252</td>
</tr>
<tr>
<td>C2-Dibenzothiophenes</td>
<td>212</td>
<td>Benzo[a]pyrene</td>
<td>252</td>
</tr>
<tr>
<td>C3-Dibenzothiophenes</td>
<td>226</td>
<td>Perylene</td>
<td>252</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>178</td>
<td>Indeno[1,2,3-cd]pyrene</td>
<td>276</td>
</tr>
<tr>
<td>Anthracene</td>
<td>178</td>
<td>Benzo[ghi]perylene</td>
<td>276</td>
</tr>
<tr>
<td>C1-Phenanthrenes/Anthracenes</td>
<td>192</td>
<td>Dibenzo[a,h]anthracene</td>
<td>278</td>
</tr>
<tr>
<td>C2-Phenanthrenes/Anthracenes</td>
<td>206</td>
<td>Benzo[k]fluoranthene</td>
<td>252</td>
</tr>
<tr>
<td>C3-Phenanthrenes/Anthracenes</td>
<td>220</td>
<td>Cyclopenta[cd]pyrene</td>
<td>226</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>202</td>
<td>Naphtho[2,1-a]pyrene</td>
<td>302</td>
</tr>
<tr>
<td>Pyrene</td>
<td>202</td>
<td>Dibenzo[a,e]pyrene</td>
<td>302</td>
</tr>
<tr>
<td>C1-Fluoranthenes/Pyrenes</td>
<td>216</td>
<td>Dibenzo[a,l]pyrene</td>
<td>302</td>
</tr>
<tr>
<td>Benzo[b]naphtho[2,3-d]thiophene</td>
<td>234</td>
<td>Dibenzo[a,h]pyrene</td>
<td>302</td>
</tr>
</tbody>
</table>

6. Instrumental determination of PAHs

The greatest sensitivity and selectivity in routine analysis for parent PAH is achieved by combining HPLC with fluorescence detection (HPLC-UVF) or capillary gas chromatography with mass spectrometry (GC-MS). However, for the analysis of parent and alkylated PAHs GC-MS is the method of choice. In terms of flexibility, GC-MS is the most capable technique, as in principle it does not limit the selection of determinands in any way, while HPLC is suited only to the analysis of parent PAHs. In the past, analyses have also been conducted using HPLC with UV-absorption detection and GC with flame-ionisation detection, but neither can be recommended for alkylated PAHs because of their relatively poor selectivity. Both in terms of the initial capital cost of the instrumentation, and the cost per sample analysed, HPLC-UVF is cheaper than GC-MS. With the advent of high-sensitivity benchtop GC-MS systems, however, this cost advantage is now not as marked as in the past, and the additional information regarding sources available makes GC-MS the method of choice.

Limits of determination within the range of 0.05 µg kg⁻¹ dry weight for individual PAH compounds should be achievable by GC-MS.

6.1 GC-MS

The three injection modes commonly used are splitless, on-column and PTV (programmed temperature vaporiser). Automatic sample injection should be used wherever possible to improve the reproducibility of injection and the precision of the overall method. If splitless injection is used, the liner should be of sufficient capacity to contain the injected solvent volume after evaporation. For PAH analysis, the cleanliness of the liner is also very important if adsorption effects and discrimination are to be avoided, and the analytical column should not contain active sites to which PAHs can be adsorbed. Helium is the preferred carrier gas, and only capillary columns should be used. Because of the wide boiling range of the PAHs to be determined and the surface-active properties of the higher PAHs, the preferred column length is 25–50 m, with an internal diameter of 0.15 mm to 0.3 mm. Film thicknesses of 0.2 µm to 1 µm are generally used; this choice has little impact on critical resolution, but thicker films are often used when one-ring aromatic compounds are to be determined alongside PAHs, or where a high sample loading is needed. No stationary phase has been found on which all PAH isomers can be resolved; the most commonly used stationary phase for PAH analysis is 5% phenyl methylsilicone (DB-5 or equivalent). This will not, however, resolve critical isomers such as...
benzo[\(b\)], [\(j\)] and [\(k\)]fluoranthenes, or chrysene from triphenylene. Chrysene and triphenylene can be separated on other columns, if necessary such as a 60 m non-polar column such a DB5MS. For PAHs there is no sensitivity gain from the use of chemical ionisation (either positive or negative ion), so analyses are usually conducted in electron-impact mode at 70eV. Quadrupole instruments are used in single ion monitoring to achieve greater sensitivity. The masses to be detected are programmed to change during the analysis as different PAHs elute from the capillary column. In SIM the molecular ion is used for quantification. Qualifier ions can be used to confirm identification but they are limited for PAHs. Triple quadrupole mass spectrometry can also be used and will give greater sensitivity. Some instruments such as ion-trap and time of flight mass spectrometers exhibit the same sensitivity in both modes, so full scan spectra can be used for quantification.

An example of mass spectrometer operating conditions in SIM mode is given in Table A2.2. The ions are grouped and screened within GC time windows of the compounds. In general the number of ions should not be greater than 20. The dwell time is an important parameter and should be close for each ion. For GC capillary column analysis a dwell time should not be shorter than 20 ms, while a sum of a dwell in each retention time windows should not be greater than 500 ms. An example of conditions that can be used along with dwell times are shown in Table A2.2.

**Table A.2.2** Example of operational conditions for the GC-MS analysis of parent and alkylated PAHs.

<table>
<thead>
<tr>
<th>Group No</th>
<th>Retention time (min)</th>
<th>Dwell time (ms)</th>
<th>Ions in group (AMU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.00</td>
<td>100</td>
<td>128 136 142</td>
</tr>
<tr>
<td>2</td>
<td>21.00</td>
<td>100</td>
<td>152 156 160</td>
</tr>
<tr>
<td>3</td>
<td>23.70</td>
<td>100</td>
<td>154 164 168 170</td>
</tr>
<tr>
<td>4</td>
<td>26.80</td>
<td>80</td>
<td>166 176 180 182 184</td>
</tr>
<tr>
<td>5</td>
<td>31.60</td>
<td>80</td>
<td>178 184 188 194 196 198</td>
</tr>
<tr>
<td>6</td>
<td>35.30</td>
<td>100</td>
<td>192 198</td>
</tr>
<tr>
<td>7</td>
<td>36.60</td>
<td>100</td>
<td>206 212</td>
</tr>
<tr>
<td>8</td>
<td>39.40</td>
<td>80</td>
<td>202 206 212 216 220 226</td>
</tr>
<tr>
<td>9</td>
<td>44.65</td>
<td>100</td>
<td>216 220</td>
</tr>
<tr>
<td>10</td>
<td>45.30</td>
<td>100</td>
<td>226 228 230 234 240</td>
</tr>
<tr>
<td>11</td>
<td>48.58</td>
<td>90</td>
<td>242 248</td>
</tr>
<tr>
<td>12</td>
<td>52.00</td>
<td>100</td>
<td>252 256 264 266</td>
</tr>
<tr>
<td>13</td>
<td>59.00</td>
<td>100</td>
<td>266 276 278 288</td>
</tr>
</tbody>
</table>

Alkylated homologues of PAHs (C1–C4), mainly associated with petrogenic sources, contain a number of different isomers that can give very complex but distinct distribution profiles when analysed by GC-MS. Integration of each isomer separately is difficult for most alkylated PAHs. 1- and 2-Methyl naphthalene give well resolved peaks that can be quantified separately. C1-Phenanthrene/anthracene gives five distinct peaks corresponding to 3-methyl phenanthrene, 2-methyl phenanthrene, 2-methyl anthracene, 4- and 9-methyl phenanthrene and 1-methyl phenanthrene. These may be integrated as a group or as separate isomers. For all other alkylated PAHs the area for all isomers may be summed and quantified against a single representative isomer. This method will, however, lead to an overestimation of the concentration as may include non alkylated PAHs. Examples of integrations of both parent and alkylated PAHs are shown in Appendix 1.

### 7. Calibration and quantification

#### 7.1 Standards

The availability of pure PAH compounds are limited. Although most of the parent compounds can be purchased as pure compounds, the range of possible alkyl-substituted PAHs is vast and only a limited selection of them can be obtained. PAH standards are available for at least one isomer of most alkyl group listed in Table A2.1. A range of deuterated PAHs (normally 5 to 7) should be used as internal standards to cover the range of PAHs being analysed in samples. A range of fully-deuterated parent PAHs is available for use as standards in PAH analysis. Suitable standards could range from \(d_8\)-naphthalene to \(d_{14}\)-dibenzo[a,h]anthracene. Crystalline PAHs of known purity should be used for the preparation of calibration standards. If the quality of the standard materials is not guaranteed by the producer or supplier (as for certified reference materials), then it should be checked by GC-MS analysis. Solid standards should be weighed to a precision of 10⁻⁵ grams. Calibration standards should be stored in the dark because some PAHs are photosensitive, and ideally solutions to be stored should be sealed in amber glass ampoules or sealed GC vials. Otherwise, they can be stored in a refrigerator in stoppered measuring cylinders or flasks that are gas tight to avoid evaporation of the solvent during storage.
Calibration

Multilevel calibration with at least five calibration levels is preferred to adequately define the calibration curve. In general, GC-MS calibration is linear over a considerable concentration range but may exhibit a change of slope at very low concentrations. Quantification should be conducted in the linear region of the calibration curve. A separate calibration curve may be used where sample concentrations are very low. An internal standard method should be employed, using a range of deuterated PAHs as internal standards.

7.3 Recovery

The recovery of analytes should be checked and reported. Given the wide boiling range of the PAHs to be determined, the recovery may vary with compound group, from the volatile PAHs of low molecular weight to the larger compounds. Deuterated standards can be added in two groups: those to be used for quantification are added at the start of the analytical procedure, whilst those from which the absolute recovery will be assessed are added prior to GC-MS injection. This allows the recovery to be calculated.

8. Analytical quality control

Planners of monitoring programmes must decide on the accuracy, precision, repeatability, and limits of detection and determination, which they consider acceptable. Achievable limits of determination for each individual component using GC-MS are 0.05 µg kg\(^{-1}\) dry weight.

Further information on analytical quality control procedures for PAHs can be found elsewhere (Law and de Boer, 1995). A procedural blank should be measured with each sample batch, and should be prepared simultaneously using the same chemical reagents and solvents as for the samples. Its purpose is to indicate sample contamination by interfering compounds, which will result in errors in quantification. The procedural blank is also very important in the calculation of limits of detection and limits of quantification for the analytical method. In addition, a laboratory reference material (LRM) should be analysed within each sample batch. The LRM must be homogeneous and well characterised for the determinands of interest within the analytical laboratory. Ideally, stability tests should have been undertaken to show that the LRM yields consistent results over time. The LRM should be of the same matrix type (e.g., liver, muscle, mussel tissue) as the samples, and the determinand concentrations should be in the same range as those in the samples. Realistically, and given the wide range of PAH concentrations encountered, particularly in oil spill investigations, this is bound to involve some compromise. The data produced for the LRM in successive sample batches should be used to prepare control charts. It is also useful to analyse the LRM in duplicate from time to time to check within-batch analytical variability. The analysis of an LRM is primarily intended as a check that the analytical method is under control and yields acceptable precision, but a certified reference material (CRM) of a similar matrix should be analysed periodically in order to check the method bias. A marine sediment (NIST SRM 1941b)\(^1\) is available, with certified values for 24 PAHs and a further 44 as reference (non-certified) values. At regular intervals, the laboratory should participate in an intercomparison or proficiency exercise in which samples are circulated without knowledge of the determinand concentrations, in order to provide an independent check on performance.

9. Data reporting

The calculation of results and the reporting of data can represent major sources of error, as has been shown in intercomparison studies for PAHs. Control procedures should be established in order to ensure that data are correct and to obviate transcription errors. Data stored on databases should be checked and validated, and checks are also necessary when data are transferred between databases. Data should be reported in accordance with the latest ICES reporting formats.

10. References


\(^1\) More info on https://srmors.nist.gov/view_detail.cfm?srm=1941B


ANNEX 2

Appendix 1

Example integrations of parent and alkylated PAHs analysed by GC-MS. The standards used for the calibration of the alkylated PAHs are asterixed.
phenanthrene

anthracene

2-methylphenanthrene

C1-phenanthrenes/anthracenes

C2-phenanthrenes/anthracenes

C3-phenanthrenes/anthracenes

2,6,9-trimethylphenanthrene

C3-phenanthrenes/anthracenes
4-methyldibenzothiophene

C1-DBT*

C2-DBT*

C3-DBT*
Ion 202.00 (201.70 to 202.70): EPG1132.D\ data.ms

fluoranthene

pyrene

1-methylfluoranthene

C1-202

2,7-dimethylpyrene

C2-202
Ion 252.00 (251.70 to 252.70): QU576.D\data.ms

- benzo[ghi]perylene
- benzo[a]pyrene
- benzo[a]pyrene
- benzo[a]fluoranthene

Ion 276.00 (275.70 to 276.70): QU576.D\data.ms

- indeno[123-cd]pyrene
- benzo[ghi]perylene
ANNEX 3

Technical Annex: Organotin compounds in biota

This annex is intended as a supplement to the general guidelines. It is not a complete description or a substitute for detailed analytical instructions. The annex provides guidelines for the measurement of organotins, in marine biota in monitoring programmes. Target compounds include tributyltin (TBT), dibutyltin (DBT) and monobutyltin (MBT) and also triphenyltin (TPhT), diphenyltin (DPhT), and monophenyltin (MPhT).

1. Species

Target species for the monitoring of organotin compounds are shellfish, in particular bivalves like *Mytilus edulis* or *Mytilus galloprovincialis*. *Mytilus edulis* occurs in shallow waters along almost all coasts of the Contracting Parties. It is therefore suitable for monitoring in nearshore waters. No distinction is made between *M. edulis* and *M. galloprovincialis* because the latter, which may occur along the coast from Spain and Portugal to the southern coasts of UK, cannot easily be discerned from *M. edulis*. A sampling size range of 3-6 cm is specified to ensure availability throughout the whole maritime area. The Pacific oyster (*Crassostrea gigas*) should be sampled in areas where *Mytilus sp.* is not available. The sampling size should be within the length range 9-14 cm to ensure individuals of the 2 year age class.

Gastropods can also be used for TBT indicators, for instance in relation to biological effect monitoring. However, gastropods do not feed as continuously as bivalves and have a higher capacity of TBT metabolism, possibly resulting in a higher variability of TBT body burdens in gastropods compared with bivalves. In addition, correlation between imposex and TBT body burdens in the environment can be low, because of a time-lag between current TBT levels and imposex induced irreversibly in the early life stages and also because of non-continuous feeding strategies. In some sensitive gastropod species, imposex can also be induced by TBT at lower levels than analytical detection limits generally achieved.

2. Sampling


3. Transportation

Samples should be kept cool and frozen at <-20°C as soon as possible after collection. Length and weight should be determined before freezing. Live mussels should be transported in closed containers at temperatures between 5-15°C, preferably <10°C. Frozen samples should be transported in closed containers at temperatures <20°C. More rigorous conditions will be necessary for samples for biological effects monitoring, e.g. storage in liquid nitrogen.

4. Pre-treatment and storage

4.1 Contamination

Sample contamination may occur during sampling, sample handling, pre-treatment, and analysis (Oehlenschläger, 1994), due to the environment, the containers or packing material used, the instruments used during sample preparation or from the chemical reagents used during the analytical procedures. Controlled conditions are therefore required for all procedures, including the dissection of organisms on board ship.

4.2 Depuration

Mussels should be placed on a polyethylene tray elevated above the bottom of a glass aquarium. The aquarium should be filled with sub-surface sea water collected from the same site as the samples and which has not been subject to contamination from point sources if possible. The aquarium should be aerated and the mussels left for 20-24 hours at water temperatures and salinity close to those from which the samples were removed.

4.3 Opening of the shells

Mussels should be shucked live and opened with minimum tissue damage by detaching the adductor muscles from the interior of one valve. The mussels should be inverted and allowed to drain on a clean towel or funnel for at least 5 minutes in order to minimise influence on dry weight determinations.
4.4 Dissection and storage

The soft tissues should be removed and deep frozen (-20°C) as soon as possible in containers appropriate to the intended analysis. TBT is stable in cockles and oysters stored at -20°C in the dark over a 7 month period. Longer storage can cause significant loss of TBT due to degradation (Gomez-Ariza et al., 1999). The dissection of the soft tissue must be done under clean conditions on a clean bench by scientific personnel, wearing clean gloves and using clean stainless steel knives. After each sample has been prepared, the tools should be cleaned regularly. Washing in acetone or alcohol and high purity water is recommended. When the analysis is eventually undertaken, all fluids that may initially separate on thawing should be included with the materials homogenised. Homogenisation should be performed immediately prior to any sub-dividing of the sample.

5. Analysis

5.1 Preparation of materials

Solvents, chemicals and adsorption materials must be free of organotin compounds or other interfering compounds. If not they should be purified using appropriate methods. Solvents should be checked by concentrating the volume normally used in the procedure to 10% of the final volume and then analysing for the presence of organotin compounds and other interfering compounds using a GC. If necessary, the solvents can be purified by redistillation. Chemicals and adsorption materials should be purified by extraction and/or heating. Glass fibre materials (e.g. thimbles for Soxhlet extraction) should be pre-extracted. Alternatively, full glass thimbles with a G1 glass filter at the bottom can be used. Generally, paper filters should be avoided in filtration and substituted for by appropriate glass filters. As all super cleaned materials are prone to contamination (e.g. by the adsorption of organotin compounds and other compounds from laboratory air), materials ready for use should not be stored for long periods. All containers, skills, glassware etc. which come into contact with the sample must be made of appropriate material and must have been thoroughly pre-cleaned. Glassware should be extensively washed with detergents, heated at >250°C and rinsed immediately before use with organic solvents or mixtures such as hexane/acetone. Alternatively, all glassware can be washed in 10% HCl (or even in concentrated HCl) and then rinsed with distilled water.

5.2 Lipid determination

Organotin data are not usually expressed on a lipid basis. Lipid content is not a good normalisator because of poor correlations to organotin content. However, the determination of the lipid content of tissues can be of use in caracterising the samples. If required, the lipid content should be determined on a separate subsample of the tissue homogenate, as some of the extraction techniques used routinely for organotin determination may destroy lipid materials. The total fat weight should be determined using the method of Bligh and Dyer (1959) or Smedes (1999).

5.3 Dry weight determination

Dry weight determinations should be carried out by air-drying homogenised sub-samples of the material to be analysed to constant weight at 105°C.

5.4 Determination of organotins by gas chromatography

5.4.1 Calibration and preparation of calibrand solutions

5.4.1.1 External calibration

When using an external calibration, multilevel calibration with at least five calibration points is preferred to adequately define the calibration curve. Standards preparation can be done in two ways depending on the methods of extraction/derivatisation used:

i) by using alkyltins salts then proceed to the derivatisation step as for samples (for hydridisation or ethylation followed by purge-and-trap analysis, there is no other appropriate way than using alkyltin salts);

ii) by using commercially readily available derivatised standards (e.g. Quasimeme http://www.quasimeme.org/).

Standard solutions can be prepared in (m)ethanol or another solvent depending on the instrumental method used. Addition of an internal standard (tripropyltin chloride TPrTCI or 13C labelled or deuterated TBT if using GC analysis with mass selective detection) to all standard and samples solutions is recommended. When using tripropyltin chloride, which is an underivatised standard, the recovery efficiency of the whole procedure can be determined.

A new calibration solution should always be cross-checked to the old standard solution.
Calibrand solutions should be stored in a refrigerator in gas tight containers to avoid evaporation of solvent during storage. It is important to determine the expiry date of standard dilutions in order to avoid a concentration shift due to deterioration of analyte or evaporation of solvents.

5.4.1.2 Isotope Dilution-Mass Spectrometry

When using Isotope Dilution-Mass Spectrometry technique (IDMS), external calibration is not required.

5.4.2 Homogenisation and drying

Homogenisation should be carried out on fresh tissue. Care should be taken that the sample integrity is maintained during the actual homogenisation and during drying. When the analysis is undertaken, all fluids that may initially separate on thawing should be included with the materials homogenised. Homogenisation should be performed immediately prior to succeeding procedures. When grinding samples after drying, classical techniques using a ball mill can be used. Cryogenic homogenisation of dried or fresh materials at liquid nitrogen temperatures using a PTFE device (cf. Iyengar and Kasperek, 1977) or similar techniques can be applied (cf. Iyengar, 1976; Klussmann et al., 1985).

5.4.3 Extraction

Release of organotin compounds from the biological matrix is a critical step, due to the strong matrix binding of the analytes and possible species degradation. Recovery standards should be added prior to extraction, however correction procedures should be used with care as equilibration between the spiked and the target compounds is not always guaranteed. Different extraction techniques are commonly used, such as microwave assisted extraction, mechanical shaking and digestion. Microwave assisted extraction (MAE) as well as mechanical shaking provide quantitative recoveries with negligible degradation of the TBT compounds (Centineo et al., 2004). However, it must be taken into account that considerable loss of DBT, due to degradation was reported for MAE. Digestion techniques can be used to extract butyltins, though species degradation is not always under control using this technique. Mechanical shaking seems to be a suitable technique. Alternatively, pressurised liquid extraction (accelerated solvent extraction) can be used to extract organotin compounds. Extraction usually takes place in an aqueous methanolic acidic environment, with subsequent extraction to an organic phase, such as pentane or hexane. Acidic conditions enhance the extraction efficiency, acetic acid is usually preferred to other acids to ensure stability of butyltins compounds. Complexing agents such as tropolone are often employed. Extraction can be performed on wet as well as on freeze-dried samples. Wet tissue must be dried by mixing with anhydrous sodium sulphate or other anhydrous materials.

5.4.4 Derivatisation

5.4.4.1 Alkylation

Grignard reagent: A variety of Grignard reagents is used for alkylation reactions in derivatisation. The smaller the alkylation group, the more volatile the products of derivatisation, and the greater the losses during the transfer and work up. This method is time-consuming and requires very dry conditions and non-protic solvents. The use of Grignard reagents is hazardous as they react violently with protic solvents such as water, acid, alcohol, ketones and appropriate safety precautions must be taken. A liquid-liquid extraction step is necessary to isolate the derivatised organotins. However, unlike hydride derivatives of butyltins which may degrade in hours or days, the tetraalkyl derivatives formed with Grignard reagents are very stable (Morabito et al., 2000). Derivatisation with Grignard reagents include extra steps in the analytical procedure as clean up of excess Grignard reagent with acid is required.

Sodium Tetraethylborate (NaBEt₄): Derivatisation with this complexing agent has been developed to minimise the analysis time. The NaBEt₄ procedure allows a simultaneous extraction-derivatisation in a buffered medium (optimum pH 4-5). NaBEt₄ derivatisation produces more thermally stable derivatives. However, NaBEt₄ is extremely air sensitive, since it is considered as pyrophoric, care must be taken to keep its chemical integrity. Although solutions in water have been shown to be stable for about 1 month at 4 °C, it is recommended to prepare them freshly for use. Solutions of the reagent in an organic solvent (e.g.tetrahydrofuran, methanol or ethanol) seem to be more stable (Smedes et al., 2000). The determination of organotin compound in complex matrices, such as biological matrices with high lipid content, has led to several problems, including low recovery and low derivatisation efficiency. A clean-up step might be subsequently required.

Sodium Diethyldithiocarbamate (NaDDTC): NaDDTC is preferable to Grignard reagents as it does not require anhydrous conditions but it does not simultaneously derivatise and extract like NaBEt₄. Yet this step can be combined with Grignard reagent to provide better derivatisation for a wider spectrum of organotins.
5.4.4.2 Hydride generation

The butyltin species are converted to an hydride form by sodium tetrahydroborate (NaBH₄). Hydride generation produces a large volume of hydrogen as a by-product, which facilitates the purging of butyltin hydrides from a large volume of sample.

5.4.5 Clean-up

The most commonly used clean-up methods involve the use of alumina or silica adsorption chromatography. For the latter, phenyltin compounds like triphenyltin may not co-elute with butyltins. Gel permeation chromatography and similar high performance liquid chromatography (HPLC) based methods are also employed. The major advantages of using HPLC-based clean-up methods are their ease of automation and reproducibility.

5.4.6 Pre-concentration

Evaporation of solvents using a rotary evaporator should be performed under controlled temperature and pressure conditions, and the sample volume should be kept above 2 ml. Evaporation to total dryness should be avoided. To reduce the sample volume even more, e.g. to a final volume of 100 µl, solvents like pentane or hexane can be removed by concentration with a gentle stream of nitrogen. Only nitrogen of a controlled high quality should be used. Iso-octane is recommended as a keeper for the final solution to be injected into the GC.

5.5 Instrumental determination

Most of the analytical techniques developed for the speciation of organotin compounds are based on GC. GC remains the preferred separation technique owing to its high resolution and the availability of sensitive detectors such as (pulsed) flame photometry ((P)FPD), mass spectrometry (MS) or inductively coupled plasma- mass spectrometry (ICP-MS)

As an alternative approach, high performance liquid chromatography has become a popular technique. It mainly uses fluorescence, ultraviolet, and more recently inductively coupled plasma optical emission spectrometry (ICP-OES), inductively coupled plasma mass spectrometry (ICP-MS), and mass spectrometry detectors such as atmospheric pressure chemical ionisation mass spectrometry (APCI-MS-MS) and electrospray ionisation mass spectrometry (ESI-MS). ICP-MS and (P)FPD detectors have been applied widely because of their inherent selectivity and sensitivity. (P)FPD has been shown to have greater selectivity and lower detection limits (by a factor of 25 to 50 times) for organotin compounds than those obtained with conventional FPD (Bravo et al., 2004).

5.5.1 Gas chromatography

The two injection modes commonly used are splitless and on-column injection. Automatic sample injection should be used wherever possible to improve the reproducibility of injection and the precision of the overall method. If splitless injection is used, the liner should be of sufficient capacity to contain the injected solvent volume after evaporation. Helium must be used for GC-MS, GC-FPD and GC-ICP-MS. The preferred column length is 25–30 m, with an internal diameter of 0.15 mm to 0.3 mm. Film thicknesses of 0.3 µm to 1 µm are generally used. The most commonly used stationary phase for organotin analysis is 5% phenyl methyl siloxane. Mass spectrometric analyses are usually conducted in electron-impact mode at 70eV.

5.5.2 High Performance Liquid Chromatography

All stainless steel parts of the HPLC system that come into contact with the sample should be replaced by polyether ketone (PEEK) components. Reverse phase columns (e.g. octadecylsilane C18) are commonly used (Wahlen and Catterick, 2003) and the mobile phase can consist, for example, of a mixture of acetonitrile, water and acetic acid with 0.05% triethylamine, pH 3.1–3.4 (65:25:10 variable depending on columns used).

5.5.3 Detection

Flame photometry (FPD), equipped with a 610 nm band-pass filter, selective for tin compounds), mass spectrometry (MS) or inductively coupled plasma-mass spectrometry (ICP-MS) are mainly used as detectors for gas chromatography and high performance liquid chromatography.

6. Quality assurance

References of relevance to QA procedures include HELCOM (1988); HELCOM COMBINE manual, QUASIMEME (1992); Oehlenschläger (1994); ICES (1996); and Morabito et al. (1999).

6.1 System performance

The performance of the instrumentation should be monitored by regularly checking the resolution of two closely eluting organotin compounds. A decrease in resolution points to deteriorating instrumental conditions. A dirty MS-source can
be recognised by the presence of an elevated background signal together with a reduced signal-to-noise ratio. Chromatograms should be inspected visually by a trained operator.

6.2 Recovery

The recovery should be checked and reported. One method is to add an internal (recovery) standard to each sample immediately before extraction (e.g. tripropyltin) and a second (quantification) standard immediately prior to injection (e.g. tetrapropyltin). The recovery of MBT may be lower then for other organotin compounds,probably because of a lower derivatisation efficiency.

When using Isotope Dilution-Mass Spectrometry technique, the loss of target analytes is compensated. However, the recovery should still be calculated and should be between 50% and 150%.

6.3 Calibrant solutions and calibration

See Section 5.4.1.

6.4 Blanks

A procedural blank should be measured for each sample series and should be prepared simultaneously using the same chemicals and solvents as for the samples. Its purpose is to indicate sample contamination by interfering compounds, which will lead to errors in quantification. Even if an internal standard has been added to the blank at the beginning of the procedure, a quantification of peaks in the blank and subtraction from the values obtained for the determinands must not be performed, as the added internal standard cannot be adsorbed by a matrix.

6.5 Accuracy and precision

A Laboratory Reference Material (LRM) should be included, at least one sample for each series of identically prepared samples. The LRM must be homogeneous, well characterised for the determinands in question and stability tests must have shown that it produces consistent results over time. The LRM should be of the same type of matrix (e.g. liver, muscle tissue, fat or lean fish) as the samples, and the determinand concentrations should occur in a comparable range to those of the samples. If the range of determinand concentrations in the samples is large (> factor of 5) two reference materials should be included in each batch of analyses to cover the lower and upper concentrations. The data produced for the LRM in successive sample batches should be used to prepare control charts. It is also useful to analyse the LRM in duplicate from time to time to check within-batch analytical variability. The data produced for the LRM is primarily intended as a check that the analytical method is under control and yields acceptable precision, but a certified reference material (CRM such as ERM-CE 477 (mussel, certified for TBT, DBT, MBT) or NIES No. 11 (fish tissue certified for TBT and non certified reference value for TPhT)) of a similar matrix should be analysed periodically in order to check the method bias. Additionally a duplicate of at least one sample should be run with every batch of samples. Each laboratory should participate in interlaboratory comparison studies and proficiency testing schemes on a regular basis, preferably at an international level.

6.6 Data collection and transfer

Data collection, handling and transfer must take place using quality controlled procedures.

7. Data recording and reporting parameters

The calculation of results and the reporting of data can represent major sources of error, as has been shown in intercomparison studies for organotin compounds. Control procedures should be established in order to ensure that data are correct and to avoid transcription errors. Data stored in databases should be checked and validated, and checks are also necessary when data are transferred between databases.

Data reporting should be in accordance with the requirements of the monitoring programme and with the latest ICES reporting formats. Results should be reported according to the precision required for the programme. In practice, the number of significant figures is defined by the performance of the procedure.

The following parameters should be recorded:
7.1 **Sampling and biological parameters**

**Shellfish**
- location of sampling site (name, latitude, and longitude);
- date and time of sampling (GMT);
- sampling depth with respect to low tide (for sub-tidal sites only);
- irregularities and unusual conditions;
- name and institution of sampling personnel;
- number of pooled samples;
- number of individuals in pool;
- mean, minimum and maximum length and standard deviation;
- mean dry shell weight;
- mean soft tissue weight (wet weight);
- condition index.

7.2 **Analytical and quality assurance parameters**

- LRM and CRM results for a set of organotin compounds, reported on a wet weight basis;
- descriptions of the extraction, cleaning and instrumental determination methods;
- mean tissue lipid weight and method of extraction;
- the mean soft dry weight and method of determining water content if this differs from air drying to constant weight at 105°C (if sufficient material is available);
- the detection limit for each organotin compound. Specific performance criteria, including detection limits and precision, are usually set by the programme. A typical detection limit for single contaminants is 1 µg/kg wet weight, although this might be difficult to achieve for phenyltins compounds.
- QA information according to the requirements specified in the programme.

7.3 **Lipids**

- total lipids (e.g. Bligh and Dyer, 1959; or Smedes, 1999) (expressed as % or g/kg wet weight).

7.4 **Parameters**

- organic contaminants of interest to monitoring programmes for which these guidelines apply: organotin compounds suite required for analysis
- Butyltin compounds: Tributyltin (TBT), dibutyltin (DBT) and monobutyltin (MBT)
- Phenyltin compounds: Triphenyltin (TPhT), diphenyltin (DPhT) and monophenyltin (MPhT)
8. References


### 1.5.5.17 Response to OSPAR on nominations to list of threatened and declining species

(Advice provided in February 2007)

#### Request

“To prepare an assessment by February 2007 of the evidence on which nominations for the OSPAR List of Threatened and Declining Species as set out in the table below are based. The purpose of the assessment would be to ensure that the data used to support the nominations are sufficiently reliable and adequate to serve as a basis for conclusions that the species and habitats concerned can be identified as threatened and/or declining species and habitats according to the Texel/Faial criteria.

<table>
<thead>
<tr>
<th>Species</th>
<th>Evidence provided in support of nomination (received 31 October 2006)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BIRDS</strong></td>
<td></td>
</tr>
<tr>
<td>Puffinus mauretanicus (Balearic Shearwater)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td>Oceanodroma castro (Band-rumped Storm-petrel)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td>Phalacrocorax aristotelis (European Shag)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td>Aythya marila (Greater Scaup)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td>Melanitta fusca (White-winged Scoter)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td>Rissa tridactyla (Black-legged Kittiwake)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td>Pagophila eburnea (Ivory Gull)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td>Uria lomvia (Thick-billed Murre)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td>Gavia arctica (Arctic Loon)</td>
<td>MASH 06/3/7 Rev.1</td>
</tr>
<tr>
<td><strong>FISH</strong></td>
<td></td>
</tr>
<tr>
<td>Anguilla anguilla (European Eel)</td>
<td>MASH 06/3/8 Rev.1; MASH 06/3/10</td>
</tr>
<tr>
<td>Centroscymnus coelolepis (Portuguese dogfish)</td>
<td>MASH 06/3/8 Rev.1; MASH 06/3/10</td>
</tr>
<tr>
<td>Centrophorus granulosus (Gulper shark)</td>
<td>MASH 06/3/8 Rev.1</td>
</tr>
<tr>
<td>Centrophorus squamosus (Leafole spiker shark)</td>
<td>MASH 06/3/8 Rev.1; MASH 06/3/10</td>
</tr>
<tr>
<td>Squalus acanthias (Northeast Atlantic Spurdog)</td>
<td>MASH 06/3/8 Rev.1; MASH 06/3/10</td>
</tr>
<tr>
<td>Lamna nasus (Porbeagle)</td>
<td>MASH 06/3/8 Rev.1; MASH 06/3/10</td>
</tr>
<tr>
<td>Raja clavata (Thornback Skate / Ray)</td>
<td>MASH 06/3/8 Rev.1</td>
</tr>
<tr>
<td>Rostroraja alba (White skate)</td>
<td>MASH 06/3/8 Rev.1</td>
</tr>
<tr>
<td>Squatina squatina (Angel shark)</td>
<td>MASH 06/3/8 Rev.1</td>
</tr>
<tr>
<td>Prianace glauca (Blue Shark)</td>
<td>MASH 06/3/10 Rev.1</td>
</tr>
<tr>
<td><strong>Habitats</strong></td>
<td></td>
</tr>
<tr>
<td>Cymodocea meadows</td>
<td>MASH 06/3/10</td>
</tr>
<tr>
<td>Coral Gardens</td>
<td>MASH 06/3/10 Rev.1 [recd 27 November 2006]</td>
</tr>
</tbody>
</table>

In preparing advice in response to this request, ICES is invited to consider the scientific aspects of issues raised in MASH’s consideration of these nominations (see attached extract of the MASH 2006 Summary Record §§ 3 20-3.29).”

ICES was notified of this request in April 2006, but the full text of the request and most of the supporting evidence was not received until 31 October 2006. ICES was not asked to provide comments or suggestions for mitigation measures which may be necessary if these species and habitats are finally selected for management action.

#### Introduction and background

The documents were reviewed by experts not connected with the OSPAR nomination process.

Since the reviews were conducted outside the usual meeting cycle of ICES, all relevant experts contributed their time voluntarily. The combination of the number of seabird nominations and the limited availability of expertise for seabirds meant that not all seabird nominations were reviewed, but ICES can comment if required in the future. The problems for getting the coral gardens documentation reviewed were compounded by the supporting information for the nomination not being received by ICES until 27 November 2006.

It must be emphasized that ICES was only asked to assess the data used to produce the list of species and habitats submitted to OSPAR. ICES was not asked to provide comment on the suitability, or otherwise, of the criteria used to generate that list, nor of the list of species that are under consideration. However, ICES noted that the species-based listings adopted by OSPAR were not consistent with the stock-based units that ICES uses for i) the assessment of commercial fish stocks, and ii) the implementation of fish stock recovery plans when the abundance has declined below specified reference points. As has been pointed out by ICES previously though, the Texel-Faial criteria appear to refer
to species (or habitats) as a whole and not to stocks or other sub-divisions of the global population of a species. Despite this, OSPAR has listed sub-divisions of populations and some sub-species on its initial list of threatened and declining species. This inconsistency should addressed by OSPAR.

The preparation of a list of species, such as that now under consideration, should be based on extensive biogeographical information on the respective species. Good knowledge of the geographical distribution of the species, and of the areas where it is threatened or declining, and where it is not, is fundamental to sound decisions about the risk to various species. Also needed is a good long-term documentation of any decline; a conclusion on decline should not be based on limited information regarding spatial and temporal dynamics of the populations involved. Some of the deep-water shark species on the list are examples where the decline is not uniform over all areas in which the species occurs, this is indicated in the Table below summarising ICES’s review.

Special care is required when drawing conclusions regarding a decline of a species in areas at the border of its geographical distribution range. The list includes two bird species (Oceanodroma castro (Band-rumped storm-petrel) and Pagophila eburnea (Ivory gull)) and the Cymodocea meadows where the documented decline is at the edge of its area of distribution.
Summary of the adequacy of the evidence for declines in the OSPAR area and threats to the species and habitats listed in the additional nominations to the OSPAR List of Threatened and Declining Species and Habitats.

<table>
<thead>
<tr>
<th>Nominated threatened and/or declining species and habitats</th>
<th>Indication of decline</th>
<th>Indication of threat</th>
<th>OSPAR region where the species occurs</th>
<th>OSPAR regions where the species is under threat and/or in decline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BIRDS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Puffinus mauretanicus</em> (Balearic shearwater)</td>
<td>ICES was unable to formulate advice in the required time frame, but can comment if required in the future.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oceanodroma castro</em> (Band-rumped storm-petrel)</td>
<td>No evidence of global species decline, no evidence of current decline in OSPAR area, distinctiveness of population breeding in OSPAR unclear.</td>
<td>Potential threats to small OSPAR area population primarily at breeding colonies</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td><em>Aythya marila</em> (Greater scaup)</td>
<td>ICES was unable to formulate advice in the required time frame, but can comment if required in the future.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Melanitta fusca</em> (White-winged scoter)</td>
<td>ICES was unable to formulate advice in the required time frame, but can comment if required in the future.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rissa tridactyla</em> (Black-legged kittiwake)</td>
<td>About 10-15% of global population breeds in OSPAR area. Good evidence that those breeding in the OSPAR area increased from 1970-1990 then decreased to 2000 and more recently.</td>
<td>Populations affected by sandeel abundance, but limited evidence that sandeel abundance affected by human activity. Poor evidence of human-induced threats.</td>
<td>Breeds in I, II, III, IV. Occurs in V.</td>
<td></td>
</tr>
<tr>
<td><em>Pagophila eburnea</em> (Ivory gull)</td>
<td>About 10-15% of global population present in OSPAR area. Good evidence of decline in this population (and some other parts of global population)</td>
<td>Reasonable evidence of current threat from mercury contamination, longer term concern over effects on marine feeding area due to climate induced changes in pack ice.</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td><em>Uria lomvia</em> (Thick-billed murre)</td>
<td>Less than 10% of global population present in OSPAR area. Good evidence that majority of OSPAR area population stable but has declined in Iceland.</td>
<td>Limited evidence of threat in OSPAR area, or to populations breeding in OSPAR area. Good evidence of threat to global population from hunting outside OSPAR area.</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td><em>Gavia arctica</em> (Arctic loon)</td>
<td>ICES was unable to formulate advice in the required time frame, but can comment if required in the future.</td>
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<tr>
<td><strong>FISH</strong></td>
<td></td>
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</tr>
<tr>
<td><em>Anguilla anguilla</em> (European eel)</td>
<td>Good evidence of decline exists, but poorly presented in nominations</td>
<td>Threats probably persist, but are badly researched and poorly presented in nominations</td>
<td>All</td>
<td>I, II, III, IV</td>
</tr>
<tr>
<td><em>Centroscymnus coelolepis</em> (Portuguese dogfish)</td>
<td>Good evidence of decline exists in some fishing grounds, but poorly presented in nominations</td>
<td>Good evidence that species taken as bycatch in fisheries, but poorly presented in nominations</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td><em>Centrophorus granulosus</em> (Gulper shark)</td>
<td>Good evidence of a decline in landings from some fishing grounds, but poor evidence as to whether this due to decline in species /stock or to other factors.</td>
<td>Poor evidence of threat and inaccurate use of information in nominations.</td>
<td>IV, V</td>
<td>(IV, V)</td>
</tr>
<tr>
<td><em>Centrophorus squamosus</em> (Leafscale gulper shark)</td>
<td>Good evidence of decline exists, but poorly presented in nominations</td>
<td>Good evidence that species taken as bycatch in fisheries, but poorly presented in nominations</td>
<td>All</td>
<td>All</td>
</tr>
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<td>OSPAR region where the species occurs regions</td>
<td>OSPAR regions where the species is under threat and/or in decline</td>
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</tr>
<tr>
<td><em>Squalus acanthias</em> ([Northeast Atlantic] spurdog)</td>
<td>Widely distributed species, evidence of decline of stock in OSPAR area. Poor presentation in nomination.</td>
<td>Good evidence that species taken as bycatch in fisheries and some seasonal, localised targeted fisheries. Poorly presented arguments failed to note that aggregations of mature gravid females may be targeted.</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td><em>Lamna nasus</em> (Porbeagle)</td>
<td>Widely distributed species. Evidence of decline in OSPAR area based on landings data and fishing patterns.</td>
<td>Good evidence that species still caught as bycatch and in limited targeted fisheries</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td><em>Raja clavata</em> (Thornback skate / ray)</td>
<td>Widely distributed species. Good evidence of decline in catch rates in North Sea, poor/no evidence from other OSPAR regions</td>
<td>Good evidence that species taken as bycatch in fisheries and some seasonal, localised targeted fisheries. Poorly presented arguments failed to note that aggregations of mature gravid females may be targeted.</td>
<td>I-IV</td>
<td>Evidence only presented for Region II</td>
</tr>
<tr>
<td><em>Rostroraja alba</em> (White skate)</td>
<td>Widely distributed, but rare species. Good evidence of decline, with poor documentation in nomination.</td>
<td>Good evidence that species (although now rare) taken as bycatch in fisheries.</td>
<td>II-IV</td>
<td>II-IV</td>
</tr>
<tr>
<td><em>Squatina squatina</em> (Angel shark)</td>
<td>Widely distributed, but rare species. Good evidence of decline, with poor documentation in nomination.</td>
<td>Good evidence that species (although now rare) taken as bycatch in fisheries.</td>
<td>II-IV</td>
<td>II-IV</td>
</tr>
<tr>
<td><em>Priacanthus glauca</em> (Blue shark)</td>
<td>Globally distributed species with no evidence of separate stock in OSPAR area or of importance of OSPAR area. Evidence for decline not consistent (but data collection could improve).</td>
<td>Good evidence that species taken as bycatch in other fisheries and some seasonal, localised targeted fisheries.</td>
<td>II, III, IV, V</td>
<td>II, III, IV, V</td>
</tr>
</tbody>
</table>

**HABITATS**

| Cymodocea meadows                                      | Species on edge of distribution in OSPAR area. Good evidence of decline, although the possible interaction with *Caulerpa prolifera* deserves further investigation. | Reasonable evidence of threat from variety of human activities (particularly from construction and associated changes in local water flow/chemistry) where habitat occurs | IV | IV |
| Coral Gardens                                           | No evidence that octocoral occurrences in OSPAR waters are fully equivalent to the coral garden habitat recorded elsewhere. Evidence of decline fragmentary and poorly documented, though reasonable anecdotal evidence in Region I. | Reasonable evidence that fishing (bottom-trawling and long-lining) has caused decline and where occurs in habitat is a threat and will cause damage. No evidence of damage from other activities. | I, II, IV, V | I, II, IV, V |

1.5.5.18 Answer to request from OSPAR for a scientific peer review of proposals for areas to be considered as marine protected areas in the Northeast Atlantic beyond national jurisdiction

Request

To peer review proposals developed by the ICG-MPA for seven areas that could be considered as OSPAR MPA in areas beyond national jurisdiction (Reykjanes ridge, Southern MAR, Altair seamount, Antialtair seamount, Josephine seamount, Milne seamount cluster and south Rockall and Hatton). The review should consider the nomination pro formas for each area, as follows:

a. review the information in Section A of the nomination pro forma and provide any relevant data that is available to ICES.

b. a review of whether information provided in Section B meets the ecological criteria and considerations set out in appendix 1 of the OSPAR guidelines on identification and selection of MPAs in the OSPAR maritime area (OSPAR agreement 2003-17), focussing on the following:

(i) reviewing and adding to the information provided in relation to ecological criteria and considerations.

(ii) commenting on which of the selection criteria are fulfilled taking into account all available information.

(iii) reviewing and, if possible, adding to the information provided on possible damage by human activities.

(iv) commenting on the value of the site for scientific research.

c. commenting on the appropriateness of the proposed boundaries and suggest alternative boundary options.

d. identify and delineate, when known by the reviewers, the key locations of ecologically significant and/or vulnerable (i) habitats, (ii) species and (iii) ecological processes within the area identified in the proposal, taking into account available data.

Source of information

The ICES Working Groups on Deep-water Ecology (WGDEC) and on Biology and Assessment of Deep-sea Fisheries Resources (WGDEEP) were asked for their comments by correspondence. In addition, the Chairs of the Working Groups on Seabird Ecology and on Marine Mammal Ecology were asked to review relevant parts of the proposals.

ICES Response

The review of MPA proposals has been undertaken with reference to the criteria for assessment as described in Appendix 1 and 2 of the OSPAR Guidance document (OSPAR Commission 2003, Reference No:2003-17)). This specifies seven ecological criteria / considerations, and six practical criteria / considerations to help refine the selection process. The ICES review was made challenging by the lack of specific conservation objectives for the proposed MPAs. The generic aims of each of the proposed MPA sites were to ‘protect, conserve and restore species, habitats and ecological processes’, but it was often unclear which species or habitats (except for those listed under the Texel–Faial criteria) had been used in the proposals for the sites. It might be helpful, if in addition, the nomination pro forma (OSPAR 03/17/1-E, Annex 10, Appendix 4, A 2) explicitly asked for the definition of the site-specific objectives. The interpretation of ‘Important species and habitats/biotopes’, was interpreted broadly by ICES since it is understood that no further selection process for species or habitats is being considered at present by OSPAR.

This lack of specific objectives was particularly important when assessing practical considerations. ICES was asked to ensure that the ‘the size of the area should be suitable for the particular aim of designating the area’. In the absence of specific objectives related to species or habitats for which distributions were available, this was a difficult task. In offshore waters, for example on the mid-Atlantic Ridge, the site boundaries often delimited areas of seabed that were poorly understood. There was therefore no reason to reject the proposed size of MPAs or their site boundaries, especially as the objectives were non-specific.

ICES recommends that OSPAR considers whether a clearer statement of objectives specific to each MPA in each nomination would enable a better evaluation of the advantages and disadvantages of any proposed area and its boundaries.
In areas which are better understood and closer to national waters, however, such as Rockall and Hatton Bank, it is more important to provide well justified site boundaries. In this particular example, site boundaries apparently intersect Irish waters and seabed claimed as continental shelf extensions by a number of Contracting Parties, cut across areas closed to certain fishing activities by NEAFC for coral protection, and arbitrarily cut across patches of sensitive habitat.

**ICES recommends that a more rigorous justification of the boundary would be appropriate in the Rockall-Hatton nomination and other future similar cases.**

The proposed MPAs were easiest to evaluate in terms of whether or not threatened or declining species and habitats are present. The lack of sufficient understanding of the ecology of many of the seamount and ridge sites made it generally difficult to interpret the relative importance of their biodiversity, sensitivity, and ecological significance.

ICES had some difficulty in being sure of the precise definition of various words and terms in the OSPAR criteria, examples include “important”, “sensitive”, and “ecologically significant”. In the absence of such definitions, ICES cannot be sure that its understanding of the terms is the same as that of OSPAR, and indeed such understandings may vary between the Contracting Parties to OSPAR.

**ICES recommends that OSPAR considers improving the definition of terms within the MPA selection criteria.**

The final selection of sites by OSPAR will be based on whether they meet ‘several but not necessarily all’ of the MPA selection criteria. ICES was not asked to provide advice on this final step, and in addition there is no indication in the criteria of the importance (or weighting) of each criteria when decisions are made. It is difficult to see how this selection can be an objective process. In order to provide a more transparent and objective process, **ICES recommends that OSPAR provides guidance as to the priority of each criterion in the final selection of sites.**

In the advice provided by ICES, the term “bottom fishing” refers to bottom fishing activities where the fishing gear is likely to contact the seafloor during the normal course of fishing operations.

Detailed evaluation of each of the proposals, addressing items a to d in the request from OSPAR, can be found in the Technical Annex to this advice. A summary of this evaluation in relation to items b, c, and d is presented in Table 1.5.5.18.1. Cells in this table are marked according to whether ICES agrees that:

- there is adequate evidence that the criterion is met (Good evidence);
- evidence contained in the proposal indicates that the criteria are not met (Does not meet);
- there is insufficient evidence in the proposal to support the criteria (Insufficient evidence);
- there is insufficient evidence in the proposal, but based on other evidence the criteria are probably met (Probably meets); or
- there is no evidence in the proposal to support or refute the criteria (No evidence).

Where ICES is aware of additional information not included in the proposal, this has been noted and taken into consideration in the evaluation.

ICES notes that there is considerable overlap between the areas being proposed for protection under OSPAR and those being considered for closure to bottom fishing by NEAFC (Figure 1.5.5.18.1).

**ICES recommends that a coordinated approach be taken between the two organizations for designating areas in waters beyond national jurisdiction. If the same boundaries are used where the same features are being protected, there will be less confusion among stakeholders and a better chance of coherent management of human activities in these areas. ICES is willing to help in any coordinated approach.**
Table 1.5.5.18.1 An evaluation of areas proposed as marine protected areas in the Northeast Atlantic, based on the nomination forms for each area. The evaluation assesses the nomination against the criteria set out in Appendix 1 of the Guidelines for the Identification and Selection of Marine Protected Areas in the OSPAR Maritime Area (Reference number: 2003-17). Cells are marked according to whether ICES agrees that there is adequate evidence that the criterion is met (Good evidence), evidence contained in the proposal indicates that the criteria are not met (Does not meet), there is insufficient evidence in the proposal to support the criteria (Insufficient evidence); there is insufficient evidence in the proposal but based on other evidence the criteria are probably met (Probably meets); or there is no evidence in the proposal to support or refute the criteria (No evidence).

<table>
<thead>
<tr>
<th>Ecological considerations</th>
<th>Reykjanes Ridge</th>
<th>Southern Mid-Atlantic Ridge</th>
<th>Altair seamount</th>
<th>Antialtair seamount</th>
<th>Josephine seamount</th>
<th>Milne seamount cluster</th>
<th>South Rockall and Hatton</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Threatened or declining species and habitats/biotopes</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
</tr>
<tr>
<td>2. Important species and habitats/biotopes</td>
<td>No evidence</td>
<td>Insufficient evidence</td>
<td>No evidence</td>
<td>No evidence</td>
<td>Insufficient evidence</td>
<td>No evidence</td>
<td>Good evidence</td>
</tr>
<tr>
<td>3. Ecological significance</td>
<td>Probably meets</td>
<td>Probably meets</td>
<td>No evidence</td>
<td>No evidence</td>
<td>Partial evidence</td>
<td>Probably meets</td>
<td>Good evidence</td>
</tr>
<tr>
<td>4. High natural biological diversity</td>
<td>No evidence</td>
<td>No evidence</td>
<td>Probably meets</td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
<td>Probably meets</td>
</tr>
<tr>
<td>5. Representativity</td>
<td>Probably meets</td>
<td>Good evidence</td>
<td>Probably meets</td>
<td>Probably meets</td>
<td>No evidence</td>
<td>Probably meets</td>
<td>Probably meets</td>
</tr>
<tr>
<td>6. Sensitivity</td>
<td>No evidence</td>
<td>Probably meets</td>
<td>Probably meets</td>
<td>Probably meets</td>
<td>Probably meets</td>
<td>Probably meets</td>
<td>Partially meets</td>
</tr>
<tr>
<td>7. Naturalness</td>
<td>Does not meet</td>
<td>Insufficient evidence</td>
<td>Probably meets</td>
<td>Probably meets</td>
<td>Good evidence</td>
<td>No evidence</td>
<td>Does not meet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Practical criteria</th>
<th>Reykjanes Ridge</th>
<th>Southern Mid-Atlantic Ridge</th>
<th>Altair seamount</th>
<th>Antialtair seamount</th>
<th>Josephine seamount</th>
<th>Milne seamount cluster</th>
<th>South Rockall and Hatton</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Size</td>
<td>Insufficient evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Good evidence</td>
<td>Probably meets</td>
</tr>
<tr>
<td>2. Potential for restoration</td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
<td>No evidence</td>
<td>Probably meets</td>
</tr>
<tr>
<td>3. Degree of acceptance</td>
<td>No evidence</td>
<td>Insufficient evidence</td>
<td>Probably meets</td>
<td>Probably meets</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Does not meet</td>
</tr>
<tr>
<td>4. Potential for success of management measures</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Probably meets</td>
<td>Insufficient evidence</td>
</tr>
<tr>
<td>5. Potential damage to the area by human activities</td>
<td>Does not meet</td>
<td>Does not meet</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Good evidence</td>
</tr>
<tr>
<td>6. Scientific value</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Insufficient evidence</td>
<td>Good evidence</td>
<td>Insufficient evidence</td>
<td>Good evidence</td>
</tr>
</tbody>
</table>
Figure 1.5.5.18.1  Chart of areas on the mid-Atlantic Ridge proposed as Marine Protected Areas by OSPAR (Blue) and as areas closed to bottom fishing by NEAFC (Red). Existing NEAFC closures are indicated in solid red.
Technical Annex to OSPAR request

Detailed comments on each proposed MPA are provided below.

Reykjanes ridge

Further relevant data

The proposal is missing newer references, e.g. references to recent ICES reports, especially those from WGDEEP and ACFM or ACOM (ICES, 2005, 2006a, 2007a,b, 2008b). Some key reports from, e.g. Russian sources are missing (Kukuev, 2004; Mironov et al., 2006). ICES issues advisory reports annually and the latest evaluations of deep-water fisheries came in 2007 (ICES, 2007a). These reports should at least be consulted. Basically, the proposers have not conducted a particularly good exploration of the information on fisheries and fish resources, but often just refer to generalities that are perhaps not entirely relevant to the specific areas.

Application of OSPAR MPA identification guidelines

Ecological criteria

Criterion 1. Threatened or declining species and habitats/biotopes

ICES finds that sponge communities are present in the proposed area and that probably other threatened and declining habitats such as *Lophelia pertusa* reefs are present.

Criterion 2. Important species and habitats/biotopes

ICES finds no evidence in the proposal that this criterion is met.

Criterion 3. Ecological significance

ICES finds no site-specific evidence that the proposed area is of particular ecological significance but it is probable that the area does contain important nursery, juvenile, or spawning areas. The proposal misquotes some citations (e.g. Gislason et al., 2007).

Criterion 4. High natural biological diversity

ICES found no comparison of this area with other parts of the North Atlantic to demonstrate that this area has a higher natural variety of species than exists elsewhere.

Criterion 5. Representativity

ICES finds no direct evidence in the proposal that the proposed area is representative of part of the northern mid-Atlantic Ridge (MAR); however, it is reasonable to assume that the proposed sites contains habitats, species, or ecological processes typical of the MAR north of the sub-polar front.

Criterion 6. Sensitivity

ICES finds no evidence in the proposal that the area contains a high proportion of very sensitive or sensitive habitats or species compared to elsewhere.

Criterion 7. Naturalness

ICES finds that this area cannot be regarded as pristine. Fishing activity has occurred in the proposed area for at least three decades, and it is certain to have had some impact on pelagic and deep-water communities of this area, especially those on and around the shallower seamounts.
Practical criteria

Criterion 1. Size
ICES finds no evidence in the proposal and is unable to comment on the appropriateness of the proposed size and boundaries. There is some scientific information to support the choice of an area in the northern MAR together with an area on the southern MAR to be representative of two different faunas and faunal provinces. Oceanography as well as bathymetry is significant in determining faunal boundaries and ICES agrees that this should be taken into consideration when choosing the size of the area.

Criterion 2. Potential for restoration
ICES finds no evidence in the proposal to evaluate the potential for restoration of features within the site.

Criterion 3. Degree of acceptance
ICES finds no evidence in the proposal that the proposed area would have a high degree of acceptance. As noted above, fisheries have occurred in the area for at least thirty years.

Criterion 4. Potential for success of management measures
ICES finds insufficient evidence in the proposal that management measures within the proposed area would necessarily be successful. The major management measures likely to be required to meet the aims of designation relate to fisheries and there is evidence that existing fisheries closures have been ignored in the recent past in the Northeast Atlantic (ICES, 2006b).

Criterion 5. Potential damage to the area by human activities
ICES agrees with the evidence in the proposal that the proposed area is unlikely to suffer significant damage from human activities in the short term. ICES finds that there is no evidence in the proposal that there will be an increase in bottom fisheries on the Reykjanes Ridge in the near future. All reports from recent years point in the opposite direction.

Criterion 6. Scientific value
ICES finds insufficient evidence in the proposal that the proposed area is of particular value to science.

Appropriateness of boundaries
ICES finds there is insufficient evidence to comment on the appropriateness of the proposed boundaries. The simplicity of the boundary should help in enforcing any management regulations.

Key locations
ICES has no further evidence to add to that in the proposal.

Southern mid-Atlantic Ridge

Further relevant data
ICES has no further data to add to the proposal beyond that listed in the advice provided below.

Application of OSPAR MPA identification guidelines

Ecological criteria

Criterion 1. Threatened or declining species and habitats/ biotopes

ICES finds that there is evidence in the proposal that the area is important for threatened and declining species and habitats. During a survey of the mid-Atlantic Ridge (MAR), leaf-scale gulper-shark Centrophorus squamosus and Portuguese dogfish Centroscymnus coelolepis were both caught only in the area just north of the Azores (Fossen et al., 2008). These two species are on the OSPAR list of Threatened and/or Declining Species and Habitats. The proposed marine protected area includes the locations of these catches.

The proposed area includes several seamounts, a threatened or declining habitat on the OSPAR list.

Criterion 2. Important species and habitats/ biotopes

ICES finds limited evidence that the proposed site contains important species and habitats. Corals occur along the ridge and perhaps on most hills there, but there are no density estimates to assess whether the MAR is particularly important to corals on a basin-wide scale.

Similarly, the MAR provides the only extensive hard substrate habitat available for benthic suspension feeders off the continental shelves and the isolated seamounts provide suitable habitats for benthic or benthopelagic species. The topography of the Ridge strongly shapes the habitat characteristics in the water column, through its effects on currents (see e.g. Opdal et al., 2008). There is, therefore, some evidence that important species and biotopes might occur in the southern MAR, but no evidence that this part of the southern MAR represents a particularly important part of the MAR.

Criterion 3. Ecological significance

ICES finds no site-specific evidence that the proposed area is of particular ecological significance. However, as a representative section of the MAR in warm temperate waters, with the presence of sub-tropical species assemblages, it is likely to exhibit a higher biological productivity of these features than the surrounding open ocean.

Criterion 4. High natural biological diversity

ICES finds insufficient evidence in the proposal to demonstrate that this area has a higher natural variety of species than exists elsewhere in the North Atlantic, although it is probable that the range of habitats associated with the mid-ocean ridge leads to a relatively high diversity. Relatively good descriptions of the fauna occurring on the MAR have been published, but there are few comparative analyses between the MAR fauna and other areas such as isolated seamounts, continental slopes, and island slopes. The references given, particularly those to pelagic studies, do not support any general conclusion on this issue.

The major feature of the MAR demersal fish distribution is a concentration of biomass and numbers near the summit of the ridge and a decline in abundance with depth (Bergstad et al., 2008). There is also an associated depth-related change in species composition. It has not been convincingly demonstrated that abundance patterns are significantly related to occurrence of coral in these waters, perhaps with the exception of ‘longline species’ near the summit of hills.

Criterion 5. Representativity

ICES finds that there is evidence in the proposal to support the choice of this region as representative of different biogeographic regions or sub-regions.

Criterion 6. Sensitivity

ICES finds that there is insufficient direct evidence in the proposal that the area contains sensitive habitats, but since the proposed area includes seamount habitats (and potentially Lophelia pertusa reefs), it is probable that habitats sensitive to damage from human activities are present.

Criterion 7. Naturalness

ICES finds limited evidence in the proposal that the area has a high degree of naturalness. Fishing activity has occurred for at least three decades, and it is certain to have had some impact on pelagic and deep-water communities of this area, especially those on and around the shallower seamounts. Therefore the area is not pristine. A more thorough analysis of existing reports on fishing practices is required.
Practical criteria

Criterion 1. Size
ICES finds that there is evidence in the proposal that the size of the proposed area is appropriate as it includes several replicate habitats within each faunal province.

Criterion 2. Potential for restoration
ICES finds no evidence in the proposal to evaluate the potential for restoration of features within the site.

Criterion 3. Degree of acceptance
ICES finds insufficient evidence in the proposal that the proposed area would have a high degree of acceptance. Statements in the proposal indicate that there is no longer any fishing in the area (based on Vinnichenko, 1998); however, fishing for alfonsino was resumed in 1999–2000 (ICES, 2008a).

Criterion 4. Potential for success of management measures
ICES finds insufficient evidence in the proposal that management measures within the proposed area would necessarily be successful. The major management measures likely to be required to meet the aims of designation relate to fisheries and there is evidence that existing fisheries closures have been ignored in the recent past in the Northeast Atlantic (ICES, 2006b).

Criterion 5. Potential damage to the area by human activities
ICES agrees with the evidence in the proposal that the proposed area is unlikely to suffer significant damage from human activities in the short term. ICES finds that there is no evidence in the proposal that there will be an increase in bottom fisheries in the southern MAR in the near future.

Criterion 6. Scientific value
ICES finds limited evidence in the proposal that the proposed area is of high value to science.

Appropriateness of boundaries
ICES finds there is insufficient evidence to support precisely the proposed boundaries. The simplicity of the boundary should help in enforcing any management regulations.

Key locations
ICES has no further evidence to add to that in the proposal.

Altair seamount

Further relevant data
ICES is not aware of any further relevant data on this site. Few scientific studies have been conducted on Altair, and little is known about its biology. The proposed marine protected area incorporates and extends an existing NEAFC fishing closure due for review at the end of 2008.
Application of OSPAR MPA identification guidelines

Ecological criteria

Criterion 1. Threatened or declining species and habitats/ biotopes

ICES finds that there is evidence in the proposal that the proposed area contains seamount habitat, which is listed as priority threatened or declining habitat by OSPAR (OSPAR Commission, 2003). ICES finds no evidence in the proposal that the area is important for threatened or declining species, but Santos et al. (2007) provide evidence of the occurrence of loggerhead turtle over the seamount which was not considered in the proposal.

Criterion 2. Important species and habitats/ biotopes

ICES finds no evidence in the proposal that this criterion is met.

A Spanish survey found that one of the main fish species caught on Altair is lantern shark *Etmopterus princeps* (Durán Muñoz et al., 2000), which has been classified as vulnerable to fishing pressure as it has a relatively long recovery time (ICES, 2005, 2008b).

Criterion 3. Ecological significance

ICES finds insufficient evidence in the proposal that the proposed area has particular ecological significance.

The proposal argues that the isolation and geological age of the area make it likely that the site supports more endemic species than seamounts on the mid-Atlantic Ridge. ICES, however, finds no evidence that geological age is necessarily indicative of high endemism on this scale.

Criterion 4. High natural biological diversity

ICES finds insufficient evidence in the proposal to demonstrate that this area has a higher natural variety of species than exists elsewhere on seamounts in the North Atlantic.

Criterion 5. Representativity

ICES finds that there is no direct evidence that the proposed site has characteristics that are representative for its biogeographic region although it may be assumed that the proposed site is representative of seamounts found to the west of the mid-Atlantic Ridge.

Criterion 6. Sensitivity

ICES finds no site-specific evidence in the proposal but it is probable that the site contains sensitive habitats characteristic of seamounts.

Criterion 7. Naturalness

ICES finds that it is probable that, despite records of fishing activity, the area may have a high degree of naturalness. The proposal notes that, following the establishment of NEAFC fishing closures in 2005, bottom fishing effort was observed over one of the protected seamounts in the Altair closure (ICES, 2007a). Durán Muñoz et al. (2000) and V. Vinnichenko (pers. comm.) found that only a few areas within the proposed site were suitable for bottom trawl fishing.
**Practical criteria**

**Criterion 1. Size**

ICES finds that the size of the proposed site (i.e. including all depth zones and the inclusion of appropriate buffer zone) is suitable for the aim of designating the site and is sufficient to maintain the integrity of the site’s features and would enable effective management.

**Criterion 2. Potential for restoration**

ICES finds no evidence in the proposal to evaluate the potential for restoration of features within the sites. There is no mapping of the habitats in the area.

**Criterion 3. Degree of acceptance**

The proposed area incorporates an existing NEAFC fishery closure, which has been in effect since 2005. ICES therefore assumes that it is probable that the proposal is more likely to be accepted by NEAFC and the fishing community than an area not currently closed to fishing.

**Criterion 4. Potential for success of management measures**

ICES finds insufficient evidence in the proposal that management measures within the proposed area would necessarily be successful. The major management measures likely to be required to meet the aims of designation relate to fisheries. The NEAFC fishery closure that exists in the proposed area did not prevent bottom fishing activity within the closure in the year following its implementation (ICES, 2006b). However, because the area incorporates the current NEAFC closures the management or at least enforcement of measures may be easier.

**Criterion 5. Potential damage to the area by human activities**

ICES finds insufficient information in the proposal relevant to significant damage from human activities in the short term.

**Criterion 6. Scientific value**

ICES finds insufficient evidence in the proposal that the site contains particular features of high scientific value.

**Appropriateness of boundaries**

ICES finds that the Altair proposal is scaled to the physical dimensions of the features within and considers the proposed boundaries appropriate given that these are relatively small and contained features.

ICES finds the inclusion of all related depth zones and the inclusion of an extended buffer zone appropriate for the aims of the proposed site, including ensuring the integrity of the site. ICES finds the proposed simplification of the site’s boundaries beneficial in easing management and compliance.

Altair has been closed by NEAFC to fishing with bottom gear since 2005. This closure will continue until at least 31 December 2008. ICES considers that the existing NEAFC boundaries within the site may be fragmenting the habitat and will likely not be sufficient to achieve OSPAR objectives. The proposed marine protected area includes this fishery closure. The proposal states two primary reasons for this, firstly to make the boundaries straighter so that compliance and management is easier. Secondly to include all of the depth zones accessible to fishing at present and potentially in the future.

**Key locations**

ICES has no further evidence to add to that in the proposal.
Antialtair seamount

Further relevant data

Logan (1998) studied Brachiopods on the seamount.

Application of OSPAR MPA identification guidelines

Ecological criteria

Criterion 1. Threatened or declining species and habitats/biotopes

ICES finds that there is evidence in the proposal that this criterion is met. The ecological criteria state that an area should be important for species or habitats listed on the initial OSPAR list of threatened and/or declining species and habitats. Very limited information on the biota exists, but a Spanish survey reported catches of orange roughy *Hoplostethus atlanticus* on Antialtair Seamount (Durán Muñoz *et al.*, 2000). The site clearly contains the biotope ‘seamounts’ and it is probable that cold-water coral communities are also present.

Criterion 2. Important species and habitats/biotopes

ICES finds no evidence in the proposal that this criterion is met.

Criterion 3. Ecological significance

ICES finds insufficient evidence in the proposal that the proposed area has particular ecological significance. The proposal argues that the isolation and geological age of the area make it likely that the site supports more endemic species than seamounts on the mid-Atlantic Ridge. ICES, however, finds no evidence that geological age is necessarily indicative of high endemism on this scale.

Criterion 4. High natural biological diversity

ICES finds no evidence in the proposal that this criterion is met. There is no comparison of this area with other parts of the North Atlantic to demonstrate that this area has a higher natural variety of species than exists elsewhere. Logan (1998) showed that the Brachiopod fauna of the seamount did not differ significantly from six other seamounts or the nearby continental margin.

Criterion 5. Representativity

ICES finds that there is no direct evidence that the proposed site has characteristics that are representative for its biogeographic region although it may be assumed that the proposed site is representative of seamounts found to the east of the mid-Atlantic Ridge.

Criterion 6. Sensitivity

ICES finds no site-specific evidence in the proposal but it is probable that the site contains sensitive habitats characteristic of seamounts.

Criterion 7. Naturalness

ICES finds that it is probable that, despite records of fishing activity, the area may have a high degree of naturalness. The proposal notes that, following the establishment of NEAFC fishing closures in 2005, fishing effort was observed in 2004 and 2005 over the Antialtair closure (ICES, 2007a). Durán Muñoz *et al.* (2000) and V. Vinnichenko (pers. comm.) found that only a few areas within the proposed site were suitable for bottom trawl fishing.
**Practical criteria**

**Criterion 1. Size**

ICES finds that the size of the proposed site (i.e. including all depth zones and the inclusion of an appropriate buffer zone) is suitable for the aim of designating the site and is sufficient to maintain the integrity of the site’s features and would enable effective management.

**Criterion 2. Potential for restoration**

ICES finds no evidence in the proposal to evaluate the potential for restoration of features within the sites. There has been no mapping of the habitats in the area.

**Criterion 3. Degree of acceptance**

The proposed area incorporates an existing NEAFC fishery closure, which has been in effect since 2005. ICES therefore assumes that it is probable that the proposal is more likely to be accepted by NEAFC and the fishing community than an area not currently closed to fishing.

**Criterion 4. Potential for success of management measures**

ICES finds insufficient evidence in the proposal that management measures within the proposed area would necessarily be successful. The major management measures likely to be required to meet the aims of designation relate to fisheries. The NEAFC fishery closure that exists in the proposed area did not prevent bottom fishing activity within the closure in the year following its implementation (ICES, 2006b). However, because the area incorporates the current NEAFC closures the management or at least enforcement of measures may be easier.

**Criterion 5. Potential damage to the area by human activities**

ICES finds insufficient information in the proposal relevant to significant damage from human activities in the short term.

**Criterion 6. Scientific value**

ICES finds insufficient evidence in the proposal that the site contains particular features of high scientific value.

**Appropriateness of boundaries**

ICES finds that the Antialtair proposal is scaled to the physical dimensions of the features within and considers the proposed boundaries appropriate. ICES finds the inclusion of all related depth zones and the inclusion of an extended buffer zone appropriate for the aims of the proposed site, including ensuring the integrity of the site. ICES finds the proposed simplification of the site’s boundaries beneficial in easing management and compliance. Antialtair has been closed by NEAFC to fishing with bottom gear since 2005. This closure will continue until at least 31 December 2008. The proposed marine protected area includes this fishery closure. The proposal states two primary reasons for this, firstly to make the boundaries straighter so that compliance and management is easier. Secondly to include all of the depth zones accessible to fishing at present and potentially in the future.

**Key locations**

ICES has no further evidence to add to that in the proposal.
Josephine Seamount

Further relevant data

An account of fish caught on Josephine Seamount is given by Maul (1976), Shcherbachev et al. (1985), and Pakhorukov (2008). This information is certainly relevant for a characterization of the area. There is also more information on the physical oceanography of the area which could be included (e.g., Richardson et al., 2000 and references within).

Application of OSPAR MPA identification guidelines

Ecological criteria

Criterion 1. Threatened or declining species and habitats/biotopes

ICES finds that there is evidence in the proposal for seamount status for Josephine, which is a listed OSPAR habitat. ICES finds no evidence in the proposal to suggest the unnamed ‘seamount’ in the proposal is a seamount as defined by OSPAR since its physical characteristics are not provided. ICES finds no evidence in the proposal to support the presence of sponge aggregations in the areas. The authority cited is a taxonomic treatment only.

ICES finds that the proposal does not provide any direct evidence for threatened or declining species which meets this criterion. Observations from nearby areas strongly suggest that leatherback turtles *Dermochelys coriacea*, loggerhead turtles *Caretta caretta*, bluefin tuna *Thunnus thynnus*, leavescale gulper-shark *Centrophorus squamosus*, and Portuguese dogfish *Centroscymnus coelolepis* occur in the area; however, the importance of the area to these species is unknown.

There is direct evidence for occurrence of the white skate *Rostroraja alba* on Josephine Seamount, some of which is cited in the proposal; Shcherbachev et al. (1985) and Pakhorukov (2008) provide further evidence. This species is declining throughout its range and could be included here to present a stronger case for the selection of this area.

Criterion 2. Important species and habitats/biotopes

ICES finds limited evidence in the proposal to support this criterion.

Criterion 3. Ecological significance

ICES finds limited evidence in the application to support this criterion. There is good evidence presented in the proposal to suggest that the plateau of this seamount supports a higher abundance of meiofauna.

Criterion 4. High natural biological diversity

ICES found no evidence in the proposal to support this criterion. There is no comparison in the proposal of this area with other parts of the North Atlantic to demonstrate that this area has a higher natural variety of species than exists elsewhere. ICES notes that comparisons of the diversity of the Ophiuroidea indicate that there is in fact a lower diversity on the Josephine Seamount than on the adjacent continental margin, while gorgonian and antipatharian corals have a similar diversity and are typical of the eastern Atlantic (Stocks and Hart, 2007). This is consistent with the hydrography of the area (Richardson et al., 2000).

The number of invertebrate and fish species known at present to live in the area is not considered high (150 and 31 respectively) and there is a low percent of known endemism (0% of 15 species of gorgonian and antipatharian corals; 6% of 53 species of polychaetes (Stocks and Hart, 2007)).
Criterion 5. Representativity

ICES finds no evidence in the proposal to support this criterion. Compared with the other proposed MPAs it is the only one which represents the Lusitanean seamount group; however, the evidence presented suggests that it is not representative of the seamounts within the group (i.e., “Being the most remote seamount in the group, Josephine Seamount has the most impoverished continental faunal assemblage with a much higher percentage of open-oceanic elements than the rest of the Lusitanean seamount group (Gofas, 2007).”). Note: Gofas only studied the Molluscan family Rissoidae.

Criterion 6. Sensitivity

ICES finds no direct/site-specific evidence in the proposal that the area contains a high proportion of very sensitive or sensitive habitats/biotopes or species, but it is probable that such habitats occur given the physical and known biological characteristics of the area.

Criterion 7. Naturalness

ICES finds that it is probable that, despite records of fishing activity, the area may have a high degree of naturalness at least in the deep waters. ICES notes that the description of the fishing activity is incorrect in that there were no Russian bottom trawl and purse seine fisheries on Josephine Seamount, although there has been on other seamounts in the Madeira – Canary Island area (V. Vinnichenko pers. comm.). In addition, contrary to implications in the proposal, there is no known Nephrops fishery on the proposed site.

Practical criteria

Criterion 1. Size

ICES finds that the size of the proposed site (i.e. including all depth zones and the inclusion of an appropriate buffer zone) is suitable for the aim of designating the parts of the seamount beyond areas of national jurisdiction.

Criterion 2. Potential for restoration

ICES finds no evidence in the proposal to evaluate the potential for restoration of features within the sites.

Criterion 3. Degree of acceptance

ICES finds insufficient evidence in the proposal to suggest that there is a high probability that this proposal has support from stakeholders and is politically acceptable. At least three nations are reported to fish in the area according to the proposal, which suggests that considerable consultation will be required to achieve success. As the current level of fishing in the proposed MPA is not quantified it is difficult to evaluate this further.

Criterion 4. Potential for success of management measures

ICES finds insufficient evidence in the proposal that management measures within the proposed area would necessarily be successful. The major management measures likely to be required to meet the aims of designation relate to fisheries and there is evidence that existing fisheries closures have been ignored in the recent past in the Northeast Atlantic (ICES, 2006b).

Criterion 5. Potential damage to the area by human activities

ICES finds that the proposal misquotes references (e.g. ICES, 2007a) in relation to possible fisheries on the seamount, and there is insufficient evidence to assess future potential damage on the proposed site.

The statement in the proposal (Section b.5) that extensive samples of organisms that are of potential interest to bioprospectors have been found at Josephine, contradicts the argument in Section b.4 that bioprospection will more likely occur around hydrothermal vents.

Criterion 6. Scientific value

ICES finds that there is evidence in the proposal that Josephine has a high scientific value, in particular considering the long history of studies at the site. Benthic dredge samples were taken on the bank as early as 1869, with follow-up studies on the RV Meteor from 1925–1927 as part of the German–Atlantic Expedition. These early studies provide historical perspective for more recent work which may be valuable for long-term monitoring. This latter point is
enhanced by the proximity of this area to the continents, making the possibility of routine scientific exploration more affordable than areas further distant.

**Appropriateness of boundaries**

ICES finds no evidence in the proposal to evaluate the appropriateness of the MPA boundaries. The selection of the boundaries appears to be driven by jurisdiction rather than scientific evidence. The boundaries encompass the only two features in the immediate area outside of the EEZs of Portugal and Morocco. There is no evidence to support the inclusion of the “unnamed seamount”, assuming it is a seamount, other than the physical properties of the feature.

**Key locations**

ICES has no further evidence to add to that in the proposal.

**Milne seamount cluster**

**Further relevant data**

ICES is not aware of any further relevant data on this site.

**Ecological criteria**

**Criterion 1. Threatened or declining species and habitats/biotopes**

ICES finds that there is evidence in the proposal that the proposed area contains seamount habitat, which is listed as priority threatened or declining habitat by OSPAR. ICES agrees that although there is no site-specific information available about the benthic biological communities present at this seamount, it is reasonable to assume that there may be bottom-living organisms present such as cold-water corals and sponges based on research at the nearby Corner Rise Seamounts (Waller *et al.*, 2007).

**Criterion 2. Important species and habitats/biotopes**

ICES finds insufficient evidence in the proposal that this criterion is met. ICES notes that sperm whales are ubiquitous throughout deep-water areas of the Atlantic and that in fact evidence presented in the proposal (Skov *et al.*, 2008) indicates that the area may not be particularly important for this species. In addition, based on the evidence presented in the proposal, ICES would not agree that the waters above the seamount are of particular importance to Cory’s shearwater (Magalhães *et al.*, 2008).

**Criterion 3. Ecological significance**

ICES finds insufficient information in the proposal describing the ecological communities within the proposed marine protected area.

**Criterion 4. High natural biological diversity**

ICES finds that there are no published accounts of this area so it is not possible to make site-specific comments about the biological diversity that may be present.

**Criterion 5. Representativity**

ICES finds that there is no direct evidence that the proposed site has characteristics that are representative for its biogeographic region although it may be assumed that the proposed site is representative of seamounts found to the west of the mid-Atlantic Ridge.

**Criterion 6. Sensitivity**

ICES finds no direct site-specific evidence in the proposal that the area contains a high proportion of sensitive habitats or species compared to elsewhere, although it is reasonable to hypothesize that the presence of sensitive cold-water corals and sponges may be found along the seamounts. However, ICES acknowledges that any area that has not been subjected to anthropogenic impacts is likely to be more sensitive than areas that have been impacted (FAO, 2007).
Criterion 7. **Naturalness**
ICES finds insufficient evidence that the proposed protected area is relatively undisturbed and represents a relatively pristine seamount example within the OSPAR area.

**Practical criteria**

**Criterion 1. Size**
ICES finds that the size of the proposed site (i.e. including all depth zones and the inclusion of an appropriate buffer zone) is suitable for the aim of designating the site and is sufficient to maintain the integrity of the site’s features and would enable effective management.

**Criterion 2. Potential for restoration**
ICES finds that as there is no site-specific resource information presented in the proposal, it is therefore not possible to assess any potential for restoring unknown resources that may or may not be present.

**Criterion 3. Degree of acceptance**
ICES finds insufficient evidence in the proposal to suggest that there is a high probability that this proposal has support from stakeholders.

**Criterion 4. Potential for success of management measures**
ICES finds insufficient evidence in the proposal that management measures within the proposed area would necessarily be successful. The major management measures likely to be required to meet the aims of designation relate to fisheries and there is evidence that existing fisheries closures have been ignored in the recent past in the Northeast Atlantic (ICES, 2006b). ICES finds despite there being insufficient evidence in the proposal, protection may be easier to achieve in remote areas such as Milne Seamount due to the lower number of users compared to areas closer to land.

**Criterion 5. Potential damage to the area by human activities**
ICES finds insufficient information in the proposal relevant to significant damage from human activities in the short term.

**Criterion 6. Scientific value**
ICES finds insufficient evidence in the proposal that the site contains particular features of high scientific value.

**Appropriateness of boundaries**
ICES finds that the Milne Seamount cluster proposal is scaled to the physical dimensions of the features within and considers the proposed boundaries appropriate.
ICES finds the inclusion of all related depth zones and the inclusion of an extended buffer zone appropriate for the aims of the proposed site, including ensuring the integrity of the site.

**Key locations**
ICES has no further evidence to add to that in the proposal.
**South Rockall and Hatton**

**Further relevant data and comments on existing data in the proposal**

The information on cetaceans provided in section A describes areas not within the proposed site. There is little information on cetaceans of the area. There is only a brief description of the distribution of habitats and geomorphological features of Hatton and southern Rockall Banks. The data on the distribution of *Lophelia pertusa* "reef" given in Figure 3 appears to be the distribution of *L. pertusa* occurrence, which is not necessarily indicative of the presence of reef habitat.

The following points are provided by ICES based on personal knowledge of scientists working within the ICES framework. Some points have already been published in ICES expert group reports.

Acoustic, video, and photographic surveys of Hatton Bank (including some parts outside the proposed area) by the UK Government identified numerous seafloor structures on areas of the bank less than 1000 m in depth, including ridges, rock outcrops, pinnacles, channels, and hollows. These data suggest much of the shallowest area of the bank is characterized by iceberg plough marks and sand substrate with isolated dropstones heavily encrusted with a diverse fauna (K. Howell, pers. obs.). *Lophelia pertusa*, *Madrepora oculata*, and other coral species were observed associated with ridge, outcrop, and pinnacle features (Howell *et al.*, 2007). Within the NEAFC closed area *Lophelia pertusa* reef was observed associated with rock ridges, rock outcrop, and pinnacle structures. Coral rubble, indicative of the presence of reef habitat, was observed associated with extensive ridges and terrace structures on the bank. Small growths of *Lophelia pertusa*, *Madrepora oculata*, and other coral species were observed at many sites both associated with ridge features and iceberg plough-mark zones where small growths were observed attached to isolated cobbles and small boulders. Historical records of cold-water coral occurrence on Hatton Bank suggest that coral distribution is associated with ridge features and iceberg-ploughmark areas.

Information on the benthic communities of the Franken Mound (Wienberg *et al.*, 2007) could be included in the proposal.

Information obtained in recent Multidisciplinary Surveys carried out under the Spanish ECOVUL/ARPA project, allowed the identification and mapping of the main deep-sea habitats in the Western flank of Hatton Bank. These habitats are developed on two geomorphological domains, the contouritic sedimentary seabed called "Hatton Drift" (Rebesco, 2005) and the Hatton Bank outcrops, that is, parts of the bank which begin to show in the surface of the seabed and which are not covered by the sedimentary deposit. These different habitats show differing degrees of vulnerability and sensitivity. According to these results, the main vulnerable habitats are nowadays located on the outcrops of the Hatton Bank, not on the contouritic deposits (Durán Muñoz *et al.*, 2008).

Preliminary analysis of data collected by the Spanish Institute of Oceanography (IEO) has revealed additional seafloor features including ridges, mounds, furrows, moats, waves, and slumps on the flanks of Hatton Bank (1000–1500 m) along with the Hatton Drift (Sayago-Gil *et al.*, 2006, 2007). Durán Muñoz *et al.* (2008) reported three areas of live cold-water coral, coral rubble, and other biogenic debris with high associated biodiversity on the western slope of the bank, associated with these seafloor features.

**Application of OSPAR MPA identification guidelines**

**Ecological criteria**

*Criterion 1. Threatened or declining species and habitats/biotopes*

ICES finds evidence in the proposal that the area is important for two of the habitats on the OSPAR list. *Lophelia pertusa* reef structures associated with carbonate mounds, and those structures not associated with carbonate mounds, are both present on Hatton Bank. There is no doubt there are *Lophelia* reefs on Hatton Bank and southern Rockall Bank that are contained within the proposed boundary. Harbour porpoises occur in low densities on shallow parts of the Rockall Bank, but there is no evidence of occurrence in the proposed area.

*Criterion 2. Important species and habitats/biotopes*

ICES finds that there is evidence for a range of important species and habitats at Rockall and Hatton Banks. There is no review of data relating to the southern Rockall Bank.
Criterion 3. Ecological significance

ICES finds no direct site-specific evidence in the proposal of the ecological importance of the Rockall and Hatton Banks, but ICES is aware of other evidence that there are discrete fish stocks in this area and thus it has important nursery, juvenile, and spawning areas. ICES notes that many of the comments in relation to the importance of coral to other fish species stem from studies of this habitat off Norway and off the Faroes and may not be applicable to this more southerly area.

Criterion 4. High natural biological diversity

ICES finds insufficient comparative evidence in the proposal to assess the importance of the proposed area. However, the high topographic and sedimentary variability within the proposed area would indicate a high diversity of habitats and biological niches. The section does not provide information on the biological diversity of southern Rockall and we refer the authors to Wienberg et al. (2007).

Criterion 5. Representativity

ICES finds no direct site-specific evidence in the proposal, but it is probable that the Rockall and Hatton Banks support habitats and species that are representative of the wider OSPAR region.

Studies (K. Howell, pers. obs.) of communities of this part of the Northeast Atlantic suggest that the part of the Hatton Bank enclosed by the proposed boundary supports communities representative of the biological communities of the area. These analyses will be submitted for publication towards the end of 2008.

Criterion 6. Sensitivity

ICES finds limited evidence that the area contains a high proportion of sensitive habitats or species. L. pertusa as well as other coral species are known to be very sensitive to physical disturbance as a result of their slow growth rates. We know very little about the sensitivity of other habitats and benthic communities observed on Hatton and Rockall Banks.

Criterion 7. Naturalness

ICES finds evidence in the proposal that the area does not have a high degree of naturalness, and that past and present fisheries have had impacts within the areas and depth zones fished. Southern Rockall Bank (the area contained with the proposed MPA) appears to experience a reasonable level of fishing pressure and thus is likely to be in a less natural state. Fishing activity on the southern Rockall Bank (the area enclosed by the proposed MPA) is focused on the western flanks of the Bank and to a certain degree on the summit. Visual surveys of the seabed suggest parts of Hatton are substantially less impacted by bottom trawling than the northern Rockall Bank (Howell, pers. obs.), these observations being supported by VMS data. Data provided by the Spanish Institute of Oceanography suggest much of the bottom trawl fishing on Hatton is restricted to the soft sediments of the Hatton drift.

Practical criteria

Criterion 1. Size

ICES finds no direct site-specific evidence in the proposal, but it is probable that the size of the area suggested would be suitable for the aim of site designation. See comments below on the appropriateness of the boundary.

Criterion 2. Potential for restoration

ICES finds evidence in the proposal that recovery would not occur in the medium term in habitats already damaged by human activities, but it is probable that in the long term the site will eventually return to a more natural state under appropriate management. In terms of L. pertusa reef, recovery rates are low, and little is known about recovery of other epibenthic communities / species on the Hatton and Rockall Banks.

Criterion 3. Degree of acceptance

ICES disagrees with the optimistic assessment of degree of acceptance in the proposal. There is evidence that there will not be a high degree of acceptance of the site should bottom-trawl fishery closures be proposed. A number of nations seem unlikely to accept a bottom trawl ban around Hatton given the significant research that has occurred to ensure fishing is being undertaken in a manner unlikely to damage sensitive habitats on this bank. Nations fishing on Rockall are also unlikely to support a bottom-trawl ban outside coral areas.
Criterion 4. Potential for success of management measures

ICES finds insufficient evidence in the proposal that management measures will meet the aims of designation. ICES notes that acceptance of management measures has been difficult in some fisheries in the area in the past and has no reason to believe that this will be any different in the future. No management measures have been suggested but it is assumed a bottom fisheries ban may be considered. It is unclear whether the current fisheries closures have been successful so it is difficult to assess the potential for success of further management measures. The proposal itself states that regional management measures are prone to failure.

Criterion 5. Potential damage to the area by human activities

ICES finds evidence in the proposal that significant damage from fishing activity may happen in the short term. The proposal suggests the area most impacted by fishing is the shallow area above 1000 m. This is not the case on Hatton Bank where the VMS data and reports suggest fishing effort is focused on the area between 1000–1500 m and not in the same area as the known locations of sensitive coral reef habitat (ICES, 2007c, 2008c). This section however does highlight the damage that has occurred to coral reef habitat as a result of bottom trawling on some of the northern sections of Rockall Bank and thus supports the idea that, should fishing activity on Hatton Bank intensify or change area focus, it could lead to significant damage to reef habitat.

Criterion 6. Scientific value

ICES finds evidence in the proposal for the scientific value of Rockall and Hatton Banks. The proposal suggests there is more to be done in terms of assessing the biodiversity of this region. At least two other research programs / cruises have recently been conducted on Hatton Bank while the Franken Mound area (southern Rockall) was investigated a few years earlier.

Appropriateness of boundaries

ICES finds that there is inadequate justification in the proposal for choosing the proposed boundaries and the area of this site. The proposed boundary encompasses the entirety of three existing areas and parts of two further areas closed to some fisheries to protect corals and parts of an area closed to some bottom gear (the Haddock Box). This is inconsistent with the statement in the proposal that the boundaries were “drawn based on the presence of Lophelia pertusa reef / carbonate mound occurrence, distribution of marine mammals, and location of existing protected areas.” The distribution of marine mammals is not known in this area. In addition, the proposal appears to extend into the EEZ (or equivalent) waters of two EU Member States.

ICES has provided recommendations to NEAFC to protect coral habitat; NEAFC have subsequently closed these areas to bottom fishing. ICES suggests that the entirety of these areas at least be protected also by OSPAR designation. ICES can conceive many possible boundaries in addition to these areas in light of the greater knowledge that we have of this area compared with other sites reviewed in this advice. In the absence of explicit management objectives for the proposed area, ICES finds it inappropriate to propose any possible boundary.

While it is recognised the objectives of the OSPAR MPAs are different to those of the existing protected areas it may not be desirable to have inconsistent boundaries between protected areas (however, this is recognised as a political, not an ecological decision). The proposed boundary does enclose a wide depth range and thus would be expected to enclose a wider range of benthic communities than any of the existing management areas.

Key locations

The location of coral species on Hatton and Rockall Banks is provided in ICES (2006c; 2007c; 2008c). Habitat maps of parts of the region are currently being produced as part of an ongoing research programme and are due for completion by June 2009. These will form the basis of an ongoing research project (due for completion at the end of 2010) investigating possible MPA network scenarios in the deep waters of the UK part of the Northeast Atlantic, being undertaken by a UK partnership between the Joint Nature Conservation Committee, University of Plymouth, Scottish Association of Marine Science, British Geological Survey, and the National Oceanography Centre Southampton.
References


ICES. 2008b. ICES Advice 2007. Book 9 Section 9.3.2.3. NEAFC request to continue to provide all available new information on distribution of vulnerable habitats in the NEAFC Convention Area and fisheries activities in the vicinity of such habitats. ICES, Copenhagen, Denmark. 9 pp.


1.5.6 Member States

1.5.6.1 The management of Natura 2000 sites in the German EEZ: summary and advice derived from the results of the EMPAS project

Summary of the process

ICES was contracted by the German government to gather information on the distribution and impacts of fisheries in Natura 2000 sites in German offshore waters. This innovative and ground-breaking process was designed to include stakeholders and their information. The project was successful, so much so that ICES is able to provide advice on options for fisheries management that will help achieve the objectives of the German Natura 2000 sites. The process will also provide many useful lessons for EU Member States as well as other interested parties to consider when formulating management proposals for Natura 2000 sites (or similar MPAs) elsewhere. The main features to be protected in these Natura 2000 sites were specific benthic habitats (shallow sandbanks and reefs), seabirds, and harbour porpoises. Regarding benthic features, the main management considerations were related to impacts of mobile, bottom-contacting fishing gears (primarily trawls), while bycatch (primarily in gillnets) was the main issue for both seabirds and harbour porpoises.

ICES was not asked specific questions by the German government in setting up this project; instead ICES (with some input from the German government) composed a set of questions considered to be relevant to the objectives of the project. These are answered in the extended advice provided below. In relation to specific management questions, ICES has usually chosen to provide options.

The process that ICES undertook included participation of some fishing industry groups with an economic interest in the sites; their input was valuable but ICES did not carry out any form of socio-economic analysis. ICES does not advise on social and economic aspects of management of fisheries (or any other human activity in the seas). However, ICES draws attention to the impacts that many of the management options provided in this document are likely to have on employment levels and the distribution of opportunities to fish among communities and fleets. These potential impacts are relevant to any choices among options, and need to be reviewed in an inclusive and transparent process, using the best information available. While the process also included participation by members of conservation advocacy groups, the advice is provided relative to the Objectives set for Natura 2000 sites as per the EU Birds and Habitats Directives, and not the objectives of either the conservation groups or the fishing industry.

The ICES advice provided below is organized around these questions relating to each type of fisheries effect. Some of the advice is very specific for individual Natura 2000 sites while other advice is more general. A concluding section summarizes some of the more general lessons learnt from the project.

Summary of the results

ICES assumed that sites would be in favourable condition if the objectives for each feature for which a site was designated were met.

ICES advises that species typical of reef habitats are generally more vulnerable to the impact of bottom-contacting fishing gears than those of sandbanks. Heavy bottom trawls can destroy the physical structure of reefs. ICES advises that it is a societal choice as to what percent of all reef (or sandbank) habitat need to be protected from bottom-contacting fishing gears before favourable condition is achieved for each site. The first two passes of a mobile, bottom-contacting fishing gear have the most severe effect on benthic habitats. It is likely that reef areas with the highest potential to recover to favourable conservation status are those areas with lowest historical and current bottom trawling activity. It is also likely that areas that are trawled more than 4–5 times a year do not support self-sustaining populations of some of the characteristic benthic species most vulnerable to mobile, bottom-contacting fishing gears, particularly for reef communities.

In contrast to reefs, the physical integrity of ‘sandbanks’ is unlikely to be seriously affected by mobile, bottom-contacting fishing gears, but the use of such gears may have ecological effects. ICES advises that the characteristic benthic communities of such sandbank habitats are dominated by species adapted to frequent disturbance and high energy environments. An unfished sandbank community might nonetheless include many individuals of long-lived, low-fecundity species. Fishing would be expected to reduce the abundance of such species and to change the community towards one more dominated by species that are less vulnerable to the mortality imposed by mobile, bottom-contacting fishing gears. ICES recommends that further research be carried out to describe the communities on an ‘unimpacted’ sandbank and the effects of mobile, bottom-contacting fishing gears on sandbanks. Such research is likely to involve experimental fisheries closures.
A summary of existing and potential conflicts between effort in fisheries and the achievement of favourable condition for reefs and sandbanks indicated that most sites have some areas that are fished strongly and other areas that are much less fished. Precise management options are generally a choice of partial or complete site closure to fisheries, particularly to those gears that contact the seabed. In some cases an experimental closure would help understand the degree to which a site is altered by fishing, and how rapidly it might return to that state.

For both seabirds and harbour porpoises, the greatest impact comes from fixed, bottom-set nets. The spatial distribution of fishing effort using such gears is very heterogeneous, as is the known distribution of seabirds and harbour porpoise in the sites (although harbour porpoise distribution is not so well known). Management options consist of changing gear or closing fisheries known to cause impacts. In most cases such closures could be limited in both time and spatially. Site-specific management options are provided.

Background

The EMPAS project

The EMPAS1 (Environmentally Sound Fisheries Management in Marine Protected Areas) project was undertaken by ICES starting in 2006. The clients were the Federal Agency for Nature Conservation, Isle of Vilm Branch (BfN) and the Federal Ministry of Environment, Nature Protection and Nuclear Safety (BMU). The EMPAS project has hosted three ICES workshops (WKFMMPA, Workshop on Fisheries Management in Marine Protected Areas): April 2006 for planning, April 2007 for mid-project review, and June 2008 for consolidation of results. A full-time staff member at ICES organised the workshops and worked intersessionally to collect and analyse information. The present advice is based primarily on the 2008 WKFMMPA Report 2 which incorporates the results of the two earlier workshops. Participation at the workshops included experts from fisheries and from nature conservation agencies of many ICES countries, members of fisheries industry organisations, and members of international conservation groups. In addition, many diverse information sources were used.

EMPAS was a research project and its initial focus was to collect new information and bring together existing information in a consistent and integrated way, not to provide advice. This was intentional, because at the commencement of the EMPAS project, there was not sufficient information to serve as a basis for science advice that would meet ICES standards, neither with regard to options for fisheries management in marine protected areas in general, nor for the German Natura 2000 sites in particular. At the start of EMPAS it was unknown whether the project would be able to collect enough information to answer requests for advice.

EMPAS analysed and evaluated:

- potential conflict – to what extent do specific fishing activities represent a significant threat to achieving the conservation objectives of the Natura 2000 sites?
- mitigation measures – which management measures would reduce these conflicts and how effective would they be at ensuring favourable condition in these sites?

Three main issues with regard to potential conflict in the German Natura 2000 sites were identified:

1) Impacts of bottom contacting fishing gears on Habitats Directive features (reef and sandbank benthic habitats, and their typical benthic species) in sites in the North Sea [Note: The habitat listed under the Habitats Directive is actually ‘sandbanks slightly covered by seawater at all times’, which does not include all sandbanks. Although the following advice usually merely refers to ‘sandbanks’ instead of the longer phrase, in all cases the advice is specific to ‘sandbanks slightly covered by seawater at all times’ and their characteristic benthic communities];

2) Bycatch of seabirds in static gears, especially bottom set gillnets, in sites in the Baltic Sea;

3) Bycatch of the harbour porpoise in static gears, mainly bottom set gillnets, in the sites in the North and Baltic seas.

1 http://www.ices.dk/projects/empas.asp
2 http://www.ices.dk/iceswork/wgdetail.asp?wg=WKFMMPA
ICES advisory process

As standard practice, ICES provides advice in response to specific requests from a client. The wording of the request for advice may be discussed between ICES and the client to ensure that the request poses questions that are scientifically tractable, and that are likely to elicit responses from the advisory process that actually address the needs of the client. In this case there was no formal request for advice from the client, but rather the contract for the science work to be done by ICES. EMPAS was sufficiently successful, however, that the 2008 Report of WKFMMPA contains many conclusions and supporting results that could be interpreted as ICES advice. ICES stresses that it is always the case that Reports of Expert Groups do not constitute advice, but are exclusively the product of a meeting of experts. ICES advice requires a peer review process for Expert Group Reports, drafting by an Advice Drafting Group, and release by ACOM. Those processes have been completed in the production of this advice, and this document, not the Workshop Report, constitutes ICES advice on options for fisheries management in the German Natura 2000 sites.

The context for this advice is intended to be both specific and general. The advice first addresses scientific questions and information specific to the areas designated by the German government as Natura 2000 Sites under the Birds and Habitats Directives of the EU (79/409/EEC and 92/43/EC, respectively). Note that sites under the Birds Directive are Special Protection Areas (SPA) while those under the Habitats Directive (at the current stage of designation in German waters) are Sites of Community Interest (SCI). The three themes at the end of the previous section are addressed individually. The ten Natura 2000 sites designated to protect habitats and species are shown in Figure 1.5.5.19.1.

The EMPAS project was focused on the Natura 2000 sites in the German EEZ, but a number of lessons were learned that will be valuable when considering fisheries management options for Natura 2000 sites and MPAs elsewhere as well. Consequently, following the specific advice for the German Natura 2000 sites, several topics are discussed in a broader context of at least EU waters and marine Natura 2000 sites in general. Topics where additional information for the German Natura 2000 sites, or fisheries that have operated within them would improve the basis for scientific advice are also identified, and topics where incomplete knowledge affects the quality of advice are discussed as sources of uncertainty.

Because the specific advice is provided with regard to specific Natura 2000 sites, the advice addresses options for measures to achieve favourable condition(s) for the ecosystem property(ies) for which the respective Natura 2000 site was designated. That is the full scope and basis for advice. This advice does not consider if any or all of the Natura 2000 sites are either necessary or sufficient to achieve Favourable Conservation Status for the relevant species or habitat within the entire German EEZ, or within the full North or Baltic seas.

Figure 1.5.5.19.1 The ten nominated Natura 2000 sites in the German EEZ. North Sea: 1. SCI Dogger Bank; 2. SCI Sylt Outer Reef; 3. SCI Borkum Reef Ground; 4. SPA Eastern German Bight. Baltic Sea: 1. SCI Fehmarn Belt; 2. SCI Kadet Trench; 3. SCI Western Rönne Bank; 4. SCI Adler Ground; 5. SCI Pomeranian Bay with Odra Bank; 6. SPA Pomeranian Bay. Both SPAs are implemented as national nature reserves (IUCN category IV) and they have been designated to the OSPAR/HELCOM MPA network. SCI = ‘Site of Community Interest’. The SCIs are to become SACs when designated by Germany. The Special Protection Areas (SPAs) of the Birds Directive together with the Special Areas of Conservation (SACs) of the Habitats Directive constitute the elements of Natura 2000.
The EMPAS project was nearly complete before the European Parliament and the European Council adopted the Marine Strategy Framework Directive (2008/56/EC). The implications of this new policy for details regarding the implementation of the Birds and Habitats Directives in marine ecosystems were not considered by the WFFMMPA and ICES in developing the science advice, but are likely to be relevant for the government agencies charged with implementing these Directives.

Advisory answers to questions relating to fishing activities and sandbanks and reefs in the North Sea

Q1  From a scientific perspective, characterize what would constitute favourable condition for sandbanks and reefs in the sites in the North Sea, and the benthic species typical of those habitats. To what extent would such favourable condition contribute to a favourable conservation status for those features in the German EEZ of the North Sea?

It is the statutory objective of sites designated under the Habitats Directive for their condition to be ‘favourable’. It was assumed that a site would be in favourable condition if the specific conservation objectives of each site were being met. The conservation objectives for reefs and sandbanks were provided in a generic form by BfN (Table 1.5.5.19.1).

ICES was not provided with detailed information on the ecological functions (or quality), habitat structure, or surface area within each site, but would assume that each site would certainly be in favourable condition if these generally described functions, structures, or amount of a particular type of area were within the range of natural variation of these features, taking account of the precision of measurement of these features in the surveillance and monitoring programmes. Equally ICES was not provided with information on the morphological and hydrological features of each site.

Without full information on the extent or usage by fisheries of all ‘reefs’ and ‘sandbanks’ within German waters (including areas within the 12 NM territorial limit) it is not possible to assess the full extent to which these sites contribute to favourable conservation status of these habitats in German territories. The high proportion of German waters within these sites would indicate that the contribution is potentially substantial.

Table 1.5.5.19.1  Preliminary nature conservation objectives for Natura 2000 sites for reefs and sandbanks in the German EEZ (provided by BfN).

<table>
<thead>
<tr>
<th>Feature/species</th>
<th>Principle conservation objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reefs</td>
<td>… are the conservation and/or recovery of</td>
</tr>
<tr>
<td></td>
<td>- the specific ecological functions, the characteristic habitat structure and its extent (area),</td>
</tr>
<tr>
<td></td>
<td>- the characteristic morpho-dynamic and general local currents together with its characteristic</td>
</tr>
<tr>
<td></td>
<td>and endangered communities and species,</td>
</tr>
<tr>
<td></td>
<td>- conservation of the characteristic benthic communities and species within their natural</td>
</tr>
<tr>
<td></td>
<td>occurrence and abundance, e.g. anemones, tunicates, bryozoans, and fishes.</td>
</tr>
<tr>
<td>Sandbanks slightly covered by seawater at all times</td>
<td>… are the conservation and/or recovery of</td>
</tr>
<tr>
<td></td>
<td>- the current ecological quality, habitat structure, and surface area of the habitat type,</td>
</tr>
<tr>
<td></td>
<td>- the characteristic morphological and hydrological dynamics and the typical species and</td>
</tr>
<tr>
<td></td>
<td>communities in their largely natural population dynamics,</td>
</tr>
<tr>
<td></td>
<td>- the characteristic benthic communities of this habitat and its characteristic species.</td>
</tr>
</tbody>
</table>

Q2  To the extent that information allows, and specifically with regard to the Natura 2000 sites in the North Sea:

Q2.1  To what extent are typical benthic species and communities on reefs and sandbanks vulnerable to the fisheries that operated in these habitats during the period of the EMPAS project?

Typical species of reef habitats are generally more vulnerable to the impact of bottom-contacting fishing gears than those of sandbanks. Heavy bottom trawls can destroy the physical structure of reefs.

ICES understands the boundaries of each Natura 2000 site to enclose mixtures of reef (or sandbank) habitat and non-reef (or sandbank) habitat, and that detailed habitat mapping within each North Sea Natura 2000 site has largely been completed. Maps are available in WKFMMMPA workshop reports and some, but not all are included in this advice (Figures 1.5.5.19.2–1.5.5.19.4). Sustainable fishing with bottom-contacting fishing gears in the subareas of habitats that are not listed under the Habitats Directive is not considered to pose a threat to achieving favourable condition for the listed habitat and community types intended to be protected within each site. Where these subareas of habitat not listed
under the Habitats Directive are large enough to allow fishing activities such as individual tows of a bottom trawl to occur (including allowing the activity to continue into similar areas of habitat outside the Natura 2000 sites), ICES advises that:

- these subareas of habitat not listed under the Habitats Directive pose an opportunity for fishing to continue within the Natura 2000 sites, as long as spatial regulation of the fishery is precise, and
- restrictions on fishing with bottom-contacting gears in these subareas of habitat not listed under the Habitats Directive would not contribute in any substantive way to achieving favourable condition in the Natura 2000 sites as a whole, given the Conservation Objectives for the sites.

ICES stresses that it is a policy decision (and consequently a societal choice), what percent of all reef (or sandbank) habitat and communities need to be protected from bottom-contacting fishing gears before favourable condition is achieved for the entire site. However, on strictly biological grounds ICES has advised in the past that:

- For benthic communities to be in favourable condition all characteristic species need to be established in the community. However, with current knowledge there is no reason to expect that maintaining ecological functions requires all species to be at relative or absolute abundances typical of pre-human impact conditions;
- Benthic communities in subareas of an entire site could achieve favourable condition, even if benthic communities in other subareas were fished with bottom-contacting fishing gears and supported communities where species vulnerable to bottom-contacting fishing gears were not as abundant as they would be if no fishing with bottom-contacting fishing gears occurred, and species highly tolerant of disturbance were more common than they would be expected to be with no fishing with bottom-contacting fishing gears.
- Consequently, from a biological perspective the choice does not have to be ‘all or nothing’. As long as subareas are large enough to support mature benthic communities, their status relative to ‘favourable condition’ could be assessed and managed individually. Policy has to decide what percent of them have to remain undamaged habitat (reefs) and their characteristic benthic communities (reefs and sandbanks) (See Table 1.5.5.19.1).

The first and the second passes of a mobile, bottom-contacting fishing gear exert the most severe effect on benthic structures, communities, and species. It is likely that the reef areas with the highest potential to recover soonest to favourable conservation status are those areas with lowest historical and current bottom trawling activity. It is also likely that areas that are trawled more than 4–5 times a year do not support self-sustaining populations of some of the characteristic benthic species most vulnerable to mobile, bottom-contacting fishing gears, particularly for reef communities.

For protected reefs in areas frequently exposed to mobile, bottom-contacting fishing gears, complete closure may be necessary to restore habitats and species to favourable conservation status. ICES notes that such closures may have high economic costs for the existing fisheries. ICES did not have the information to formally assess these costs.

Even in areas heavily impacted by past use of mobile, bottom-contacting fishing gears, ICES did not identify any barriers to recovery of characteristic benthic communities, if areas were protected from further disturbance. Recovery of the characteristic benthic reef and sandbank communities would likely be on a timescale of several years (for all but the very slowest maturing benthic species). Recovery, if ever possible, of structural features of reef habitats already seriously altered by past use of mobile, bottom-contacting fishing gears would be on much longer timescales.

To the extent that policy gives discretion to allow some subareas of reef or sandbank habitat within the Natura 2000 sites where benthic communities are exposed to fishing impacts (either because an adequate number of sites and subareas are protected fully so that the policy goals associated with favourable condition are achieved, or because the impacts are not severe enough to impede progress towards favourable condition) then a mosaic of different levels of fishing with bottom-contacting fishing gears, including some total closures, would be possible. Closures of ecologically important and regularly less fished subareas within the Natura 2000 sites in the North Sea would be the most efficient fisheries management measures to improve the conservation status of ‘reefs’. ICES notes that closures of these subareas may have a low cost to the fishing industry and have a lower risk of displacing fishing effort to ecological sensitive areas outside the closures. While ICES did not have the information to formally assess these costs and risks, ICES does note that the extensive databases on distribution of fishing effort compiled as part of EMPAS as well as the information on habitat mapping for the Natura 2000 sites and the adjacent areas can inform case-specific discussions of the opportunities for effort relocation. Such discussions could take account of risks of new or increased harm to other habitats or benthic communities, and increased costs and/or reduced returns to participants in fishing.

In contrast to reefs, the physical integrity of ‘sandbanks’ is unlikely to be seriously affected by mobile, bottom-contacting fishing gears, but the use of such gears may have ecological effects.
If such ecological effects are affecting the favourable condition of sandbank benthic communities it is likely that most fisheries management measures to improve the condition will be costly to the industry as most such sandbanks are important fishing grounds. ICES did not have the information to formally assess these costs. Additionally, there is little scientific evidence describing the impact of any fishing gear on this habitat. However, ICES advice in 2000 agreed that the characteristic benthic communities of such sandbank habitats are dominated by species adapted to frequent disturbance and high energy environments.

Fishing with mobile, bottom-contacting gears, particularly large and heavy-rigged beam trawling will increase total mortality on the benthic community. There have been few studies that have described an unimpacted sandbank benthic community in the German North Sea. Elsewhere in the North Sea, studies in unfished areas, such as those near gas platforms show that fishing causes a loss of large, long-lived species from the benthic community. It is expected that such changes would also occur in German waters. A mature community might have many long-lived, low fecundity species, and fishing would change this towards a community with species that are less vulnerable to the mortality imposed by mobile, bottom-contacting fishing gears.

ICES recommends that further research be carried out to describe the communities on an ‘unimpacted’ sandbank and the effects of mobile, bottom-contacting fishing gears on sandbanks in order to better inform future management. Such research is likely to involve experimental fisheries closures on spatial scales large enough to monitor community responses.

Q2.2 For the vulnerable species or communities identified in Q2.1, describe the nature and extent of existing and potential conflicts, in any, between specific fisheries and achievement or maintenance of favourable condition of typical habitats, species, or communities of sandbanks and reefs.

SCI Sylt Outer Reef (Figure 1.5.5.19.2)

The main fishery on sandbanks (e.g. Amrum Bank) in the eastern part of SCI Sylt Outer Reef is for brown shrimp, targeted with beam trawls. The variation in intensity of beam trawling on reef habitats indicates that some subareas of reef habitat are intensively trawled, but many are not.

Figure 1.5.5.19.2 Trawling frequency (number of times each square metre was trawled in 2006) of all bottom trawls and designated habitat types in the SCI Sylt Outer Reef.

SCI Borkum Reef Ground (Figure 1.5.5.19.3)

There is some otter trawling in the southern part of the SCI Borkum Reef Ground, but the central reef complexes formed of boulders are avoided by beam and otter trawlers (Figure 1.5.5.19.3).
SCI Dogger Bank (Figure 1.5.5.19.4)

The SCI Dogger Bank has long been an important trawling ground, and most sandbank habitats are likely to have been impacted by mobile, bottom-contacting fishing gears. The ‘Conservation Assessment’ of the site submitted to the European Commission by Germany in 2008 indicates the habitat to be in ‘Unfavourable’ condition.
Q2.3 To what extent do the conflicts in Q2.2, if any, currently impede achievement or maintenance of favourable condition for reef or sandbank habitats and their typical species and communities?

SCI Sylt Outer Reef

The current intensity of fishing with mobile, bottom-contacting gears on some reef habitats within this site makes it unlikely that favourable site conditions could be achieved for those sites. However, some reef habitats in the central and western part of the SCI Sylt Outer Reef are not frequently trawled, and may be in or near favourable condition. The impact of the shrimp fishery on the Amrum Bank is unclear.

SCI Borkum Reef Ground

It is not known whether the current intensity of fishing in the southern part of the SCI Borkum Reef Ground is affecting the conditions of the site. However, for the rest of the SCI Borkum Reef Ground, either favourable condition is being achieved at present, or if not, some factor other than fishing is responsible.

SCI Dogger Bank

It is not known if the current intensity of fishing on the SCI Dogger Bank is affecting the condition of the presumably already substantially altered site. Modelling analysis indicates that the (greater) Dogger Bank (i.e. including those parts of the Dogger Bank in the waters of other EU Member States) is relatively resilient to mobile, bottom-contacting fishing gears in comparison to deeper areas. Consequently, if favourable condition is not being achieved, the potential to achieve them if fishing impacts are managed effectively (and if there are no other threats that are not being managed) is considered to be high.

Q2.4 To the extent that Q2.2 identified current or likely potential conflicts, what mitigation measures are available to address those conflicts, including spatial and temporal management of fisheries, and how would they function to mitigate conflicts?

SCI Sylt Outer Reef

A potential management option to help achieve favourable condition in this site would be to exclude all types of mobile, bottom-contacting fishing gears in the less trawled reef subareas. This would include closure of reef areas in the southwest and in the north of the site. These subareas are of especially high ecological importance and the current fishing intensity with mobile bottom contacting gears is relatively low. In relation to the shrimp trawl fishery, ICES recommends that experimental closures of sufficient size and duration to assess the impact of brown shrimp fisheries on long-lived, late-maturing and otherwise low productivity benthic species be considered.

A more extreme management option would be to also exclude mobile, bottom-contacting fishing gears from some or all of the additional reef subareas that are presently heavily trawled. Given the past history and intensity of fishing with mobile, bottom-contacting fishing gears in these subareas, it is likely that the structural features of the reefs have been substantially altered already, and recovery of those structural features would be an extremely slow process, if possible at all. Until the structural features of those reef habitats were recovered, there would be biological constraints on the recovery of the benthic communities of those habitats and their associated ecological functions as well. Consequently the additional contribution that these closures would make to favourable condition would be realised very slowly. This option would be associated with significant displacement of fishing effort. The ecological consequences of the relocated effort should be taken into account if this option is chosen. There would also be social and economic costs associated with this option which could, depending on the opportunities available for relocating the fishing effort, become large.

SCI Borkum Reef Ground

A potential management option would be to exclude all types of mobile, bottom-contacting fishing gears in the subareas of the site which are comprised of reefs. This option would allow favourable condition to be achieved in those biotope complexes in biologically reasonable timeframes. Based on the information available to ICES (2006 only), this is not likely to result in major displacements of current fishing effort and the ecological, social and economic consequences associated with such displacements.

A further management option would be to exclude mobile, bottom-contacting fishing gears from all sandbank and reef habitat in the site. Compared to the previous option, such larger exclusion zones for mobile, bottom-contacting fishing gears would help achieve favourable condition of reef and sandbank habitats and communities, but would result in much greater displacement of fishing effort, with associated costs and consequences.
SCI Dogger Bank

There are no direct studies that can indicate whether the historical or current levels of fishing are affecting the condition of the site. Consistent with the information from the modelling studies discussed briefly in Q2.2, experimental closures of some subareas, with careful monitoring of both the closed experimental areas and appropriate control areas, would provide at least some of the information needed to make knowledge-based decisions about managing fisheries in this Natura 2000 site to achieve favourable condition for sandbank habitats and communities.

Q2.5  What options, using measures described in Q2.4, would contribute to mitigating the conflicts in Q2.2 and how large could such contributions be, individually or in combination.

ICES advises that there are very limited opportunities for prosecuting the fisheries that currently use bottom-contacting gear with another gears that do not contact the seabed. Catch rates of the target species would be too low (sometimes close to zero) for viable fisheries.

Static pots and traps on the seabed would catch some but not all of the species targeted by the current fisheries. However, the extremely limited information about the performance of those gears in other fisheries for the same or similar species suggests efficiency is lower, and possibly much lower. Consequently, although there is very high uncertainty about the economics of this gear substitution, there could be a high risk that such fisheries would not be economically viable.

The impacts of concern are of mobile, bottom-contacting fishing gears with seabed habitats and benthic communities where many species have low mobility. Temporal management of mobile, bottom-contacting gears provides little or no opportunity mitigate these impacts.

The spatial management options presented in 3.2.4 appear to offer the most realistic possibilities for achieving favourable condition for the benthic habitats and communities in these Natura 2000 sites, while allowing some fishing, including some fishing with mobile, bottom-contacting gears, in parts of the sites.

Advisory answers to questions relating to fishing activities and seabirds

Q3  From a scientific perspective, characterise what would constitute favourable condition for seabirds in the sites in the Baltic Sea. To what extent would such favourable condition contribute to favourable conservation status for those seabirds in the German EEZ of the Baltic Sea?

Two Special Protection Areas (SPAs) have been designated in 2004 in areas of highest concentration of seabirds, one in the North Sea, the other in the Baltic Sea.
Table 1.5.5.19.2 Nature Conservation Objectives according to § 3 of the German ordinances for the designation of (a) Eastern German Bight and (b) Pomeranian Bay as Special Protection Areas.

<table>
<thead>
<tr>
<th>BIRD SPECIES</th>
<th>OVERALL OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>(a) SPA Eastern German Bight</em></td>
<td>*... are the conservation and/or recovery of:</td>
</tr>
<tr>
<td>red-throated diver, black-throated diver, northern fulmar, northern gannet, common scoter, little gull, black-headed gull, common gull, herring gull, lesser black-backed gull, great black-backed gull, black-legged kittiwake, Sandwich tern, common tern, arctic tern, common guillemot, razorbill.*</td>
<td>- the qualitative and quantitative composition of bird species and populations, especially of those declining within their biogeographic region;</td>
</tr>
<tr>
<td><em>(b) SPA Pomeranian Bay</em></td>
<td>- the characteristic features of the area, in particular salinity and geo-and hydro-morphological factors contiguous habitats within the site with their specific ecological functions and interactions;</td>
</tr>
<tr>
<td>red-throated diver, black-throated diver, Slavonian grebe, red-necked grebe, great crested grebe, common eider, long-tailed duck, common scoter, velvet scoter, great cormorant, black-headed gull, little gull, common gull, herring gull, lesser black-backed gull, great black-backed gull, common guillemot, razorbill, black guillemot.</td>
<td>- the natural quality of the habitats, in particular their protection from pollution and disturbance.</td>
</tr>
</tbody>
</table>

ICES has no basis to advise on the extent to which favourable condition in the two SPAs would contribute to the conservation status for those seabirds in the German EEZ of the North or Baltic Seas. These sites were chosen because they support comparatively high seasonal concentrations of seabirds. Consequently safeguarding these sites for seabirds should contribute to the conservation of seabirds in the southern North and Baltic seas.

Q4 To the extent that information allows and specifically with regard to the Natura 2000 sites in the North and Baltic Seas:

Q4.1 To what extent, if any, do activities of fisheries contribute to deterioration of SPAs (Eastern German Bight, Pomeranian Bay)?

ICES advises that at current (2006) fishing effort there is likely to be a low bycatch risk for seabirds in the German EEZ of the North Sea in set nets. There is very limited fishing effort with static gear in the SPA Eastern German Bight. However, gillnet fishery effort might increase in the future, for any of several reasons. Rising fuel costs might lead to a shift from mobile gears to set nets. Recovery of the North Sea cod stock, which traditionally was the main target species in gillnet fisheries, might result in renewed effort in that fishery. Measures to reduce the impact of mobile, bottom-contacting fishing gears on benthic habitats and communities might result in shifts in effort from those gears to gillnets and other static gears with higher seabird bycatch. If any of those circumstances were to occur, management of seabird bycatch in set-net fisheries in the North Sea would have to be reconsidered.

In the Baltic German EEZ, a major conflict between conservation targets and fishing activities is the bycatch of seabirds in set nets (mainly bottom-set gillnets). Highest bycatch rates occur in areas where fishing grounds and feeding areas of seabirds spatially and temporally overlap. Conflicts are most likely within the SPA Pomeranian Bay because it has the greatest concentration of protected seabirds.

Almost all seabirds are concentrated in shallow waters and the typical diving depth of sea ducks is around 5-20 metres when foraging for bivalves and other benthic invertebrates. There is a relatively low probability of seabird bycatch in set nets in water depths exceeding 25 m.

Q4.2 What are the best estimates of the current fishery bycatch mortality of the local seabird populations in the SPAs due to fisheries?

Limited data exist on mortality rates of seabirds in the SPA Pomeranian Bay. The calculation of the impact of bycatch to wintering, resting, and moulting seabirds in the SPA is limited due to incomplete and/or missing data on fisheries effort (amount of static gear, deployment parameters in space and time, etc.) and observed bycatch rates. Therefore, scientifically sound estimates of bycatch rates at the scale of the fisheries or the SPA are not possible at this time. The best quantitative evidence on the magnitude of the potential conflict of seabird bycatch in set nets is available from the southern coast of the Pomeranian Bay along the coast of the island of Usedom. Data collected and published show that some individuals of almost all diving seabird species have been caught in nets. Long-tailed ducks, common scoters, red-throated divers, and red-necked grebes are among the species caught most often.
Q4.3 Are the mortality rates in Q4.2 sustainable, and do they allow the populations to increase for species where recovery is specified as a management objective?

The species of most concern are those with low reproductive rates, those with more than 1% of their biogeographical population in an SPA, and those with small or declining populations. In the SPA Pomeranian Bay, these species are black-throated diver, red-throated diver, Slavonian grebe, red-necked grebe, long-tailed duck, velvet scoter, common scoter, black guillemot, razorbill, and common guillemot.

Because the bycatch data on specific species are incomplete, but the available information is sufficient to document that the rates can vary on fine scales in space and time, it is not possible to provide global quantitative estimates of bycatch rates, and consequently to evaluate whether mortality is sustainable or not. However, noting that there are at least occasional high bycatches, and applying the precautionary approach in the face of uncertainty, ICES cannot advise that the likelihood of recovery is secure for the species where recovery is a management objective. The following advice therefore seeks options to decrease bycatch by noteworthy amounts while allowing fishing to occur if and as appropriate.

Q4.4 If potential conflicts between fisheries bycatch and seabird management objectives are identified in Q4.3, describe the pattern of mortality in space and time.

The overlap between set-net fisheries and seabird concentrations is especially high in the Adler Ground subarea of the SPA Pomeranian Bay during winter and in the Odra Bank subarea in late spring/early summer. Nevertheless, due to the high concentration of seabirds year round, any fishing activities with set nets at any time of the year will lead to conflicts that have the potential to affect achievement of the objectives of the Birds Directive in the SPA Pomeranian Bay.

Figure 1.5.5.19.5 Overlaps in the occurrence of seabird concentrations and set nets in the SPA Pomeranian Bay.

Q4.5 Based on Q4.2 and Q4.4, describe the options for management of fisheries to mitigate the impacts and conflicts, and the residual impacts or conflicts that remain if the measures were implemented individually or in combination.

Option: Full spatial year-round exclusion of static gear from the SPA Pomeranian Bay

This management measure would reduce the bycatch of seabirds to zero in the SPA Pomeranian Bay.

There is a high likelihood that seabirds wintering in this general area are relatively consistent in their use of feeding grounds within the SPA. However, there is likely to be a frequent exchange of individuals between the different feeding
and resting areas by some species. While seabirds using the SPA at times may therefore still be exposed to some risk of bycatch outside the SPA, their overall bycatch risk would be lessened by this measure.

A total closure of set-net fishing inside the SPA might lead to an increase in total fishing effort with these gears in the southern Baltic Sea, because fishing effort would be likely to be displaced into areas with lower densities of target fish species. More fishing effort would be required to harvest the same total target catch in the area. There are partial data on how bycatch rate varies spatially and seasonally, providing limited potential to estimate the expected increase in bycatch of seabirds outside the SPA that would result from increased hours of effort of set nets in those areas. These changes in fishing opportunities would have social and economic consequences for those fishers affected. Notwithstanding the shortcomings of the available data, detailed planning of closures of set-net fishing within the SPA should use such data as have been collected to provide estimates for discussion during the planning process.

**Option: Closures for static gear in subareas of the SPA Pomeranian Bay at seasons with the highest overlap between set-net fisheries and seabirds**

Bycatch mortality of seabirds would be reduced close to zero in the subareas of the SPA Pomeranian Bay during the season of highest overlap between set-net fisheries and seabirds.

Based on the very limited information available to ICES on seasonal patterns of bycatch of seabirds in set nets the greatest benefits could result in closures on the Adler Ground subarea during winter and early spring and on the Odra Bank subarea in late spring/early summer. In the latter case, this benefit would only occur if fishing effort would remain very low or (close to) zero at other times of the year as is currently the case. However, it must be noted that this advice is not based on actual bycatch data of seabirds, but only on distribution data of seabirds and limited data of fishing effort in these sites.

Outside the closed areas/seasons, fishing effort (soak time) could possibly increase, because fishing effort is displaced into areas/seasons with lower densities of target fish species. All the comments made with regard to effects of effort displacement from total closures of set-net fisheries in the SPA apply to these partial closures as well.

**Option: Use of alternative fishing gears, for example fish traps**

The replacement of bottom-set gillnets with passive gears (such as fish traps) that have lower risks of seabird bycatch could reduce seabird bycatch close to zero, without the necessity of displacing fishing effort in space or time.

There are no data on which to evaluate the economic or practical feasibility of this option.

Gear research should be carried out in the areas as to how effective such traps are and whether traps could provide a viable alternative for the fishery.

**Advisory answers to questions relating to fishing activities and harbour porpoise**

ICES advises that harbour porpoise are highly mobile on spatial scales much larger than the Natura 2000 sites that have been proposed. Consequently, even full protection of harbour porpoise within the boundaries of the Natura 2000 sites would not ensure a high likelihood of achieving very low bycatch mortality for harbour porpoise in the southern Baltic Sea or southern North Sea, if bycatch of harbour porpoise outside the Natura 2000 sites was not managed effectively.

Full protection of harbour porpoise within the Natura 2000 sites would not even ensure high likelihood of favourable condition for harbour porpoise within the sites. If bycatch mortality was not managed effectively over the full range of the harbour porpoise populations, the risk of bycatch mortality outside the Natura 2000 sites would remain high enough that populations could not be assured of maintaining favourable condition in subsets of their range, including the subsets that coincide with the boundaries of the Natura 2000 sites.

Many of the questions below can therefore not be answered strictly in the context of management of fisheries in the German Natura 2000 sites alone, but apply to management of fisheries in the German EEZ more generally, and in many cases to the full North Sea and Baltic Sea, as the harbour porpoise populations are widely migratory within these seas. This is logical as this mobile species can move easily between areas within and outside a specific Natura 2000 site.

**Q5 From a scientific perspective, characterize what would constitute favourable condition for harbour porpoise in the sites in the North Sea and Baltic Sea?**

Favourable condition for harbour porpoises within the Natura sites would be characterized by the conservation and/or recovery of: i) the existing harbour porpoise stock, recognizing their natural population dynamic and fluctuations; ii) their feeding, migration, and reproduction habitats with preservation of their functional integrity within the sites and the
possibility for migration to other areas, that may or may not be other Natura 2000 sites; iii) the natural genetic diversity; and iv) the occurrence and abundance in space and time of their food.

In simple words, a site for harbour porpoise in favourable condition would be one where the species is prospering (in both quality and extent/population) and with good prospects to do so in the future as well.

From a wider perspective, the German national report on conservation status of harbour porpoise for the years 2000–2006 reported the species to be in ‘Unfavourable conservation status’ for both the North and Baltic seas. It is therefore important that site management for this species should minimize any unnatural mortality, but management above the Natura 2000 site scale would be necessary for improved conservation status.

Q6 To the extent that information allows and specifically for the sites in the North Sea and Baltic Sea:

Q6.1 To what extent are protected species, especially harbour porpoises, vulnerable to specific fisheries as such fisheries have operated during the period of the EMPAS project?

In the Baltic Sea, set-net fisheries account for a major part of the total fishing effort. Bycatch of porpoises in set nets along the German coast occurs regularly. However, net marks and mutilations found on stranded carcasses indicate that only a small fraction of all bycaught animals is reported. True numbers of bycaught porpoises remain unknown and most probably bycatch numbers are underestimated in official reports.

Assessing the impact of set-net fisheries on porpoises in the Baltic Sea is especially difficult. More than 70% of the set-net fishing activity is carried out by small vessels and in part-time fisheries. These vessels are not VMS equipped (<15 m length) and a fraction furthermore has no obligation to fill out logbooks (<8 m length). Hence, neither movement nor fishery effort of these fleet segments are monitored. To approximate the temporal and spatial effort of set-net fisheries in the German Baltic, set-net flag sightings, recorded during aerial surveys following line transect methodology, were used to calculate flag density (flags/km) as a proxy for set-net density.

This limited information is inadequate to evaluate fishing effort using set nets in these sites. In order to analyse any potential conflict of harbour porpoises with set-net fisheries, fisheries effort and bycatch of small boats and the part-time fisheries must be described. Implementation of an effective fisheries monitoring scheme including all fishery vessels within Natura 2000 sites could be a first step toward improving the data situation regarding effort and bycatch number.

In the North Sea, there is an overlap of set-net fishery and harbour porpoise distribution in summer (May–July), in a subarea of the SCI Sylt Outer Reef. This subarea is an important feeding, calving, and nursery ground for harbour porpoises at this time. Set-net fisheries in this period are associated with especially high bycatch risk in that subarea and are considered to pose a particularly high potential conflict.

Q6.2 Describe the nature and extent of existing and potential conflicts between the specific fisheries and the achievement or maintenance of favourable condition for harbour porpoise.

Bottom-set gillnets are the major source for anthropogenic mortality of harbour porpoises and have by far the highest bycatch rates among fishing gear types.

In the wide sense (i.e. considering the whole population both within and outside the Natura 2000 sites), there has been a rise of porpoise carcass numbers since 2000 from an average 30–40 dead animals collected per year to more than 150 in 2007 on German Baltic Sea coasts. Although search effort might have increased slightly over the years (e.g. due to public awareness), it could not possibly account for the high increase in animals found. Moreover, a 150 km strip of coastline in Schleswig-Holstein with constant effort since 1987 exhibited the same trend as the overall trend. These trends could be caused by increased population numbers, increased fishing effort, or by a change in behaviour of harbour porpoises to make them more susceptible to capture. Insufficient evidence exists to evaluate these hypotheses. Abundance estimates from 2007 are not available and earlier population estimations neither exhibited a population trend nor showed a significant change in densities.

Q6.3 To what extent do the conflicts in Q6.2, if any, currently impede achievement or maintenance of favourable condition for harbour porpoise populations?

There is insufficient information to assess the proportion of the harbour porpoise population that is bycaught each year either within or outside the German Natura 2000 sites. To assess this, a bycatch observation scheme would need to be established and figures derived from such a scheme compared with the overall population size. Pilot schemes that are required under EU Regulation 812/2004 would be suitable for such an evaluation, but it is not known whether such schemes have been established in German waters.
Q6.4 If potential conflicts between fisheries bycatch mortality and harbour porpoise management objectives are identified in Q6.2 or Q6.3, describe the pattern of mortality rates in space and time.

As noted above, the information does not exist to describe in detail mortality rates in space and time either in the German EEZ or within German Natura 2000 sites. Set netting is carried out in Germany’s Baltic Sea coastal waters as well as in the EEZ throughout the year, with highest effort in winter and spring.

Harbour porpoises occur throughout the year in German waters. In winter, highest densities are found in the Western Baltic. From spring to September, high densities can be found in the Mecklenburg Bight. In the eastern part of the German Baltic, harbour porpoises are thought to belong to the separate small ‘Baltic Proper’ population. Densities here are generally low, but sometimes peak in spring and summer. Overlap with bottom-set net fisheries in winter (November–February) is most likely in the Kiel Bight, as elsewhere porpoise densities are low. In spring (March–June), overlap extended into the area around Fehmarn, including the SCI Fehmarn Belt and also in the Mecklenburg and Pomeranian Bays, including all three Natura 2000 sites in these areas. In summer/autumn (July–October) a high overlap remained around Fehmarn and along the western Mecklenburg coast, as well as in the Kiel Bight and Pomeranian Bay.

An investigation of porpoise and fisheries distribution in the German North Sea showed high overlap between bottom-set net fisheries and porpoises in summer (May–July), including in the SCI Sylt Outer Reef.

Q6.5 Based on Q6.2–Q6.4, describe the options for a management of fisheries that might mitigate the impacts and conflicts, as well as the residual impacts or conflicts that remain of the measures that were implemented effectively.

There are three distinct areas of harbour porpoise distribution in German waters: 1) Baltic (German waters to the east of the Darss Ridge); 2) western Baltic (connected with the Belt Sea); and 3) North Sea. Options for fisheries management measures are described for the Natura 2000 sites in these marine areas, taking into account different levels of overlap between harbour porpoises and current fishing activities. These include:

SCI Western Rönne Bank, SCI Adler Ground, SCI Pomeranian Bay with Odra Bank
i) closing of set-net fisheries in all sites. This option would reduce bycatch rates of harbour porpoise to zero inside the sites. However, the resulting benefits to the harbour porpoise population would depend completely on bycatches in fisheries outside the site. These bycatch rates are currently not zero, and displaced effort from these phased out fisheries is likely to make them higher. There are insufficient data to estimate whether there would be any ecological benefit to the harbour porpoise populations, but the likelihood of little or no net benefit is high enough to be a concern. There would be social and economic consequences to the fisheries.

ii) mandatory use of acoustic deterrent devices on all set nets and all vessel sizes (combined with an effective observer scheme). ICES advised the European Commission in 2002 on the potential effectiveness of these measures and that advice applies in this case as well.

iii) gear modifications (e.g. barium sulphate nets, fish traps, etc.). Most of these gear modifications are still experimental, and neither their ecological benefits nor costs to the fishery can be estimated with current information. Further experimental work with these alternative gears is encouraged.

SCI Fehmarn Belt, SCI Kadet Trench
Closing of set-net fisheries in SCI Fehmarn Belt during the abundance peak (March–October) of harbour porpoises. All the comments in option i) above apply in this case as well. The other options also apply in this case, but more restricted in time to the March–October period, with the same comments on limitations on potential ecological benefits and social and economic costs.

SCI Sylt Outer Reef
Closing of set-net fisheries. All the comments in the previous site also apply to this site.

The risk of effort displacement needs to be carefully considered in all closure schemes. As previously discussed, displacement of effort can carry the risk of overall greater mortality on the population as a whole. It should also be noted that German waters are comparatively small compared with the overall range of individual harbour porpoises, so it will be necessary to work with other neighbouring EU Member States to ensure that displacement of effort does not compromise harbour porpoise conservation on the scale of the full distribution of the populations.
General points from EMPAS relative to the German Natura 2000 sites

ICES advises that the options presented above are intended to promote achievement of favourable condition in relevant Natura 2000 sites. However, ICES has no basis for advising whether achievement of favourable condition within the MPAs assures achievement of favourable conservation status of the relevant habitats or species for the entire German EEZ. Natura 2000 sites that are intended to contribute to protecting listed seabird and marine mammal species, in particular, would benefit from further study in this broader context, but this was beyond the mandate of the EMPAS project.

ICES notes that measures implemented inside specified sites, including these Natura 2000 sites, often have consequences outside those areas. In the present case, a relevant consequence would be the migration of fishing effort (and related impact on habitats and species) from inside an MPA to outside its boundaries, with potential resultant changes in total fishing effort, changing thereby also catch per unit effort for the target species. These potential consequences must be considered in the application of management measures within the Natura 2000 sites, so the total effects of management options can be evaluated as fully as possible. The data on spatial variation in catch per unit of effort collected by EMPAS should be used in these case-specific evaluations. Furthermore, management of fisheries outside the Natura 2000 sites needs to take account of the implications of various management measures for achievement of the Conservation Objectives within the Natura 2000 sites.

The choice of management options should consider the risks of creating unintended perverse incentives for the fisheries being affected, and consider the risks of non-compliance with the alternatives. All the management options provided here will produce their intended benefits only if effectively implemented (which usually means compliance must be high). Failure to consider risk of non-compliance in evaluating the potential costs and benefits (including potential ecological benefits) of the management options could result in choices which fail to provide their intended benefits on any or all of the ecological, social, and economic aspects of conservation and sustainable use of the species, communities, and habitats in the Natura 2000 sites.

ICES also calls attention to several sources of uncertainty in the information on which this advice is based. One major source of uncertainty is the absence of data on spatial distribution of effort and catch rates of vessels less than 15 metres. Even the total number of vessels in this size group that operate within or adjacent to the Natura 2000 sites is uncertain, as are their spatial and temporal patterns of fishing. With current knowledge the effort by this fleet sector is thought to be of such a magnitude that their possible effects on the achievement of the conservation objectives for the Natura 2000 sites cannot be discounted. Even though EMPAS greatly increased the fine-scale information on distribution and magnitude of effort, directed catches, and bycatches for all fleet and gear sectors, much of this information is for only one or two years. In essence, fisheries effort varies seasonally and interannually and there would be significant benefits from continued augmentation of local-scale information on effort allocation and catch and bycatch rates.

There is also uncertainty about the best indicators to use for measuring the effects of management measures on benthic communities and habitats, as well as on the vulnerability of many benthic species and habitats to various fishing gears. Better information on benthic species and communities could reduce this uncertainty, and possibly by a large amount if the studies were specifically designed and conducted to provide information directly relevant to assessing fishery impacts and health of the benthic communities. In addition, the concept of the r-K continuum used in the workshop report when discussing potential indicators of the benthic community is considered to be a fairly out-of-date ecological approach. More contemporary ecological reasoning, or at least language, should be used when selecting the community indicators for the habitats.

There is uncertainty about the sustainable bycatch mortality level, not only for a number of species of seabirds but also for many benthic species and communities. Reducing this uncertainty will again require directed research, focused on these advisory needs.

Sources of information


### Acronyms and terminology

<table>
<thead>
<tr>
<th>Term / acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bayesian method</td>
<td>Assessment method that quantifies uncertainties and formulates advice on the basis of probabilities of reaching a limit or target point.</td>
</tr>
<tr>
<td>$B_{\text{lim}}$</td>
<td>Limit reference point for spawning stock biomass (SSB)</td>
</tr>
<tr>
<td>$B_{\text{pa}}$</td>
<td>Precautionary reference point for spawning stock biomass (SSB)</td>
</tr>
<tr>
<td>$B_{\text{MSY}}$</td>
<td>SSB that is associated with MSY.</td>
</tr>
<tr>
<td>$B_{\text{trigger}}$</td>
<td>Value of spawning stock biomass (SSB) which triggers a specific management action</td>
</tr>
<tr>
<td>Catchability</td>
<td>The fraction of a fish stock which is caught by a defined unit of the fishing effort</td>
</tr>
<tr>
<td>Cpue</td>
<td>Catch per unit effort: The quantity of fish caught (in number or in weight) with one standard unit of fishing effort; e.g. number of fish taken per 1000 hooks per day or weight of fish taken per hour of trawling. Cpue is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate.</td>
</tr>
<tr>
<td>Discards</td>
<td>Are those components of a fish stock thrown back after capture e.g. because they are below the minimum landing size or because quota have been exhausted for that species. Most of the discarded fish will not to survive.</td>
</tr>
<tr>
<td>Ecosystem approach</td>
<td>Ecosystem approach to fisheries management. Management that takes into account the effects of fisheries on the ecosystem and the effects of the ecosystem on the fish stocks.</td>
</tr>
<tr>
<td>Exploitation boundary</td>
<td>Threshold on exploitation (catch, mortality, effort) that is consistent with a management strategy or international agreement (e.g. exploitation boundary consistent with precautionary approach)</td>
</tr>
<tr>
<td>Exploitation pattern</td>
<td>Distribution of fishing mortality over the age composition of the fish population, determined by the type of fishing gear, area and seasonal distribution of fishing, and the growth and migration of the fish.</td>
</tr>
<tr>
<td>F</td>
<td>Instantaneous Rate of Fishing Mortality. When fishing and natural mortality act concurrently, F is equal to the instantaneous total mortality rate (Z), multiplied by the ratio of fishing deaths to all deaths. Expressed on an exponential scale: $F=0.5$ means that $1-\exp(-0.5)=39%$ are removed.</td>
</tr>
<tr>
<td>Fishing mortality</td>
<td></td>
</tr>
<tr>
<td>$F_{\text{pa}}$</td>
<td>Precautionary reference point for fishing mortality (mean over defined age range)</td>
</tr>
<tr>
<td>$F_{\text{lim}}$</td>
<td>Limit reference point for fishing mortality (mean over defined age range)</td>
</tr>
<tr>
<td>$F_{\text{target}}$</td>
<td>Target fishing mortality in a management plan or management strategy</td>
</tr>
<tr>
<td>$F_{\text{MSY}}$</td>
<td>Fishing mortality consistent with achieving Maximum Sustainable Yield (MSY)</td>
</tr>
<tr>
<td>$F_{0.1}$</td>
<td>The fishing mortality rate at which the marginal yield-per-recruit (i.e. the increase in yield-per-recruit in weight for an increase in one unit of fishing mortality) is only 10 percent of the marginal yield-per-recruit on the unexploited stock. The fishing mortality rate at which the slope of the yield-per-recruit curve is only one-tenth the slope of the curve at its origin.</td>
</tr>
<tr>
<td>Term / acronym</td>
<td>Description</td>
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</tr>
<tr>
<td>$F_{\text{med}}$</td>
<td>Fishing mortality rate $F$ corresponding to a SSB/R equal to the inverse of the 50th percentile of the observed R/SSB.</td>
</tr>
<tr>
<td>$F_{\text{max}}$</td>
<td>Fishing mortality rate that maximizes equilibrium yield per recruit. $F_{\text{max}}$ is the $F$ level often used to define growth overfishing.</td>
</tr>
<tr>
<td>$F_{\text{sq}}$</td>
<td>$F$ status quo</td>
</tr>
<tr>
<td>Fecundity</td>
<td>In general, the potential reproductive capacity of an organism or population expressed in the number of eggs (or offspring) produced during each reproductive cycle. Fecundity in fish usually increases with age.</td>
</tr>
<tr>
<td>Fishery</td>
<td>Group of vessel voyages targeting the same (assemblage of) species and/or stocks, using similar gear, during the same period of the year and within the same area (e.g. the Dutch flatfish-directed beam trawl fishery in the North Sea). See also: fleet, metier.</td>
</tr>
<tr>
<td>Fleet</td>
<td>A physical group of vessels sharing similar characteristics in terms of technical features and/or major activity (e.g. the Dutch beam trawler fleet &lt; 300 hp). See also: fishery, metier.</td>
</tr>
<tr>
<td>FLR</td>
<td>Fisheries Library in R. The FLR library is a collection of tools in the R statistical language that facilitates the construction of bio-economic simulation models of fisheries and ecological systems. It is a generic toolbox, but is specifically suited for the construction of simulation models for evaluations of fisheries management strategies. The FLR library is under development by researchers across a number of laboratories and universities.</td>
</tr>
<tr>
<td>HCR</td>
<td>An algorithm for pre-agreed management actions as a function of variables related to the status of the stock. For example, a control rule can specify how $F$ or yield should vary as a function of spawning biomass. Also known as ‘decision rules’ or ‘harvest control laws’.</td>
</tr>
<tr>
<td>Harvest Control Rule</td>
<td></td>
</tr>
<tr>
<td>Harvest rate</td>
<td>(= harvest ratio) Ratio between landings and total stock abundance (e.g. as estimated from TV surveys for Nephrops).</td>
</tr>
<tr>
<td>High-grading</td>
<td>The discarding of a portion of a vessel’s legal catch that could have been sold in order to retain a higher or larger grade of fish that will bring higher prices. It may occur in quota and non-quota fisheries.</td>
</tr>
<tr>
<td>ICA</td>
<td>Integrated Catch Analysis; Stock assessment method</td>
</tr>
<tr>
<td>Lpue</td>
<td>Landings per unit effort, similar to cpue, but based on that part of the catches that are landed and reported.</td>
</tr>
<tr>
<td>Management plan</td>
<td>A management plan includes the decision-making processes (harvest control rules, tactical decision making) and the sanctions on implementation and the requirements for monitoring and reporting. Management plans may also exist in the form of rebuilding plans or recovery plans.</td>
</tr>
<tr>
<td>Management strategy</td>
<td>Management strategies consist of objectives with associated performance criteria, the implementation measures (e.g. input or output control) and what is considered a relevant knowledge base for decisions.</td>
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<tr>
<td>Term / acronym</td>
<td>Description</td>
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</tr>
<tr>
<td>Metiér</td>
<td>Homogeneous sub-division of a fishery by fleet (e.g. the Dutch flatfish-directed beam trawl fishery by vessels &lt; 300 hp in the North Sea). See also: fishery, fleet.</td>
</tr>
<tr>
<td>TRIP ID</td>
<td>(gear, area, mesh size (target species))</td>
</tr>
<tr>
<td>VESSELD</td>
<td>Fleet A</td>
</tr>
<tr>
<td></td>
<td>Fleet B</td>
</tr>
<tr>
<td>MSY</td>
<td>Maximum Sustainable Yield. The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions.</td>
</tr>
<tr>
<td>Population</td>
<td>A group of fish of one species which shares common ecological and genetic features. The stocks defined for the purposes of stock assessment and management do not necessarily coincide with self-contained populations.</td>
</tr>
<tr>
<td>Recruitment</td>
<td>The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable stock that year. This term mostly used in referring to the number of fish from a year class reaching a certain age. For example, all fish reaching their first year are age 1 recruits.</td>
</tr>
<tr>
<td>Reduced reproductive capacity</td>
<td>When SSB is at a level where the stock reproduction is impaired as evident from historical observations.</td>
</tr>
<tr>
<td>SSB</td>
<td>Spawning stock biomass. Total weight of all sexually mature fish in the stock.</td>
</tr>
<tr>
<td>SSB/R</td>
<td>Spawning Stock Biomass per Recruit: expected lifetime contribution to the spawning stock biomass for a recruit of a specific age (e.g., per age 2 individual). For a given exploitation pattern, rate of growth, and natural mortality, an expected equilibrium value of SSB/R can be calculated for each level of fishing mortality.</td>
</tr>
<tr>
<td>S/R</td>
<td>Spawning Stock Biomass per Recruit: expected lifetime contribution to the spawning stock biomass for a recruit of a specific age (e.g., per age 2 individual). For a given exploitation pattern, rate of growth, and natural mortality, an expected equilibrium value of SSB/R can be calculated for each level of fishing mortality.</td>
</tr>
<tr>
<td>SMS</td>
<td>Stochastic Multispecies Model; Stock assessment method.</td>
</tr>
<tr>
<td>Stock</td>
<td>A part of a fish population usually with a particular migration pattern, specific spawning grounds, and subject to a distinct fishery. In theory, a Unit Stock comprises all the individuals of fish in an area, which are part of the same reproductive process. It is self-contained, with no emigration or immigration of individuals from or to the stock. On practical grounds, a fraction of the unit stock is considered a ‘stock’ for management purposes (or a management unit), as long as the results of the assessments and management remain close enough to what they would be on the unit stock.</td>
</tr>
<tr>
<td>SURBA</td>
<td>SURvey Based Assessment. Uses only relative abundance indicator(s)</td>
</tr>
<tr>
<td>Surplus production model</td>
<td>Mathematical representation of the way a stock of fish responds to the removal of its individuals. Usually a relationship between yield and/or cpue, and fishing effort or mortality. Expressed in biomass.</td>
</tr>
</tbody>
</table>
1.7 Maps

Figure 1.8.1  ICES Areas in the Northeast Atlantic
Figure 1.8.2  ICES Areas in the Northeast Atlantic (detail)
Figure 1.8.3  ICES areas in the Baltic.