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Report of the Working Group on Ecosystem Effects of Fishing Activities (WGECO)

May 6–13 2008

Copenhagen, Denmark

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Executive summary

WGECO was given a heavy workload this year and participants are to be commended for their dedication to completing the ToRs assigned. Several of the ToRs involved interaction with and/or review of the work done by other ICES expert groups, and we thank those groups who completed their ToRs in a comprehensive manner, so that we could proceed with ours.

ToRA was one such assignment as we were asked to make 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 for input to the *OSPAR 2010 Quality Status Report.* Contributions from WGITMO, WGLESP, WGZE, BEWG, WGFE, WGSE, WGMME, and WGOH were reviewed along with the scientific literature. Given the time available, it was necessary to take information at quite coarse scales, and extract and interpret patterns and relationships with simple analytical methods and expert judgement. To minimize the risk of bias, 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 and by different experts. We had hoped to be able to undertake more analytical work during the meeting, and this may be possible next year.

ToR B, likeToR A, involved the preparation of part of ICES input to the *OSPAR 2010 Quality Status Report*. OSPAR does not have any competence in fisheries management but has a role in ensuring ecosystem health and, given the long history and spatially persuasive nature of fisheries in the NE Atlantic, fisheries are a key human factor in determining the quality of the marine environment. WGECO, using the framework developed in 2007, drew on a wide variety of sources to develop a draft of the fisheries sections of the QSR overview and 5 regional accounts. The information synthesis allowed a number of common patterns and issues to be identified and a series of recommendations for OSPAR were produced.

WGECO considered how managers might use the North Sea Fish Community EcoQO, concluding that they should aim to meet both the EcoQO as well as objectives for individual commercial stocks. Given this logic, WGECO reviewed WGFE's and WGSAM's work. WGFE could not complete their ToR, concluding that none of the six theoretical species-specific size-based fish community models with potential to inform scientific advice were sufficiently developed to perform this role. WGSAM ran MSVPA in forecast mode, but ultimately calculated the proportion of large fish index incorrectly. Nevertheless the issues raised by WGSAM contributed strongly to our deliberations regarding the EcoQO management process. Following WGSAM's and WGFE's work, WGECO were able to prepare a more definitive ToR for WGSAM in 2008 and identified a programme of work for a study group, which WGECO recommends be established to investigate the management action necessary to achieve the North Sea Fish Community EcoQO.

In ToR d) we began the process of developing a framework to identify methodologies to assess and quantify the efficacy of gear-based technical measures introduced to reduce the environmental impact of fishing. Working with colleagues from WGFTFB, we developed an overall framework, and a methodology for identifying significant adverse impacts (SAIs) to ecosystem components from any fishing gear being considered. This methodology will require trialling by WGECO in 2009, and a ToR to address this has been recommended. In addition, a parallel ToR will be recommended

to consider the fundamental issue of defining some of the key terminology required to classify SAIs. Having classified the SAIs of the main gear types the next step is to identify which of these can be reduced by gear-based measures, and whether methods exist for assessing any reduction in impact due to these. As a result we have also recommended a ToR for WGFTFB in 2009 to work on progressing this, and to review the framework and methodology developed so far.

WGECO were requested to assess and score the interactions between pressures resulting from human activities and ecosystem components based on previous WGECO and OSPAR work. The University of Liverpool and Cefas have recently developed a risk-based methodology to assess these interactions which is a great advance on previous work as it provides a consistent and transparent method of assessment. WGECO attempted to use this approach to score the interactions between pressures and components, but decided that it was premature to attempt the assessment without further input from a wider body of expertise and stakeholders. WGECO identified three main steps which need to be addressed before the methodology can be made operational: 1) reduce and finalise the list of pressures and components (WGECO used a matrix of 1648 combinations, whilst the latest OSPAR matrix contains 2,700 combinations - neither of these are a tractable number of combinations to assess), 2) develop thresholds for each component (how much of an impact is acceptable?), and 3) finalise the methodology (the approach has not yet been fully tested). Indicators for those combinations of pressures considered of urgent or high priority for demersal fish by the Liverpool-Cefas study were identified.

Lastly, WGECO made some comments and recommendations for developing capacity within ICES to monitor change and use statistical tools in relation to hydrographic change and requests in similar areas.

1 Opening of the meeting

The Working Group on Ecosystem Effects of Fishing Activities (WGECO) met at ICES HQ, Copenhagen, from 6–13th May 2008. The list of participants and contact details are given in Annex 1.

The meeting opened with introductions and an overview of the Terms of Reference (ToR; see Annex 2) was provided. Mark Tasker then made a presentation on reorganization within ICES and provided us with an opportunity to ask questions about the new review process. Prior to the meeting ToR leads had been selected through correspondence. Participants organized into subgroups under direction of the ToR lead to plan the approach to use in addressing the ToRs and to assign tasks.

On Wednesday 7th May Dominic Rihan, Chair of the WG on Fisheries Technology and Fish Behaviour (WGFTFB), made a presentation on the work this group has been doing on the subject of fishing impacts. WGFTFB had addressed a joint ToR with WGECO on the impacts of *Crangon* beam trawl fisheries in the North Sea in 2007. Later in 2007, at the ICES ASC in Helsinki, a ToR was formulated between the chairs of WGFTFB and WGECO as follows:

> "*For each OSPAR region, select and succinctly describe one or more representative examples of gear modifications, which have resulted in changes to the ecosystem effects of these gears, including if possible a range of ecosystem components.*"

The work done by WGFTFB was used in addressing our ToR b) in preparation for the OSPAR QSR. The participation of WGFTFB members at the WGECO meeting was of mutual benefit and we hope to continue this practice in the coming years.

1.1 Acknowledgements

WGECO would particularly like to thank Helle Gjeding Jørgensen, Cristina Morgado and other members of the ICES Secretariat for their support in enabling the meeting to run smoothly and in ensuring that the final report was completed to schedule. Data made available by Henrik Sparholt was very much appreciated.

2 Adoption of the agenda

The workplan agreed to by the ToR subgroups was presented to a plenary session on the 7th of May and adopted.

3 Changes in the distribution and abundance of marine species in relation to climate change for the 2010 OSPAR QSR

In 2006 OSPAR sent a request to ICES for information and advice on:

Completion of 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]

> To complete an assessment of what is known 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. The assessment should look at ecologically indicative species, including the threatened and declining species identified by OSPAR, for which adequate time series data exist, in order to assess to what extent there have been changes in distribution, population and condition of species going beyond what might have been expected from natural. The aim is to prepare an overview of as a major contribution towards JAMP Product BA-3 and material that can be included in the Quality Status Report in 2010.
>
> ICES ACE 2007 will provide a review of existing science and new data analysis that allows links between climate and distribution and abundance to be identified, on the identification of affected components and on the development of advisory text and basic maps for review by OSPAR. This will be reviewed by MASH 2007 and comments will be fed back to ICES. ICES ACE 2008 will provide a final advisory product for OSPAR, to include maps showing changes of selected component species in standard format that can be used as basis for QSR.

In response to that request, in 2008 WGECO was assigned a Term of Reference to:

a) review and integrate the contributions of WGITMO, WGLESP, WGZE, BEWG, WGFE, WGSE, WGMME, WGOH, WGECO to 'the 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', based on the recommendations of the Ad Hoc/Study groups on:

1) Hydrographic Attributes

2) Trend Analyses and Quantifying Relationships (SGSMACCC)

3) Formulating Hypotheses and Predictions about Mechanisms (SGWRECC)

4) Selecting Species for More Intensive Investigations

5) and provide a draft final report for OSPAR;

There is ample circumstantial evidence that global warming 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

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[1] On going request from the 2007 ICES Work Programme.

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. This request from OSPAR for information to include in the next QSR will allow the QSR to 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 area, should the forecasts for continued warming of the planet prove true.

ICES entrained experts in oceanographic hydrography, ecology of phytoplankton, zooplankton, benthos, fish, seabirds, marine mammals, and invasive species in assembling relevant information from the OSPAR area. The evidence is 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 weak, collectively allow the request from OSPAR to be addressed by means of a meta-analysis which follows the methodology used by the IPCC and is intended to complement that work.

3.1 Oceanographic background

The ocean variability in the OSPAR regions has been observed with high quality measurements over the last 50 to 60 years (Hughes and Holiday, 2007), but such *in situ* observations are relatively sparse or unavailable in many places, which restricts 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 tempertature 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 a general Atlantic Water temperature increase of about 1 ^{o}C from the 1970ies to date, consistent along the shelf break from Ireland to the Barents Sea and Fram Strait (Figure 3.1.1). In the North Sea the rate of warming is even greater (1-2 ^{o}C) whereas in the western OSPAR regions the warming is less (.4–8 ^{o}C) (Figure 3.1.2). The increase in temperature in OSPAR region IV (Biscay and West Iberia) is lower in the south and is also strongly influenced by upwelling. Superimposed on this general warming over the last 30 years are substantial inter-annual variations. Notably the Atlantic Water temperature at the start of the modern measurements in the 1950ies was only slightly colder than today.

Regional attribution is difficult-IPCC, 2007: Summary for Policymakers

"Limitations and gaps prevent more complete attribution of the causes of observed system responses to anthropogenic warming. First, the available analyses are limited in the number of systems and locations considered. Second, natural temperature variability is larger at the regional than at the global scale, thus affecting identification of changes due to external forcing. Finally, at the regional scale other factors (such as land-use change, pollution, and invasive species) are influential.

Nevertheless, the consistency between observed and modelled changes in several studies and the spatial agreement between significant regional warming and consistent impacts at the global scale is sufficient to conclude with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems."

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7–22.

It is difficult to distinguish between anthropogenic and natural variability in the climate and hence in the impacts of climate, particularly when moving down in scale from global to regional or to the local level (see box and IPCC, 2007). One approach is to estimate the level of the natural variability previous to the onset of the anthropogenic warming. The longest instrumental record of the Barents Sea climate is from the Kola section (Bochkov, 1982; Tereschenko, 1997, 1999). Focusing on the multi-decadal scales, the series shows substantial variations; cold at the beginning of the 20th century, a warm period in the 30–40s, followed by a cold period in the 60–70s and finally, a still ongoing warming (Figure 3.1.3). These variations have amplitudes of the order 0.5 °C. The close relation of this series to the Atlantic Multidecadal Oscillation (AMO) index (Sutton and Hodson, 2005) suggests that this is a large-scale natural mode of variability and that we presently are in a positive phase of the AMO. Recent investigations conclude that using the observed sea surface temperature (Keenlyside *et al.*, 2008) or upper ocean heat content (Smith *et al.*, 2007) significantly improve the predictability on decadal time scales. Keenlyside *et al.*, 2008 predict that over the next decade, the Atlantic meridional overturning circulation will weaken to its long-term mean, and the North Atlantic SST will cool slightly, as natural climate variations in the North Atlantic will temporarily offset the projected anthropogenic warming.

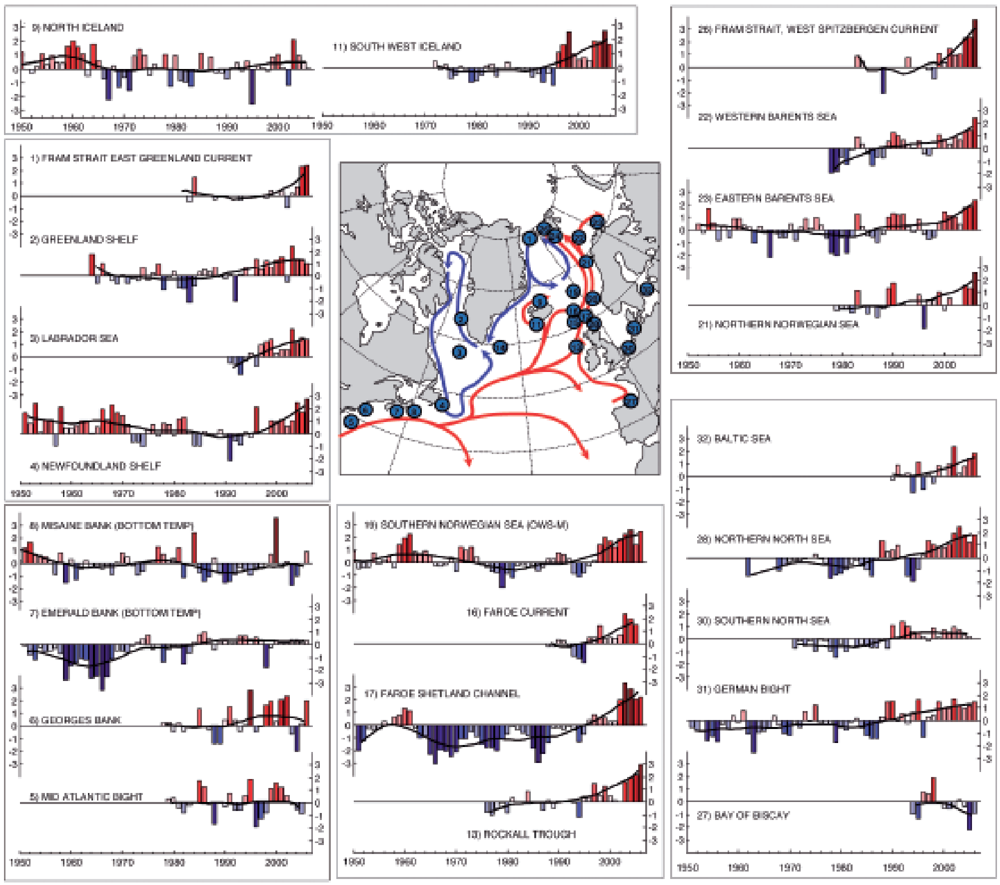

Figure 3.1.1 Overview of upper ocean temperature anomalies from the long-term mean across the North Atlantic. The anomalies are normalized with respect to the standard deviation (e.g., a valud of +2 indicates 2 sstandard deviations above normal). The maps show conditions in 2006 (colour intervals 0.5, reds are positive/warm and blues are negative/cool).

A regional scale of natural variability in the North-Atlantic is connected to changes in the Sub-polar gyre (Häkkinen and Rhines, 2004). The weakening of the Sub-polar 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 1970ies (ICES, 2008) coinciding with increased temperature of the Atlantic Inflow (Skagseth *et al.*, 2008).

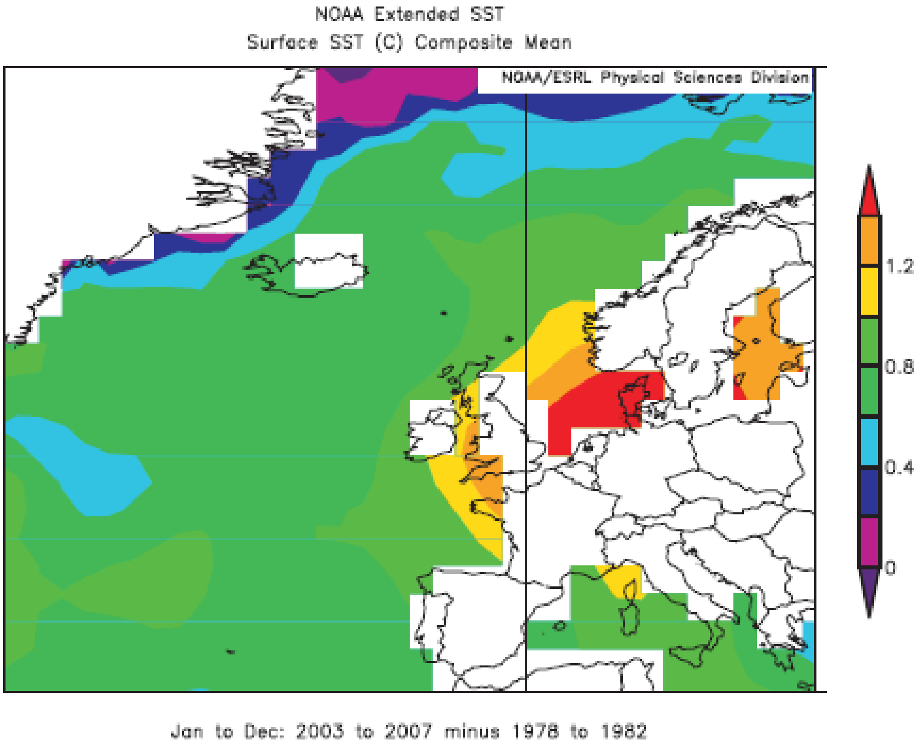

Figure 3.1.2 Sea surface temperature (SST) showing the mean 2003–2007 minus the 1978–1982. The plots are based on NOAA NCDC ERSST version 2 which is an extended reconstruction of global SST data based on ICOADS (Worley *et al.*, 2005) monthly summary trimmed group data (http://www.cdc.noaa.gov/).

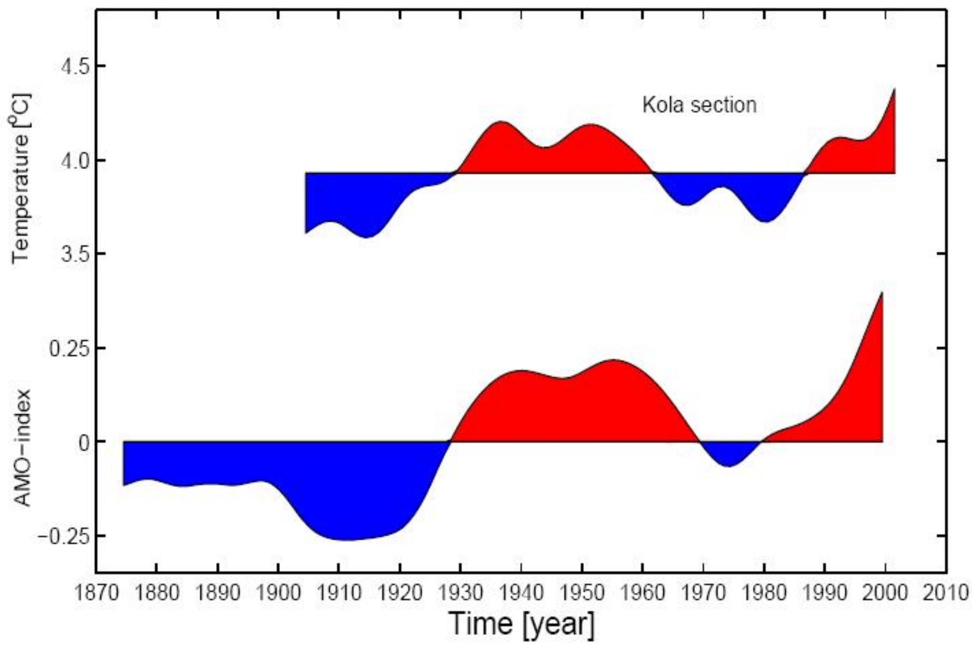

Figure 3.1.3 Time series of the Kola section mean temperature (upper graph) and the Atlantic Multidecadal Oscillation (AMO) index (lower graph). The series were filtered using a two-way 14-year Hamming window. The AMO index is based on the sea surface temperature in the region 0–60oN and 7.5–75oW. The Kola section data were obtained from PINRO.

The question is whether the observed changes to date are greater than expected from natural variability and if yes what is the size of the anthropogenic contribution? There is an observed change in the global ocean heat content over the period from 1961 to 2003 (IPCC, 2007) but the associated mean increase in temperature is small (< 0.02 °C). The anthropogenic warming signal initially is expected to be more apparent in the surface layer, and the global mean sea surface temperature shows an increase of the order 0.5°C over the last 50 years (Figure 3.1.5). Compared to this the typical scale of the natural variability in the OSPAR region is more of the order 1°C (i.e. twice the amplitude mentioned above for the Barents Sea time series). Based on this the major part of the observed variability in the OSPAR area to date cannot be distinguished from natural variability.

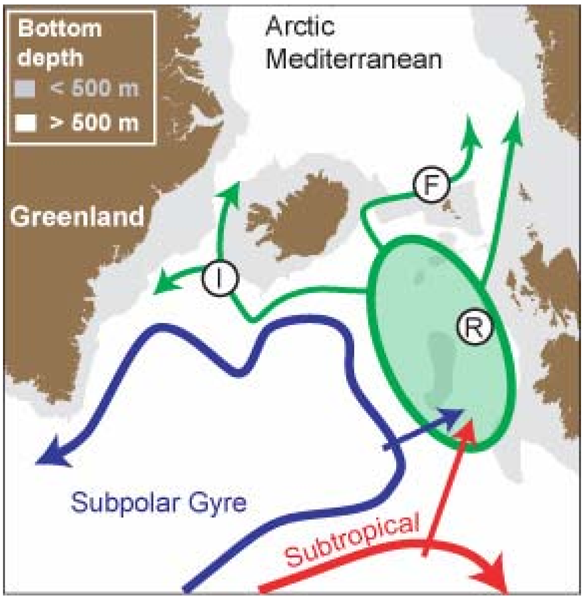

Figure 3.1.4 Schematic illustration of the circulation in the northern North Atlantic. R is the Rockall Trough, F is the Faroe Current, and I is the Irminger Current. From Hatun *et al.*, 2005.

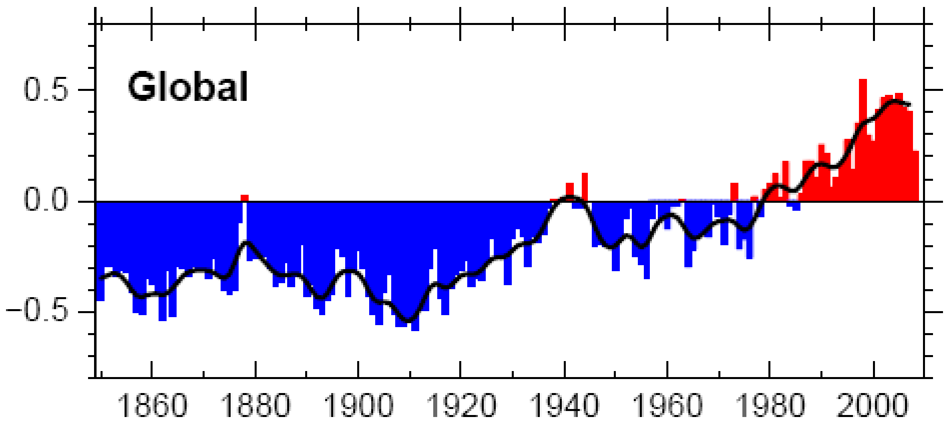

Figure 3.1.5 Global mean sea surface temperature change from the HadISST data set.

3.1.1 References

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3.2 Detection of effects of climate change on marine biota

In the present context we wish to distinguish between climate and non-climate causes of observed changes in biota and between "natural" and anthropogenic factors. In the case of non-climate causes the division between natural and anthropogenic causes is fairly clear, but for climate the factors are the same in both cases and the requirement is to partition them in order finally to attribute a proportion of the observed changes in biota to anthropogenic climate change:

CAUSES OF CHANGE	NATURAL	ANTHROPOGENIC
NON-CLIMATE	Competition, predation, disease, internal dynamics, etc.	Fishing, eutrophication, pollution, habitat alterations, species introductions, etc.
CLIMATE	Temperature, vertical mixing, circulation, etc.	Temperature, vertical mixing, circulation, pH, etc

A brief account of observed changes in ocean climate in the OSPAR area is given in Section 3.1 and the partitioning of these changes into natural and anthropogenic fractions is provided in the table above. However the partitioning of causes shown in the table is not complete. Interactions between causes within and among the four categories should not be ignored. For the present advice, we consider the effects which fishing may have on the sensitivity of marine systems to climate impacts.

The size 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. 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. The consequence is that heavily exploited species may be perturbed more strongly by climate than less exploited or unexploited species. Therefore a key adaptation strategy to reduce the impact of climate on marine systems is to reduce fishing pressure (McFarlane *et al.*, 2000; Beamish and Noakes, 2002; Brander, 2007).

3.2.1 References

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3.3 Strategy of working group

ICES Expert Groups investigated a number of possible approaches to providing the most complete possible answer to this request. A number of suggestions for intensive analyses of correspondence in patterns in space and time between oceanographic information and data on species occurrences had great scientific merit, but were infeasible without a major allocation of time by a number of ecological, oceanographic and statistical experts. The same was the case for possible analyses to partition causes of change in abundance or distribution among effects of environmental conditions, targeted and bycatch fishing mortality, physical and chemical habitat alterations from a variety of causes, species interactions, and many other causes. Again, the best science for such decomposition of trends would demand unfeasibly large investments of resources.

As a consequence, it was necessary to take information at quite coarse scales, and extract and interpret patterns and relationships with simple analytical methods and expert judgement. There can be a high risk of confirmatory bias in advice relying partially on expert judgement. 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[2] and by different experts.

Within this relatively coarse approach, ICES first looked separately at information from phytoplankton, zooplankton, benthos, fish, seabirds, marine mammals and invasive species. Experts provided information from literature sources considered to report scientifically sound studies, and from data bases that had been subjected suitable quality control in collection and handling of data. Studies of individual species are included in the information base, but priority was given to long-term studies where the abundance, distribution and/or condition of a number of species were monitored in a consistent manner. In these cases common patterns of change across a number of species could 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 areas II and IV.

From the literature and monitoring studies used for each species group, information was tabulated for as many species as possible covering. Information tabulated included: taxon (usually species, but occasionally higher group, particularly for plankton and benthos), start and end of time series, sampling frequency within the time series (including years missed), 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

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[2] 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.

specific cases not all of the columns in the tabulation were informative (usually the same value for all cases), and only the informative rows are presented in the tables in Section 3.4. Each table is followed by a short section of observations on the information in the table, but major conclusions are reserved for later in the Section. Each tabulation is also accompanied by a few brief case histories, providing for a few species a bit more information about the nature of the changes reported in the tabulation.

Section 3.4 presents the total information extracted for each species group. It is intentionally as comprehensive as possible, to provide as large as 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. The criteria and processes for screening are described in Section 3.5. The cases meeting the screening criteria are combined into an integrated meta-analysis across all species groups, of the frequency with which there is evidence to support the hypothesis that changes in oceanographic conditions will result in changes in a species' distribution, abundance, or condition. Following this meta-analysis, the major results of these investigations are summarised for each species group, and then integrated into a narrative interpretation of the total evidence for oceanographic/climate effects. This interpretation synthesises the information from previous less systematic treatments of these issues with the present results, and supports the interpretation with a few case histories for each major taxon.

3.4 Tabulation of evidence

3.4.1 Plankton

3.4.1.1 Data sources and related information

The reports of the Working Group on Zooplankton (ICES, 2007; ICES, 2008) were used to extract specific information from reported peer-reviewed material, where possible, since the working group reports concentrated mainly on trends in functional groups. WGZE supplied focussed information on the OSPAR areas. Additional peer reviewed material was obtained to supplement the available information supplied by the working group. Much of the information on the zooplankton in the OSPAR area is a result of the Continuous Plankton Recorder (CPR) time series reflecting its wide ranging coverage.

3.4.1.2 Approach taken to use of data

For the main sources of data we describe the logic that was applied to decide whether a specific observation is expected to be caused by climate change.

Within the available material on changes in zooplankton ecology and phenology, trends are often reported, e.g. changes in meroplankton, rather than particular species-specific information. In order to interpret the observed changes in abundance, distribution and/or condition from WGZE reports and other information, the ultimate sources of these generic trends or responses of functional groups were extracted from peer-reviewed articles where possible.

For each report we assessed if there had been an overall change (decrease or increase) in abundance, distribution or condition, based on the presented material. Where possible the species affinities (e.g., temperate species or cold-water) were determined to aid interpretation of the results when authors were exploring potential relationships between sea surface temperature and hydrology with observed changes in a response variable.

The general trend in the North Atlantic is one of warming. Where peer-reviewed material was reviewed to identify the response of plankton to warming, the hypotheses being tested in cases of distribution and abundance were related to the biogeographic affinities of the plankton understudy, i.e. a warm-affinity species is presumed to increase in abundance and distribution-this is termed an expected response. Similarly a cold-affinity species is presumed to decrease in abundance and distribution with a warming trend. The period under study is 1960 onwards, where available. Phenological changes were identified as change/no change based on phenological deviations over a thirty year period.

Literature

Beaugrand *et al*., 2002 reports on the distribution of organisms which can be linked to their relative biogeographical affinities by using the CPR survey and Northern Hemisphere (NHT) anomalies and the NAO index. This allowed understanding of regional modifications in the marine ecosystem modified by changes in the hydrological regime. Strong biogeographical shifts in all calanoid copepod assemblages were identified with a northward extension of more than 10^{o} 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 temperature through marine systems. This approach can be extended to other material if the biogreographical affinity of the identified zooplankton is known, e.g., Beaugrand *et al*., 2007 studying *Centropages typicus* and Bonnet *et al*., 2005 studying *Calanus helgolandicus*.

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, e.g., pseudo-oceanic temperate species association such as the *Centropages typicus, Candacia armata*, *Calanus helgolandicus* group. 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; Kirby *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). The work of ICES (2006) is used to identify changes in phenology such as the start of zooplankton production season and the duration of the zooplankton season. A negative correlation of the timing of phenophases with increasing seawater temperature is regarded as a consequence of accelerated physiological processes, but also as a function of the species-specific characteristics. But unlike some of the documented changes in abundance and distribution linking to increase in temperature, changes in phenology in ICES (2006) tends to be reported at the functional group or genus level, although known species within the same genus, e.g., *Calanus finmarchicus*, C. *helgolandicus* and *C.* hyperboreus, have distinctly different biogeographic affinities. In light of this lack of species specific data, a change-whether or not an earlier or later start of a production period or a shorter or longer duration of a production period-is identified as a 'change' over time in a warming environment. The variability in the observed seasonality is related to the warming of the sea by 1.4°C during the past 40 years at the Helgoland Roads monitoring station.

3.4.1.3 Tabulation

The information derived from the WGZE is shown in Table 3.4.1.3.1. Within the time available there was an attempt to obtain information on extant studies relating to distribution, abundance and condition. Generally, there is more information on changes in distribution relating to warming trends (see below) than condition or abundance.

Table 3.4.1.3.1 Summary of available information of zooplankton response to climate change.

Table A.1. Summary of responses of zooplankton species to climate change.

Taxon	OSPAR Area	Property (1 - distribution; 2 - abundance ; 3 - condition)	Observed variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change: 1 - expected change; 2 - unexpected change)	Selection (1 - included in meta analysis)	Latitude	Longitude	Source	Group of Species
Acartia spp.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Acartia spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Acartia spp.	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Cold-temperate species association/ Indicator species of mixed water more usually found at the boundary between warm water and subarctic water
Actinotrocha	II	3	phenology -- change in start date of season	species response dependant on biology	0	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Actinotrocha	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Aetideus armatus	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Cold-temperate species association/ Indicator species of mixed water more usually found at the boundary between warm water and subarctic water
Alaurina composita	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Alaurina composita	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Asterias rubens bip.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Asterias rubens bip.	II	3	phenology -- change in length of season	species response dependant on biology	0	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Aurelia aurita	II	2	increasing abundance correlated with increasing temp (linked to NAO)		1	1	east of Scotland, 56-58.5°N	0-3°W	Lynam *et al*., 2004	
Aurelia aurita	II	2	increasing abundance correlated with increasing temp (linked to NAO)		2	1	north of Scotland, 58.5-59.5°N	3-5°W	Lynam *et al*., 2004	
Aurelia aurita	II	2	increasing abundance correlated with increasing temp (linked to NAO)		2	1	east of Shetland, 59-61°N	1°W-2°E	Lynam *et al*., 2004	
Aurelia aurita	II	2	increasing abundance correlated with increasing temp (linked to NAO)		1	1	west of northern Denmark 56-57°N	5-8°W	Lynam *et al*., 2004	
Beroe spp. juv.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Beroe spp. juv.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Calanoides carinatus	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Southern shelf edge species association/ Warm pseudo-oceanic species generally south of about 50°N along the European shelf edge
Calanus finmarchicus	I-V	1	change of distribution -- further north reduction in south	shift northwards	1	1			Beaugrand *et al*., 2002	Subarctic species association /Indicator species of subarctic water
Calanus finmarchicus	I-V	1	change of distribution -- further north reduction in south	correlated with warming trend	1				ICES, 2007(WGZE)	

Table 3.4.1.3.1 continued.

Calanus glacialis	I-V	1	reduction of distribution	concentration within suitable regions within the arctic		1			Beaugrand *et al*., 2002	Arctic species association/ Indicator species of arctic water
Calanus helgolandicus	II-IV	1	expansion of distribution -- further north	shift northwards	1	1			Bonnet *et al*., 2005	
Calanus helgolandicus	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Pseudo-oceanic temperate species association / Species can be found in oceanic and neritic water, but their abundance is higher along shelf edges generally until about 55°N
Calanus helgolandicus	I-V	1	change of distribution -- further north	correlated with warming trend	1				ICES, 2007 (WGZE)	
Calanus hyperboreus	I-V	1	reduction of distribution	concentration within suitable regions within the arctic		1			Beaugrand *et al*., 2002	Arctic species association/ Indicator species of arctic water
Calanus spp.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Calanus spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Candacia armata	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Pseudo-oceanic temperate species association / Species can be found in oceanic and neritic water, but their abundance is higher along shelf edges generally until about 55°N
Centropages spp.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Centropages spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Centropages typicus	I-V	2	increase in abundance	increasing abundance with increasing temp	1	1			Beaugrand *et al*., 2007	
Centropages typicus	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Pseudo-oceanic temperate species association / Species can be found in oceanic and neritic water, but their abundance is higher along shelf edges generally until about 55°N
Cirripedia nauplii	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Cirripedia nauplii	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Copepoda nauplii	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Copepoda nauplii	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Corycaeus spp.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Corycaeus spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Ctenocalanus vanus	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Southern shelf edge species association/ Warm pseudo-oceanic species generally south of about 50°N along the European shelf edge

Table 3.4.1.3.1 continued.

Cyanea lamarckii	II	2	increasing abundance correlated with increasing temp (linked to NAO)		2	1	east of Scotland, 56-58.5°N	0-3°W	Lynam *et al*., 2004	
Cyanea lamarckii	II	2	increasing abundance correlated with increasing temp (linked to NAO)		2	1	north of Scotland, 58.5-59.5°N	3-5°W	Lynam *et al*., 2004	
Cyanea lamarckii	II	2	increasing abundance correlated with increasing temp (linked to NAO)		2	1	east of Shetland, 59-61°N	1°W-2°E	Lynam *et al*., 2004	
Cyanea lamarckii	II	2	increasing abundance correlated with increasing temp (linked to NAO)		1	1	west of northern Denmark, 56-57°N	5-8°W	Lynam *et al*., 2004	
Cyphonautes	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Cyphonautes	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Echinocardium cordatum	II	1	increase distribution north and abundance	correlated with warming trend (winter and spring SST)	1	1			Kirby *et al*., 2007	
Echinocardium cordatum	II	2	increase distribution north and abundance	correlated with warming trend (winter and spring SST)	1	1			Kirby *et al*., 2007	
Eucalanus crassus	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Pseudo-oceanic temperate species association / Species can be found in oceanic and neritic water, but their abundance is higher along shelf edges generally until about 55°N
Euchaeta gracilis	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Southern shelf edge species association/ Warm pseudo-oceanic species generally south of about 50°N along the European shelf edge
Euchaeta hebes	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Southern shelf edge species association/ Warm pseudo-oceanic species generally south of about 50°N along the European shelf edge
Euchaeta norvegica	I-V	1	change of distribution -- further north reduction in south	shift northwards	1	1			Beaugrand *et al*., 2002	Subarctic species association /Indicator species of subarctic water
Evadne spp.	II	3	phenology -- change in start date of season	species response dependant on biology	0	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Evadne spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Fish-eggs	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Fish-eggs	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Fish-larvae	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Fish-larvae	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	

Table 3.4.1.3.1 continued.

Fritillaria borealis	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Fritillaria borealis	II	3	phenology -- change in length of season	species response dependant on biology	0	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Gastropod larvae	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Gastropod larvae	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Heterorhabdus norvegicus	I-V	1	change of distribution -- further north reduction in south	shift northwards	1	1			Beaugrand *et al*., 2002	Subarctic species association /Indicator species of subarctic water
Lamellibranch larvae	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Lamellibranch larvae	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Lanice spp.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Lanice spp.	II	3	phenology -- change in length of season	species response dependant on biology	0	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Magelona spp.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Magelona spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Metridia longa	I-V	1	reduction of distribution	concentration within suitable regions within the arctic		1			Beaugrand *et al*., 2002	Arctic species association/ Indicator species of arctic water
Metridia lucens	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Cold-temperate species association/ Indicator species of mixed water more usually found at the boundary between warm water and subarctic water
Mnemiopsis leidyi	II	1	spread with increasing temp	appearance/occurance potential linked to higher temperatures (greater than 4°C in winter)	1	1	54°11.18'N	07°54'E	Boersma *et al*., 2007	
Mnemiopsis leidyi	II	1	spread with increasing temp	appearance/occurance potential linked to higher temperatures	1	1			Faasse and Bayha ,2006	
Noctiluca scintillans	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Noctiluca scintillans	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Obelia spp.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Obelia spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Oikopleura dioica	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Oikopleura dioica	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	

Table 3.4.1.3.1 continued.

Oithona spp.	II	3	phenology -- change in start date of season	species response dependant on biology	0	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Oithona spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Ophiuroidea pluteus	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Ophiuroidea pluteus	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Para- Pseudocalanus	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Para- Pseudocalanus	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Penilia avirostris	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Penilia avirostris	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Pleurobrachia p. juv.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Pleurobrachia p. juv.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Pleuromamma robusta	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Cold-temperate species association/ Indicator species of mixed water more usually found at the boundary between warm water and subarctic water
*Podon s*pp.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Podon spp.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Rathkea + Lizzia	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Rathkea + Lizzia	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Rhincalanus nasutus	I-V	1	expansion of distribution -- further north	shift northwards	1	1			Beaugrand *et al*., 2002	Pseudo-oceanic temperate species association / Species can be found in oceanic and neritic water, but their abundance is higher along shelf edges generally until about 55°N
Sagitta	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Sagitta	II	3	phenology -- change in length of season	species response dependant on biology	0	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Scolecithricella spp.	I-V	1	change of distribution -- further north reduction in south	shift northwards	1	1			Beaugrand *et al*., 2002	Subarctic species association /Indicator species of subarctic water
Spatangoid pluteus	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Spatangoid pluteus	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	
Spionid larva	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)	

Table 3.4.1.3.1 continued.

Spionid larva	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)
Temora longicornis	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)
Temora longicornis	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)
Temora stylifera	IV	1	increase distribution north and abundance	correlated with warming trend	1	1			Valdés *et al*., 2007
Temora stylifera	IV	2	increase distribution north and abundance	correlated with warming trend	1	1			Valdés *et al*., 2007
Trochophora unident.	II	3	phenology -- change in start date of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)
Trochophora unident.	II	3	phenology -- change in length of season	species response dependant on biology	1	1	54° 11'N	7° 54'E	ICES, 2006 (CRR 281)

3.4.1.4 Observations regarding the tabulation

By far, changes in distribution are the most obvious response to climate change displayed by zooplankton. Phenology appears to be very sensitive to temperature variation; however, the response appears to vary substantially across functional groups. This may reflect the hierarchal level of analyses, as breaking down the information to the species level may elucidate specific characteristic species trends to temperature variation.

3.4.1.5 Case histories

Beaugrand *et al.*, 2002 offers persuasive 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 3.4.1.5.1). The information presented offers articulate and credible evidence of change in the OSPAR areas. 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.

These changes in the physical oceanographic regime and the biological component (e.g. phyto- zooplankton community composition: Beaugrand, 2003; Beaugrand and Reid, 2003; Reid *et al.*, 2001; Reid *et al.*, 2003) are reflected in changes in the higher trophic community composition of the ecosystem (Alheit *et al.*, 2005; Beaugrand, 2004).

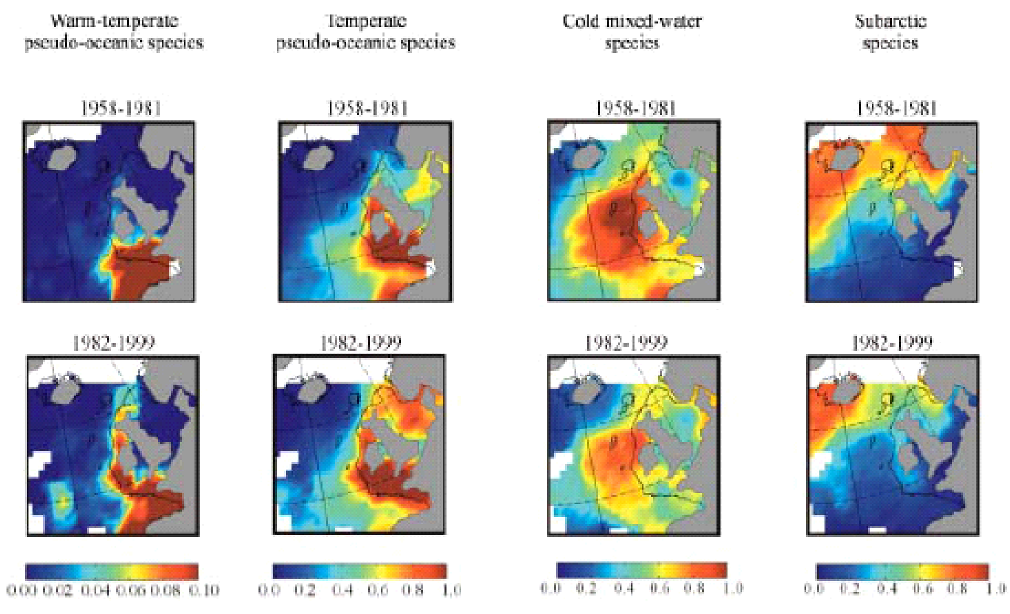

Figure 3.4.1.5.1 Maps showing biogeographical shifts of calanoid copepod communities in recent decades, with the warm water species shifting northwards and the cold water species likewise retracting north, by over 10o of latitude (Beaugrand *et al.*, 2002).

3.4.1.6 References

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3.4.2 Benthos

3.4.2.1 Data sources and related information

Four information sources were used to extract information about benthos in the OSPAR area, including evidence for effects of responses in abundance and range relative to oceanographic conditions.

The first was the 2008 report of the ICES Working Group on Benthic Ecology. They included a number of brief summaries of studies of either individual benthic species or benthic communities. These summaries were organized by the environmental or climatic factor thought to be influencing the species rather than by taxonomic group or region. The selected studies all covered time periods long enough to warrant examination of trends, and were considered by the experts in WGBE to show effects of oceanographic conditions, usually temperature, on distribution or abundance of the species or the aggregate community property being reported. Information from each of the examples presented in that section of the WGBE report was transferred into the generic template.

The second was the report by Kronke *et al.*, 1998 of a 28 year study of the benthos in the southern North Sea. Macrofaunal samples were collected seasonally from 1978 to 2005 in the sublitoral zone off the island of Norderney, one of the East Frisian barrier islands. Samples were taken at five stations in water depths of 10–20 m. The results for species number, abundance and biomass from the 5 stations were pooled and treated as replicates for the area. Interface-feeders dominate in the area, followed by sand lickers and subsurface deposit-feeders. The analyses reported in the Kronke *et al.*, 1998 study focus on trends in community metrics, and relate these to oceanographic features, particularly temperature, and the North Atlantic Oscillation. However, the study does include figures for a dozen individual species of benthos, selected because their annual abundance was high enough for meaningful consideration. The WGBE report had captured the results of the community-scale analyses. However the time series of the 12 individual species reported in Kronke *et al.*, 1998 were included individually in the data base for meta-analyses and investigation of trends.

The third was a study of the benthos at two stations in La Coruna Bay, off northern Spain. The original study, with sampling methods and data processing protocols, was reported in Lopez-Jamar *et al.*, 1995 for 1982–1993. Additional information was available to extend those series to 2006, with breaks in the sampling in some years from a presentation by Parra *et al.*, 2007 to the Benthic Ecology working group. One of the stations was located in a muddy area that had been dredged in 1982 and local disturbances were fairly common in the area thereafter. The other site was on fine sand further out in the bay, where water quality was higher and disturbances were rarer. Consequently, for reasons independent of water temperate and climatic factors, the species composition of the two sampling areas was quite different. For the species with time series reported in Parra *et al.*, 2007 it was often the case that the abundance of the species in one of the sampling sites was consistently much higher than it was in the other site. In those cases we accepted the arguments of the authors, considered the area of substantially greater abundance to be the area with the sediment type, disturbance regime, or water quality more suitable for the species, and used the time series for the more abundant site. For species with comparable abundances in both sites, we used the combined abundance over both sites as the basic information for our template. In total, adequate data were available for 12 species from this long-term study.

The fourth source of information was the Report of the North Sea Benthic Project, which were recently released as ICES Cooperative Research Report No. 288 (Rees *et al.*, 2007). That report has a variety of sections reporting, among other things, possible relationships between benthic community parameters and climate and/or oceanographic conditions. Most of those relationships had been picked up in the first information source, the WGBE Report. However, Section 5.4 of the CRR has figures of abundance and distribution for a suite of species at each of 156 stations sampled consistently in 1986 and 2000. Information on sampling methods and handling of data are available in that source. The suite of species was selected solely because they were found to be systematically informative about patterns of change in abundance or range when used in multivariate statistical analyses. The overall changes, if any, in abundance and range between the two years were entered into the tabulation for all the species in that section of the report.

3.4.2.2 Approach taken to use of data

For the species from the WGBE report, we used whatever ecological property was selected by the WGBE experts, and simply tabulated the prediction of directional change as reported in their report. We also took the observed trend in the same property, again exactly as reported by the Expert Group, and accepted the WGBE's conclusion whether the predicted and observed trends were consistent, contradictory, or if the experts concluded for some reason that the time series data would not be informative about trends in abundance, distribution or other property of interest. From the WGBE report there were also a few examples of trends over time in entire (or partial) benthic communities. In these cases the Expert Group also provided directional predictions for the communities and conclusions about matching to expected patterns based on oceanographic influence. The conclusions were reviewed and considered to be individually well justified.

For the Kronke *et al*., 1998 data, the authors report the trends in temperature and NAO over the time period of the sampling. In that area a high NAO is generally associated with warmer conditions, particularly in winter, whereas winters with low NAO may be colder than normal. Overall hydrographic conditions were considered to be cooler in the early 1980s, warmer in the late 1980s, then anomalously cold again in the early 1990s, and warmer again thereafter, until the early 2000s. That was taken as overall guidance for the trends in hydrographic conditions, with the strong signal in the early 1990s particularly important. For the abundance data, each species was assigned to a biogeographic zonation, based on literature sources. The Kronke *et al*., 1998 article assigned a few of the species to classifications of "deep, cold water" or "warm, souther", and these assignments were used. A few others were similarly classified in the NSBP report, and those classifications were also used. For the rest of the species the primary source was the MARLIN website (http://www.marlin.ac.uk/baski/ref). When the MARLIN site had no information on the distribution and habitat preferences of the species, then other sources were used. The two primary alternatives where the "Zipcode Zoo" website (http://zipcodezoo.com/Animals/), associated with the Global Biodiversity Information Facility, and the MARBEF website (http://www.marbef.org/data/) associated with the EU-funded MARBEF project. For species considered to have their centres of distribution in the southern North Sea, Iberian Seas, or extending strongly into the Mediterranean, these were considered "southern" or "warm" species, particularly if reports from the northern North Sea and the Norwegian and Barents Sea were rare or absent. Species with centres of distribution in the Northern North Sea or further North, and/or designated in the sources as inhabiting deep and cold sites, were considered "northern" or "cold species. When there was insufficient information on distribution to make such as assessment, the species was not classified, and no expectations were developed. The "expected" patterns were that "warm" species would have increased in the late 1980s and late 1990s and beyond, but been at relatively low abundance (for the species) in the early 1980s, and would have underwent substantial declines in abundance in the early 1990s. For the "cold" or "northern" species, exactly the opposite patterned was considered the "expected".

A conclusion that the two patterns matched required that, "warm" species show a recognisable decline during or immediately after the cold winters in 1991 and 1992, and have been at a higher abundance in the late 1980s and late 1990s than in the early 1980s and early 1990s. "Cold" species needed to show a recognisable increase during or immediately after the cold winters in 1991 and 1992, have been at a lower abundance in the late 1980s and late 1990s than in the early 1980s and early 1990s.

For the La Coruna cases, exactly the same approach was taken to develop "expected". According to the authors, the environmental conditions in the area, particularly at the sandy site, are strongly influenced by the state of the NAO, whose influence is explained in the sources. For the 1980s the NAO started in a condition which was thought to be somewhat favourable to the more northerly species in winter, but with summer conditions showing an overall warming trend until the mid 1990s. Over this period southern species would have been generally favoured over northern species. However, two anomalously cold winters were reported in 1991 and 1992. Through the 2000s the NAO was of moderate value, with summer conditions slowly cooling. This period was considered unlikely to strongly favour either "warm" or "cold" species, although "warm" species that had built up large abundances through the 1990s might not maintain such high abundances. The "expectations" of these species was that the most temperature sensitive species should have a marked spike in the early 1990s due to the cold winters, with "cold" species first increasing quickly then declining after 1993 and "warm" species dropping quickly in 1991 and rebounding after 1993. Otherwise "warm" species were expected to increase slowly over the time series until the late 1990s and gradually decline thereafter, whereas "cold" species would generally decrease, except in the early 1990s, and show little trend through the 2000s.

For a conclusion that the two patterns matched "cold" species had to show a marked increase in abundance between 1990 and 1993, but have had their abundance decline substantially by the end of the 1990s. "Warm" species had to show some increase through the 1980s, and an abrupt decline in abundance in the early 1990s. For the "warm" species that built up large abundances through the mid-late 1990s, their abundance had to decline to some extent during the 2000s. Warm species that only increased slowly in abundance through the 1990s did not need to show a decline in the 2000s.

For the species from the NSBP report, the data were maps of abundance by site for 1986 and 2000. In the majority of cases the species-wise predictions were based on biogeographic classifications of the species that were presented in the NSBP report. For the ones whose distributional tendencies were presented in the source report, the MARLIN data-based was used as in the tabulation of the Kronke data. Consistent with the information in 3.1 it was simply assumed that the North Sea was warmer in 2000 than in 1986. For species considered "warm" or preferring the shallower parts of the North Sea, their abundance should be higher and their range should be broader in 2000 than in 1986. A match was assumed when such an increase occurred. For species considered "cold" or "deep" their abundance should be lower and their ranges narrower. A match was assumed when such a decrease occurred.

3.4.2.3 Tabulation

The information on individual species or species groups from the Working Group on Benthic Ecology is summarized in Table 3.4.2.3.1. The majority of cases in the table are of changes in distribution over time, with some time series extending over 20 years or more. All but two of the cases are from OSPAR area II, and the exceptions are from IV. All examples extracted from the WGBE report show trends that were consistent with the predictions based on each species' biology and distribution. This is not surprising, as the WGBE report states that the cases were selected just because they all show evidence of the influence of ocean conditions on abundance, range or some aspect of the species' life histories.

Table 3.4.2.3.1 The information on individual species or species groups from the Working Group on Benthic Ecology is summarized.

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
Abra alba	II	1	Increase range, abundance	Prefers warm waters ++	1	1	Rees *et al.* 2007
Abra alba	II	2	Increase range, abundance	Prefers warm waters ++	1	1	Rees *et al.* 2007
Abra alba communities	II	2	--				Fromentin & Ibanez 1994
Amphipod *Amphiura brachiata*	II	2	--	Biogeographic zonation as "warm"	1		Wieking & Kröncke 2001
Amphipod *Megaluropus agilis*	II	2	Increase in abundance	Biogeographic zonation as "warm"	1		Wieking & Kröncke 2001
Amphiura brachiata	II	1	Increase range, abundance	Apparently widespread, more southernly +	1	1	Wieking & Kröncke 2001
Amphiura brachiata	II	2	Increase range, abundance	Apparently widespread, more southernly +	1	1	Wieking & Kröncke 2001

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis—see section 3.5)	Source
Amphiura chiajei	II	1	Large increase in range, abundance	Widespread and common southern Norway to Morocco - burrowing +	1	1	Wieking & Kröncke 2001
Amphiura chiajei	II	2	Large increase in range, abundance	Widespread and common southern Norway to Morocco - burrowing +	2	1	Wieking & Kröncke 2001
Amphiura filiformis	II	1	Decrease in abundance in south	Widespread and common Iceland to Iberia -	1	1	Wieking & Kröncke 2001
Amphiura filiformis	II	2	Decrease in abundance in south	Widespread and common Iceland to Iberia -	0	1	Wieking & Kröncke 2001
Antalis entalis	II	1	Major decrease in range and abundance	Deep northern waters --	1	1	Wieking & Kröncke 2001
Antalis entalis	II	2	Major decrease in range and abundance	Deep northern waters --	1	1	Wieking & Kröncke 2001
Arctica islandica	II	1	Decrease range, abundance	Northern species, but not extremely so -	1	1	Wieking & Kröncke 2001

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis—see section 3.5)	Source
Arctica islandica	II	2	Decrease range, abundance	Northern species, but not extremely so -	1	1	Wieking & Kröncke 2001
Bathyporeia elegans	II	2	Eliminated in cold winters; overall upward recently	Central north sea	2	1	Kröncke *et al.* 1998
Bathyporeia guillamsoniana	II	2	Increased early 1990's and ealrly 2000's; uncommon at other periods	Southern north sea only	1	1	Kröncke *et al.* 1998
Bathyporeia spp.	II	1	No change in range, decrease in abundance	Southern and central distribution +	0	1	Kröncke *et al.* 1998
Bathyporeia spp.	II	2	No change in range, decrease in abundance	Southern and central distribution +	2	1	Kröncke *et al.* 1998
Benthos aggregated	II	1	Increase in warm species, decrease in cold	Biogeographic zonation of taxa	1	1	Wieking & Kröncke 2001
Benthos aggregated	II	1	Northern species increased	Biogeographic zonation of taxa	1	1	Wieking & Kröncke 2001
Benthos aggregated	II	1	Highly variability with NAO and freshwater inflow; overall decline	???	0	1	Josefson & Hansen 2003
Benthos aggregated	II	1	Increase in warmer years linked to bottom temperature	Biogeograhic classification	1	1	Hagberg *et al.* 2004
Benthos aggregated	II	1	Northern species increased	Biogeographic zonation of taxa	2	1	Wieking &

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
							Kröncke 2001
Benthos aggregated	II	2	No change in biomass	Increase	0	1	Rees *et al.* 2007
Benthos aggregated	II	2	Decrease in warm winters	Biogeographic classification as "deep"/"cold" species	1	1	Rees *et al.* 2006
Benthos aggregated	II	2	Increase in diversity, drop in density	Warm species increased especially after 1996	1	1	Warwick *et al.* 2002
Benthos aggregated	II	2	Increase in warm species, decrease in cold	Biogeographic zonation of taxa	1	1	Wieking & Kröncke 2001
Benthos aggregated	II	2	Northern species increased	Biogeographic zonation of taxa	1	1	Wieking & Kröncke 2001
Benthos aggregated	II	2	Northern species increased	Biogeographic zonation of taxa	2	1	Wieking & Kröncke 2001
Benthos aggregated	II	3	Increase in diversity, drop in density	Warm species increased especially after 1996	1	1	Warwick *et al.* 2002
Bivalve *Arctica islandica*	II	3	Feeding conditions and growth affected by inflow in Dooley Current	Unclear	1		Witbaard 1996

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis—see section 3.5)	Source
Bivalve *Nucula*	II	1	Increase in range	Biogeographic zonation as "warm"	1		Rees *et al.* 2007
Bivalves	II	2	Increase in mortality in cold winters	Predicted increase with climate change	1		Beukema 1990; 1992 and Bhaud *et al.* 1995
Brittle star *Amphiura brachiata*	II	1	Increase in range	Biogeographic zonation as "warm"	1		Rees *et al.* 2007
Callianassa subterranea	II	1	No marked change	Southern central - Med. to southern Norway +	0	1	Rees *et al.* 2007
Callianassa subterranea	II	2	No marked change	Southern central - Med. to southern Norway +	0	1	Rees *et al.* 2007
Chaetoderma nitidulum	II	1	Increase in range, decrease in abundance	Southern/central species -	2	1	Rees *et al.* 2007
Chaetoderma nitidulum	II	2	Increase in range, decrease in abundance	Southern/central species -	1	1	Rees *et al.* 2007
Chamelea gallina	II	1	Increase in range to north, decrease in abundance to east	Central NS generalist neutral	2	1	Rees *et al.* 2007
Chamelea gallina	II	2	Increase in range to north, decrease in abundance to east	Central NS generalist neutral	2	1	Rees *et al.* 2007
Coarser sediment (*e.g. Echinocyamus pusillus*)	II	2	Increase with strong NAO	Positive with increase in large sediments and large food	1		Wieking & Kröncke

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis—see section 3.5)	Source
				particules			2001
Corbula gibba	II	1	Major increase, range and abundance	Widespread generalist neutral	2	1	Wieking & Kröncke 2001
Corbula gibba	II	2	Major increase, range and abundance	Widespread generalist neutral	2	1	Wieking & Kröncke 2001
Crassostrea gigas	II	2	Increase in abundance	Warm water Pacific species	1		Nehls & Büttger 2007
Dog whelks	II	1	Increase in range	Biogeographic zonation as "warm"	1		Rehm & Rachor 2007
Donox vittatus	II	2	Only increased with warm winters	Warm species +	1	1	Kröncke *et al.* 1998
Echinocardium cordatum	II	1	Increase in range, abundance not changed	Southern species ++	1	1	Kröncke *et al.* 1998
Echinocardium cordatum	II	2	Increase in range, abundance not changed	Southern species ++	0	1	Kröncke *et al.* 1998
Echinocardium cordatum	II	2	High variability, no trend	Southern species	0	1	Kröncke *et al.* 1998
Echinocyamus pusillus	II	1	Increase in range, decrease in abundance	Widespread Finmark to Med. Neutral	2	1	Kröncke *et al.* 1998

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
Echinocyamus pusillus	II	2	Increase in range, decrease in abundance	Widespread Finmark to Med. Neutral	2	1	Kröncke *et al.* 1998
Exogone verugera	II	1	Major decrease in abundance and range	Deep - cold - fine sediments --	1	1	Kröncke *et al.* 1998
Exogone verugera	II	2	Major decrease in abundance and range	Deep - cold - fine sediments --	1	1	Kröncke *et al.* 1998
Fabulina fabula	II	2	Disappeared after cold winters overall increase	Wide tolerance	0	1	Kröncke *et al.* 1998
Fabulina fabula	II	1	Increase in range, little change in abundance	Shallow, generalist neutral	2	1	Kröncke *et al.* 1998
Fabulina fabula	II	2	Increase in range, little change in abundance	Shallow, generalist neutral	1	1	Kröncke *et al.* 1998
Hardbottom macrofauna	II	1	Increase in warm-water species	Biogeographic zonation as "warm"	1		Franke & Gutow 2004
Lanice conchilega	II	1	Large increases, range and abundance	Warm southern coastal ++	1	1	Franke & Gutow 2004
Lanice conchilega	II	2	Large increases, range and abundance	Warm southern coastal ++	1	1	Franke & Gutow 2004
Macoma balthica	II	2	Decrease in abundance	Mismatch of timing	1		Philippart *et al.* 2003
Macrofauna	II	2	Increase in abundance and biomass	Cold winters associated with	1		Kröncke *et*

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
				higher mortality			*al.* 1998
Magelona spp	II	2	Consistent decrease in warm NOA condictions, increase in cold & positive NAO	Widespread in northern Europe	1	1	Kröncke *et al.* 1998
Many benthic species	II	1	North and south shifts in boundaries	Biogeographic zonation into "warm" and "cold" species	1		Alcock 2003
Myriochele spp.	II	1	Decrease in range, increase in abundance	Deep northern waters --	1	1	Alcock 2003
Myriochele spp.	II	2	Decrease in range, increase in abundance	Deep northern waters --	2	1	Alcock 2003
Mysella bidentata	II	1	Decrease in abundance in south, increase in north	Southern range for species +	0	1	Alcock 2003
Mysella bidentata	II	2	Decrease in abundance in south, increase in north	Southern range for species +	1	1	Alcock 2003
Nephtys longosetosa	II	1	Decrease in abundance, no change in range	Central NS habitat specialist neutral	1	1	Alcock 2003
Nephtys longosetosa	II	2	Decrease in abundance, no change in range	Central NS habitat specialist neutral	2	1	Alcock 2003
Nephtys spp	II	2	Decline during cold winters, increase in early 1990s	Warm water species	1	1	Kröncke *et al.* 1998
Nucula nitidosa	II	1	Increase range, little change in	Coastal warm does reach	1	1	Kröncke *et*

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
			abundance	norway +			*al.* 1998
Nucula nitidosa	II	2	Increase range, little change in abundance	Coastal warm does reach norway +	0	1	Kröncke *et al.* 1998
Nuculoma tenuis	II	1	Increase in range, decrease in abundance	Southern species ++	1	1	Kröncke *et al.* 1998
Nuculoma tenuis	II	2	Increase in range, decrease in abundance	Southern species ++	0	1	Kröncke *et al.* 1998
Ophelia borealis	II	1	Decrease in abundance, no change in range	Sidespread, central-northern habitat specialist -	2	1	Kröncke *et al.* 1998
Ophelia borealis	II	2	Decrease in abundance, no change in range	Sidespread, central-northern habitat specialist -	1	1	Kröncke *et al.* 1998
Other rare bivalves	II	2	All increased after cold periods ended	--	1	1	Kröncke *et al.* 1998
Owenia fusiformis	II	2	Only present in warm years	Widespread, southern	1	1	Kröncke *et al.* 1998
Paramphinome jeffreysii	II	1	Major increase in range, some increase in abundance	Northern species --	2	1	Kröncke *et al.* 1998
Paramphinome jeffreysii	II	2	Major increase in range, some increase in abundance	Northern species --	2	1	Kröncke *et al.* 1998
Pollicipes pollicipes	II	2	Increase with strong NAO	Increase in wave energy			Borja *et al.* 2006

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
Polychaete *Ophelia borealis*	II	2	Decrease in abundance	Biogeographic zonation as "cold"	1		Wieking & Kröncke 2001
Prionospio cirrifera	II	1	Major decrease in abundance, decrease in range	Deep northern waters --	1	1	Wieking & Kröncke 2001
Prionospio cirrifera	II	2	Major decrease in abundance, decrease in range	Deep northern waters --	1	1	Wieking & Kröncke 2001
Pseudocuma longicornis	II	2	No consistent trend	Widespread	1	1	Kröncke *et al.* 1998
Sabellaria spinulosa	II	1	Increase in range, abundance	Widespread coastal central neutral	2	1	Kröncke *et al.* 1998
Sabellaria spinulosa	II	2	Increase in range, abundance	Widespread coastal central neutral	2	1	Kröncke *et al.* 1998
Scoloplos	II	2	No trend until mid 1990's, then increase	Arctic Species -	2	1	Kröncke *et al.* 1998
Scoloplos armiger	II	1	Decrease in abundance, no change in range	Generalist neutral	1	1	Kröncke *et al.* 1998
Scoloplos armiger	II	2	Decrease in abundance, no change in range	Generalist neutral	2	1	Kröncke *et al.* 1998
Species occurring on fine sand (*e.g.*	II	2	Decrease with strong positive NAO	Negative with increasing	1		Wieking &

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
Ophelia borealis)				mixing to reduce sediments and small food			Kröncke 2001
Spiophanes bombyx	II	1	Increase in abundance, no change in range	Generalist neutral	1	1	Wieking & Kröncke 2001
Spiophanes bombyx	II	2	Increase in abundance, no change in range	Generalist neutral	2	1	Wieking & Kröncke 2001
Spiophanes krøyeri	II	1	Increase in range, no change in abundance	Generalist neutral	2	1	Wieking & Kröncke 2001
Spiophanes krøyeri	II	2	Increase in range, no change in abundance	Generalist neutral	1	1	Wieking & Kröncke 2001
Synelmis klatti	II	1	Decrease range abundance	Southern central - fine habitats +	1	1	Wieking & Kröncke 2001
Synelmis klatti	II	2	Decrease range abundance	Southern central - fine habitats +	1	1	Wieking & Kröncke 2001
Terebellides stroemi	II	1	Increase in range, no change in abundance	Widespread Arctic to Iberia neutral	2	1	Wieking & Kröncke

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
							2001
Terebellides stroemi	II	2	Increase in range, no change in abundance	Widespread Arctic to Iberia neutral	1	1	Wieking & Kröncke 2001
Urothoe poseidonis	II	1	Increase range, little change in abundance	Southern - fine habitats +	1	1	Wieking & Kröncke 2001
Urothoe poseidonis	II	2	Increase range, little change in abundance	Southern - fine habitats +	0	1	Wieking & Kröncke 2001
Urothoe poseidonis	II	2	Large declines in cold winters, slow recoveries	Cold temperate	1	1	Kröncke *et al.* 1998
Abra alba	IV	2	Highly variable, decreasing trend in 2000's	Warm species	1	1	Lopez-Jamar *et al.* 1995
Abra nitida	IV	2	Highly variable -decreasing trend	Warm coastal	1	1	Lopez-Jamar *et al.* 1995
Armandia polyophthalma	IV	2	Increase in 1990s then decrease	Strong southern distribution	1	1	Lopez-Jamar *et al.* 1995
Capitella capitata	IV	2	Overall decrease with variability	Widespread broad tolerance	0	1	Lopez-Jamar *et al.* 1995
Chaetozone gibber	IV	2	Abundance highly variable - no net trend	Northern species	2	1	Lopez-Jamar *et al.* 1995

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis— see section 3.5)	Source
Diopatra neapolitana	IV	2	Low to late 1980s, then up and down to very low by 2000	Southern med species	1	1	Lopez-Jamar *et al.* 1995
Malacoceros fuliginosus	IV	2	Two outbreaks but no trend	Northern species	0	1	Lopez-Jamar *et al.* 1995
Mediomastus fragilis	IV	2	Major increase in early 1990's then stable	Common to north	1	1	Lopez-Jamar *et al.* 1995
Notomastus latericeus	IV	2	Highly variable, large decrease after mid 1990's	Northern abundance higher	2	1	Lopez-Jamar *et al.* 1995
Ophiodromus flexuosus	IV	2	Highly variable, decreasing trend	Northern species	2	1	Lopez-Jamar *et al.* 1995
Ophryotrocha hartmanni	IV	2	Highly variable, lower in 2000's	Northern species	2	1	Lopez-Jamar *et al.* 1995
Paradoneris armata	IV	2	Strong decrease to 1997, increase and flat thereafter	Spotty distribution	0	1	Lopez-Jamar *et al.* 1995
Phyllodoce lineata	IV	2	General decrease, outbreak in early 1990's	Strongly southern species	1	1	Lopez-Jamar *et al.* 1995
Pseudopolydora paucibranchiata	IV	2	Brief major outbreak, no trend	Warm strongly southern - invasive	0	1	Lopez-Jamar *et al.* 1995
Pseudopolydora pulchra	IV	2	Overall decrease, high variation	Widespread northern	1	1	Lopez-Jamar *et al.* 1995
Spio decoratus	IV	2	Highly variable - no trend	Southern species	0	1	Lopez-Jamar

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Selection (1 – included in meta analysis—see section 3.5)	Source
							et al. 1995
Tellina fabula	IV	2	Outbreak in mid 1990's; no trend	Lower thermal tolerance	1	1	Lopez-Jamar *et al*. 1995
Thyasira flexuosa	IV	2	Consistent decrease, especially in higher density area	Northern species	1	1	Lopez-Jamar *et al*. 1995
Tubificoides sp	IV	2	Increase 88-92, decrease thereafter	Unclear for genus	0	1	Lopez-Jamar *et al*. 1995

The information on benthic community properties from WGBE is in Table 3.4.2.3.2 and 3.4.2.3.3. Again all the reported cases do show evidence of a response of the aggregate benthic biomass, richness or diversity to environmental conditions, in the direction expected if warmer conditions were associated with more productive systems with greater richness and/or diversity. Again this is not surprising as the cases were selected to illustrate these effects.

The information on benthic species from the La Coruna study is in Table 3.4.2.3.4. All cases are change in abundance, as the two sampling stations do not give information about range.

Table 3.4.2.3.2 The information on benthic community properties from the Working Group on Benthic Ecology is summarized.

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (range, abundance) (0 - no change; 1 - equals expected; 2 - not expected)	Source
Benthos	II	2	No change in biomass	Increase	0	Rees *et al.* 2006
Benthos	II	2	Decrease in warm winters	Biogeographic classification as "deep"/"cold" species	1	Rees *et al.* 2006
Benthos	II	2,3	Increase in diversity, drop in density	Warm species increased especially after 1996	1	Warwick *et al.* 2002
Benthos	II	1,2	Increase in warm species, decrease in cold	Biogeographic zonation of taxa	1	Wieking & Kröncke 2001
Benthos	II	1,2	Northern species increased	Biogeographic zonation of taxa	1	Wieking & Kröncke 2001
Benthos	II	1	Highly variability with NAO and freshwater inflow; overall decline	???	0	Josefson & Hansen 2003
Benthos	II	1	Increase in warmer years linked to bottom temperature	Biogeograhic classification	1	Hagberg *et al.* 2004
Benthos	II	1,2	Northern species increased	Biogeographic zonation of taxa	2	Wieking & Kröncke 2001

Table 3.4.2.3.3 The information on benthic community properties from the Working Group on Benthic Ecology is summarized.

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (range, abundance) (0 - no change; 1 - equals expected; 2 - not expected)	Source
Abra alba communities	North Sea	2	WGBE			Fromentin & Ibanez 1994
Bivalves	North Sea	2	Increase in mortality in cold winters	Predicted increase with climate change	1	Beukema 1990; 1992 and Bhaud *et al*. 1995
Crassostrea gigas	Wadden Sea	2	Increase in abundance	Warm water Pacific species	1	Nehls & Büttger 2007
Macrofauna	Friesan Coast	2	Increase in abundance and biomass	Cold winters associated with higher mortality	1	Kröncke *et al*. 1998
Brittle star Amphiura brachiata	North Sea	1	Increase in range	Biogeographic zonation as "warm"	1	Rees *et al*. 2007
Bivalve Nucula	North Sea	1	Increase in range	Biogeographic zonation as "warm"	1	Rees *et al*. 2007
Dog whelks	Southern North Sea	1	Increase in range	Biogeographic zonation as "warm"	1	Rehm & Rachor 2007
Amphipod Megaluropus agilis	Dogger Bank	2	Increase in abundance	Biogeographic zonation as "warm"	1	Wieking & Kröncke 2001
Amphipod Amphiura brachiata	Dogger Bank	2	--	Biogeographic zonation as "warm"	1	Wieking & Kröncke 2001
Polychaete Ophelia borealis	Dogger Bank	2	Decrease in abundance	Biogeographic zonation as "cold"	1	Wieking & Kröncke 2001

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (range, abundance) (0 - no change; 1 - equals expected; 2 - not expected)	Source
Hardbottom macrofauna	Helgoland	1	Increase in warm-water species	Biogeographic zonation as "warm"	1	Franke & Gutow 2004
Many benthic species	Bay of Biscay	1	North and south shifts in boundaries	Biogeographic zonation into "warm" and "cold" species	1	Alcock 2003
Macoma balthica	North sea	2	Decrease in abundance	Mismatch of timing	1	Philippart *et al.* 2003
Bivalve Arctica islandica	Central North Sea	3	Feeding conditions and growth affected by inflow in Dooley Current	Unclear	1	Witbaard 1996
Species occurring on fine sand (e.g. Ophelia borealis)		2	Decrease with strong positive NAO	Negative with increasing mixing to reduce sediments and small food	1	Wieking & Kröncke 2001
Coarser sediment (e.g. Echinocyamus pusillus)	Northern Dogger Bank	2	Increase with strong NAO	Positive with increase in large sediments and large food particules	1	Wieking & Kröncke 2001
Pollicipes pollicipes	Bay of Biscay	2	Increase with strong NAO	Increase in wave energy		Borja *et al*. 2006
Lophelia pertusa						

Table 3.4.2.3.4 The information on benthic species from the La Coruna study is summarized.

Taxon	OSPAR Area	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Source
Abra alba	IV	Highly variable, decreasing trend in 2000's	Warm species	1	Lopez-Jamar *et al.* 1995
Abra nitida	IV	Highly variable -decreasing trend	Warm coastal	1	Lopez-Jamar *et al.* 1995
Armandia polyophthalma	IV	Increase in 1990s then decrease	Strong southern distribution	1	Lopez-Jamar *et al.* 1995
Capitella capitata	IV	Overall decrease with variability	Widespread broad tolerance	0	Lopez-Jamar *et al.* 1995
Chaetozone gibber	IV	Abundance highly variable - no net trend	Northern species	2	Lopez-Jamar *et al.* 1995
Diopatra neapolitana	IV	Low to late 1980s, then up and down to very low by 2000	Southern med species	1	Lopez-Jamar *et al.* 1995
Malacoceros fuliginosus	IV	Two outbreaks but no trend	Northern species	0	Lopez-Jamar *et al.* 1995
Mediomastus fragilis	IV	Major increase in early 1990's then stable	Common to north	1	Lopez-Jamar *et al.* 1995
Notomastus latericeus	IV	Highly variable, large decrease after mid 1990's	Northern abundance higher	2	Lopez-Jamar *et al.* 1995
Ophiodromus flexuosus	IV	Highly variable, decreasing trend	Northern species	2	Lopez-Jamar *et al.* 1995
Ophryotrocha hartmanni	IV	Highly variable, lower in 2000's	Northern species	2	Lopez-Jamar *et al.* 1995
Paradoneris armata	IV	Strong decrease to 1997, increase and flat thereafter	Spotty distribution	0	Lopez-Jamar *et al.* 1995
Phyllodoce lineata	IV	General decrease, outbreak in early 1990's	Strongly southern species	1	Lopez-Jamar *et al.* 1995
Pseudopolydora paucibranchiata	IV	Brief major outbreak, no trend	Warm strongly southern - invasive	0	Lopez-Jamar *et al.* 1995
Pseudopolydora pulchra	IV	Overall decrease, high variation	Widespread northern	1	Lopez-Jamar *et al.* 1995
Spio decoratus	IV	Highly variable - no trend	Southern species	0	Lopez-Jamar *et al.* 1995
Tellina fabula	IV	Outbreak in mid 1990's; no trend	Lower thermal tolerance	1	Lopez-Jamar *et al.* 1995
Thyasira flexuosa	IV	Consistent decrease, especially in higher density area	Northern species	1	Lopez-Jamar *et al.* 1995
Tubificoides sp	IV	Increase 88-92, decrease thereafter	Unclear for genus	0	Lopez-Jamar *et al.* 1995

Warmer summers 1988–1995, cooler summers in 2000+; cold winters 1991, 1992.

Table 3.4.2.3.5 The information on benthic species from the Nordeney Island study is summarized.

Taxon	OSPAR Area	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Source
Bathyporeia guillamsoniana	II	Increased early 1990's and ealrly 2000's; uncommon at other periods	Southern north sea only	1	Kröncke *et al. 1998*
Bathyporeia elegans	II	Eliminated in cold winters; overall upward recently	Central north sea	2	Kröncke *et al. 1998*
Donox vittatus	II	Only increased with warm winters	Warm species +	1	Kröncke *et al. 1998*
Echinocardium cordatum	II	High variability, no trend	Southern species	0	Kröncke *et al. 1998*
Fabulina fabula	II	Disappeared after cold winters overall increase	Wide tolerance	0	Kröncke *et al. 1998*
Magelona spp	II	Consistent decrease in warm NOA condictions, increase in cold & positive NAO	Widespread in northern Europe	1	Kröncke *et al. 1998*
Nephtys spp	II	Decline during cold winters, increase in early 1990s	Warm water species	1	Kröncke *et al. 1998*
Other rare bivalves	II	All increased after cold periods ended	--	1	Kröncke *et al. 1998*
Owenia fusiformis	II	Only present in warm years	Widespread, southern	1	Kröncke *et al. 1998*
Pseudocuma longicornis	II	No consistent trend	Widespread	1	Kröncke *et al. 1998*
Scoloplos	II	No trend until mid 1990's, then increase	Arctic Species -	2	Kröncke *et al. 1998*
Urothoe poseidonis	II	Large declines in cold winters, slow recoveries	Cold temperate	1	Kröncke *et al. 1998*

Table 3.4.2.3.6 The information on benthic species from the North Sea study is summarized.

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (range, abundance) (0 - no change; 1 - equals expected; 2 - not expected)	Source
Abra alba	II	1,2	Increase range, abundance	Prefers warm waters ++	1,1	Rees *et al*. 2007
Amphiura chiajei	II	1,2	Large increase in range, abundance	Widespread and common southern Norway to Morocco - burrowing +	1,2	Rees *et al*. 2007
Amphiura filiformis	II	1,2	Decrease in abundance in south	Widespread and common Iceland to Iberia -	1,0	Rees *et al*. 2007
Amphiura brachiata	II	1,2	Increase range, abundance	Apparently widespread, more southernly +	1,1	Rees *et al*. 2007
Antalis entalis	II	1,2	Major decrease in range and abundance	Deep northern waters --	1,1	Rees *et al*. 2007
Arctica islandica	II	1,2	Decrease range, abundance	Northern species, but not extremely so -	1,1	Rees *et al*. 2007
Bathyporeia spp.	II	1,2	No change in range, decrease in abundance	Southern and central distribution +	0,2	Rees *et al*. 2007
Callianassa subterranea	II	1,2	No marked change	Southern central - Med. to southern Norway +	0,0	Rees *et al*. 2007
Chaetoderma nitidulum	II	1,2	Increase in range, decrease in abundance	Southern/central species -	2,1	Rees *et al*. 2007
Chamelea gallina	II	1,2	Increase in range to north, decrease in abundance to east	Central NS generalist neutral	2,2	Rees *et al*. 2007

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (range, abundance) (0 - no change; 1 - equals expected; 2 - not expected)	Source
Corbula gibba	II	1,2	Major increase, range and abundance	Widespread generalist neutral	2,2	Rees *et al*. 2007
Echinocardium cordatum	II	1,2	Increase in range, abundance not changed	Southern species ++	1,0	Rees *et al*. 2007
Echinocyamus pusillus	II	1,2	Increase in range, decrease in abundance	Widespread Finmark to Med. Neutral	2,2	Rees *et al*. 2007
Exogone verugera	II	1,2	Major decrease in abundance and range	Deep - cold - fine sediments --	1,1	Rees *et al*. 2007
Fabulina fabula	II	1,2	Increase in range, little change in abundance	Shallow, generalist neutral	2,1	Rees *et al*. 2007
Lanice conchilega	II	1,2	Large increases, range and abundance	Warm southern coastal ++	1,1	Rees *et al*. 2007
Myriochele spp.	II	1,2	Decrease in range, increase in abundance	Deep northern waters --	1,2	Rees *et al*. 2007
Mysella bidentata	II	1,2	Decrease in abundance in south, increase in north	Southern range for species +	0,1	Rees *et al*. 2007
Nephtys longosetosa	II	1,2	Decrease in abundance, no change in range	Central NS habitat specialist neutral	1,2	Rees *et al*. 2007
Nucula nitidosa	II	1,2	Increase range, little change in abundance	Coastal warm does reach norway +	1,0	Rees *et al*. 2007
Nuculoma tenuis	II	1,2	Increase in range, decrease in abundance	Southern species ++	1,0	Rees *et al*. 2007

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (range, abundance) (0 - no change; 1 - equals expected; 2 - not expected)	Source
Ophelia borealis	II	1,2	Decrease in abundance, no change in range	Sidespread, central-northern habitat specialist -	2,1	Rees *et al*. 2007
Paramphinome jeffreysii	II	1,2	Major increase in range, some increase in abundance	Northern species --	2,2	Rees *et al*. 2007
Prionospio cirrifera	II	1,2	Major decrease in abundance, decrease in range	Deep northern waters --	1,1	Rees *et al*. 2007
Sabellaria spinulosa	II	1,2	Increase in range, abundance	Widespread coastal central neutral	2,2	Rees *et al*. 2007
Scoloplos armiger	II	1,2	Decrease in abundance, no change in range	Generalist neutral	1,2	Rees *et al*. 2007
Spiophanes bombyx	II	1,2	Increase in abundance, no change in range	Generalist neutral	1,2	Rees *et al*. 2007
Spiophanes krøyeri	II	1,2	Increase in range, no change in abundance	Generalist neutral	2,1	Rees *et al*. 2007
Synelmis klatti	II	1,2	Decrease range abundance	Southern central - fine habitats +	1,1	Rees *et al*. 2007
Terebellides stroemi	II	1,2	Increase in range, no change in abundance	Widespread Arctic to Iberia neutral	2,1	Rees *et al*. 2007
Urothoe poseidonis	II	1,2	Increase range, little change in abundance	Southern - fine habitats +	1,0	Rees *et al*. 2007

The expected patterns of change in species' abundances were complex in this case, and six of the species showed major and erratic changes in abundance such that their trends in abundance over time were too variable to be informative about any longer-term relationships. A couple of these species did show major spikes up or down in abundance during or soon after the cold winters of the early 1990s, but showed spikes of similar magnitude at other periods, so it seemed inappropriate to draw conclusions regarding the association of the spikes with oceanographic conditions. Of the species which did show anything resembling multi-year trends over time, however, more than two thirds showed major signals in their abundance trends that were consistent with the expected changes in local oceanographic conditions. This general ability to see patterns in abundance of a number of species that are consistent with expectations from changes in the local oceanography may be informative, as the species being monitored were selected to provide information about community responses to physical perturbations (e.g., dredging) and water quality, and not oceanographic conditions or climate.

The information from the Nordeney Island Study is in Table 3.4.2.3.5. For the Nordeney site, the large majority of trends in the populations were generally consistent with the expectations based on species biogeography and the information on annual oceanographic conditions. In only one case was the variation in abundance so great that the species was considered uninformative about the possible impacts of oceanographic conditions on a species' abundance, and in one case it was not possible to formulate a reasonable *a priori* hypothesis about how a species might respond to oceanographic conditions, due to the widespread distribution of the species. Of the remaining species, more than two thirds were again consistent with the expected changes, were the species responding to the oceanographic conditions.

The information in the North Sea Benthic Project is in Table 3.4.2.3.6. The North Sea Benthos Project may be table data set for exploring effects of oceanographic conditions on distribution and abundance. Selection of species in the section of the NSBP report were on a variety of criteria, few of them related directly to oceanographic conditions. Even though only two time periods were quantified, the most complete data are presented for these species, and the changes in oceanographic conditions, distribution and abundance are most unambiguous, because the comparisons are strictly pairwise rather than matching trends. The large majority of species for which data were available were considered informative, and again changes consistent with the climate expectations were more numerous than inconsistent changes.

3.4.2.4 Concluding thoughts

Evidence of sensitivity of benthic populations and communities to oceanographic conditions was present in all cases examined. On one hand, this in itself might be considered remarkable, as many of these benthic species were being monitored because they were considered sensitive indicators of habitat alteration or pollution. Despite those sensitivities, a relationship to oceanographic conditions can be extracted in many cases. This would justify the modest insight that benthic species are affected by water temperature and other oceanographic conditions associated with the NAO, with anomalously cold or warm winters apparently being particularly influential. This strong effect of extreme temperature conditions on benthic abundance and/or distribution does suggest that were climate change to move oceanographic conditions outside the recent historic range of natural variation, major effects on at least some species and communities would be likely.

On the other hand, there are many problems with taking these results as strong evidence for anything. Both the predictions of expected patterns were rough, and the fitting methods used were crude. No individual patterns were decomposed carefully with efforts made to partition the effects of habitat alterations and other pressures from the possible effects of temperature. However, given the nature of the information made available to WGECO, these very coarse-level inferences were all that was possible.

3.4.2.5 Case histories

In the Wadden Sea, the Pacific oyster (*Crassostrea gigas*) increased considerably in abundance after 2000, causing the partial disappearance of intertidal beds of *Mytilus edulis*, 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.

The distribution of many benthic species, including macroalgae, molluscs and arthropods, along the Bay of Biscay, has been studies between the end of 19th century and 2000–2001. Some northward and southward shifts have been documented, depending on the occurrence of warm and cool periods during the 20th century. Taking into account this development and the IPCC scenarios of temperature increase for next 50 years, the future shift of some benthic species in the Bay of Biscay, North Sea, and Norwegian Sea has been projected, and these projections will be tested in future.

The Sand Burrowing Brittle Star *Amphiura* had a long period of absence or rarity in the southern North Sea, but has been recorded with regularity since 1975 in low to moderate abundances. 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 in summer are not below 10°C and 3°C in winter.

3.4.2.6 References

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3.4.3 Fish

3.4.3.1 Data sources and related information

The sources of information for the fish component were the report of WGFE (ICES, 2008) and a selection of peer-reviewed publications. WGFE provided the results of analyses of groundfish survey data on the changes in abundance and/or distribution for four OSPAR areas (I, II, III and IV). For OSPAR areas 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). Area I was represented by the Barents Sea while for area IV this was the Bay of Biscay. For the analyses two periods were compared: a longer period (1977–1989 versus 2000–2005) and a shorter period (1990–1999 versus 2000–2005). The publications that were used are given in the Table 3.4.3.1.1.

Table 3.4.3.1.1 Summary of responses of fish species to climate change.

Table A.3. Summary of responses of fish species to climate change.

Taxon	OSPAR Area	Starting date	End date	Sampling frequency (y-1)	Property (1 - distribution; 2 - abundance; 3 - condition)	Observed variation	Expected change in relation to climate (AT - Atlantic; BO: Boreal; LU - Lusitanian)	Observed change in relation to climate (0 - no change, 1 - expected change; 2 - unexpected change)	Selection (1 - included in meta analysis)	Source
Agonus cataphractus	II	1983	2003		1	Shift to shallow water	BO	2	1	Dulvy *et al*., in press
Allocyttus verrucosus	III	1992	1994	3	1	occurrence		0		Quero *et al*., 1998
Alosa fallax	I				2	Increasing abundance	LU	1	1	Astthorsson and Palsson, 2006
Alosa fallax	IV		2000		1	no observation	LU	0		Brander *et al*., 2003
Aluterus monoceros	IV	1995	1995	1	1	1st occurrence		1		Quero *et al*., 1998
Amblyraja radiata	I	1990	2005		2	Decrease	BO	2	1	ICES, 2008 (WGFE)
Amblyraja radiata	I	1977	2005		2	Increase	BO	1		ICES, 2008 (WGFE)
Amblyraja radiata	II	1977	2005		1	Change in distribution from W to E	BO	0		ICES, 2008 (WGFE)
Amblyraja radiata	II	1977	2005		2	Overall increase	BO	2	1	ICES, 2008 (WGFE)
Amblyraja radiata	II	1990	2005			Inconclusive	BO	0		ICES, 2008 (WGFE)
Amblyraja radiata	III	1990	2005		1	Increase N	BO	0	1	ICES, 2008 (WGFE)
Amblyraja radiata	III	1977	2005		2	Overall decrease in abundance	BO	1		ICES, 2008 (WGFE)
Amblyraja radiata	IV	1990	2005		2	No Change	BO	0	1	ICES, 2008 (WGFE)
Anarhichas lupus	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Antimora rostrata	I				1	Extended distribution	BO	2		
Arnoglossus laterna	II	1983	2003		1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Arnoglossus laterna	II	1977	2001		1	distribution northward shift	LU	1		Perry *et al,*. 2005
Aspitrigla cuculus	II	1925	2004		2	increased abundance North Sea		1		Beare *et al*., 2004
Barbantus curvifrons	I	2001			1	First record	AT	1		Astthorsson and Palsson, 2006
Belone belone	I				2	Increasing abundance	LU	1	1	Astthorsson and Palsson, 2006
Belone svetovidovi	III		1990		1	1st occurrence		1		Stebbing *et al*., 2002
Bothus podas	IV		2000		1	1st occurrence		1		Brander *et al*., 2003
Brotulotaenia crassa	I	1998			1	First record	AT	1		Astthorsson and Palsson, 2006
Buglossidium luteum	II	1983	2003		1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Callionymus spp.	II	1901	1997		2	increased abundance North Sea	LU	1	1	Rogers and Ellis, 2000
Capros aper	II	1977	2005		1	Increase N	LU	1	1	ICES, 2008 (WGFE)
Capros aper	II	1990	2005				LU	0		ICES, 2008 (WGFE)
Capros aper	III	1990	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Capros aper	III	1977	2005		2	Overall increase in abundance	LU	1		ICES, 2008 (WGFE)
Capros aper	IV	1990	2005		2	Overall decrease in abundance	LU	2	1	ICES, 2008 (WGFE)
Caranx crysos	III		1993		1	1st occurrence		1		Stebbing *et al*., 2002
Chaunas spp.	III	1979	1994	15	1	1st occurrence		1		Quero *et al*., 1998
Chaunas spp.	IV	1979	1994	15	1	1st occurrence		1		Quero *et al*., 1998
Chaunax suttkusi	I	1997			1	First record	AT	1		Astthorsson and Palsson, 2006
Clupea harengus	I	1990	2005		2	Increase	BO	1	1	ICES, 2008 (WGFE)
Clupea harengus	I	1977	2005		2	No change	BO	0		ICES, 2008 (WGFE)
Clupea harengus	II	1977	2005		1	Increase S	BO	2		ICES, 2008 (WGFE)
Clupea harengus	II	1990	2005		1	Slight increase N	BO	2	1	ICES, 2008 (WGFE)
Clupea harengus	III	1990	2005		1	Increase N, descrease S	BO	1	1	ICES, 2008 (WGFE)
Clupea harengus	III	1977	2005		2	Overall increase in abundance	BO	2		ICES, 2008 (WGFE)
Clupea harengus	IV	1990	2005		2	No Change	BO	0	1	ICES, 2008 (WGFE)

Table 3.4.3.1.1 continued.

Coryphaenoids carapinus	I	2002			1	First record		1		Astthorsson and Palsson, 2006
Cyttopsis roseus	III	1963	1995	13	1	1st occurrence		1		Quero *et al*., 1998
Cyttopsis roseus	IV	1963	1995	13	1	1st occurrence		1		Quero *et al*., 1998
Diaphus effulgens	I	1998			1	First record	AT	1		Astthorsson and Palsson, 2006
Dibranchus atlanticus	III	1991	1994	3	1	occurrence	AT	0		Quero *et al*., 1998
Dicentrarchus labrax	II	1925	2004		2	increased abundance North Sea		1		Beare *et al*., 2004
Diretmoides parini	III	1993	1993	2	1	occurrence		0		Quero *et al*., 1998
Dolichopteryx longipes	I	1998			1	First record	AT	1		Astthorsson and Palsson, 2006
Echiichthys vipera	II	1925	2004		2	increased abundance North Sea		1		Beare *et al*., 2004
Echinorhinus brucus	IV	1727	1981		1	almost desapeared in Bay of Biscay				Quero *et al*., 1998
Engraulis encrasicolus	II	1990	2005		1	Strong increase S, unclear N	LU	1	1	ICES, 2008 (WGFE)
Engraulis encrasicolus	II	1925	2004		2	increased abundance North Sea	LU	1		Beare *et al*., 2004
Engraulis encrasicolus	II	1977	2005		2	Overall increase	LU	1	1	ICES, 2008 (WGFE)
Engraulis encrasicolus	III	1990	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Engraulis encrasicolus	III	1977	2005		2	Overall increase in abundance	LU	1		ICES, 2008 (WGFE)
Engraulis encrasicolus	IV	1990	2005		2	Overall decrease in abundance	LU	2	1	ICES, 2008 (WGFE)
Entelurus aequoreus	I				1	Extended distribution	LU	1	1	Astthorsson and Palsson, 2006
Eutrigla gurnardus	II	1983	2003		1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Eutrigla gurnardus	II	1977	2001		1	northward shift	LU	1		Perry *et al*,. 2005
Evermannellea balbo	I	1999			1	First record		1		Astthorsson and Palsson, 2006
Gadus morhua	I	1990	2005		2	Decrease	BO	2	1	ICES, 2008 (WGFE)
Gadus morhua	I	1977	2005		2	Increase	BO	1		ICES, 2008 (WGFE)
Gadus morhua	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Gadus morhua	II	1999	2005		1	no shift to colder waters	BO	2		Neat and Righton, 2006
Gadus morhua	II	1977	2001		1	distribution northward shift	BO	1	1	Perry *et al*,. 2005
Gadus morhua	II	1977	2005		2	Overall decrease	BO	1		ICES, 2008 (WGFE)
Gadus morhua	II	1990	2005		2	Overall decrease in abundance	BO	1	1	ICES, 2008 (WGFE)
Gadus morhua	II	1980	2000		3	northward shift of the survival probability	BO	1		Heath *et al.*, 2007
Gadus morhua	III	1990	2005		1	Decrease N	BO	0	1	ICES, 2008 (WGFE)
Gadus morhua	III	1977	2005		2	Overall decrease in abundance	BO	1		ICES, 2008 (WGFE)
Gadus morhua	IV	1990	2005		2	No Change	BO	0	1	ICES, 2008 (WGFE)
Galeoides decadactylus	IV		2002		1	occurrence		1	1	Brander *et al*., 2003
Galeorhinus sp.	IV	1727	1997		1	deep reduction at Bassin d'Arcachon				Quero *et al*., 1998
Glyptocephalus cynoglossus	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Grammicolepis brachiusculus	IV	1966	1966	1	1	occurrence		0		Quero *et al*., 1998

Table 3.4.3.1.1 continued.

Grammicolepsis brachiusculus	I	2000			1	First record		1		Astthorsson and Palsson, 2006
Haplophryne mollis	I	2001			1	First record	AT	1		Astthorsson and Palsson, 2006
Helicolenus dactylopterus	II	1925	2004		2	increased abundance North Sea	AT	1		Beare *et al*., 2004
Helicolenus dactylopterus	II	1990	2005		2	Overall decrease in abundance	AT	0		ICES, 2008 (WGFE)
Helicolenus dactylopterus	II	1977	2005		2	Overall increase	AT	0		ICES, 2008 (WGFE)
Helicolenus dactylopterus	III	1990	2005		2	Overall increase in abundance	AT	0	1	ICES, 2008 (WGFE)
Helicolenus dactylopterus	III	1977	2005		2	Overall increase in abundance	AT	0		ICES, 2008 (WGFE)
Helicolenus dactylopterus	IV	1990	2005		2	Overall increase in abundance	AT	0	1	ICES, 2008 (WGFE)
Heptranchias perlo	III		1984		1	1st occurrence		1		Stebbing *et al*., 2002
Hippoglossoides platessoides	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Hippoglossoides platessoides	II	1977	2001		1	northward shift	BO	1	1	Perry *et al*,. 2005
Hoplostethus cadenati	III	1982	1995	6	1	occurrence		1		Quero *et al*., 1998
Hoplostethus cadenati	IV	1982	1995	6	1	occurrence		1		Quero *et al*., 1998
Hyperoplus lanceolatus	IV		2000		1	no observation		0		Brander *et al*., 2003
Lamprogrammus shcherbachevi	I	2000			1	First record	AT	1		Astthorsson and Palsson, 2006
Lepidorhombus whiffiagonis	II	1983	2003		1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Leucoraja naevus	II	1977	2001		1	deeper distribution		1	1	Perry *et al*,. 2005
Lichia amia	IV	1971	1984	2	1	1st occurrence		1		Quero *et al*., 1998
Limanda limanda	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Lophius piscatorius	I	1977	2005		2	Decrease	LU	2		ICES, 2008 (WGFE)
Lophius piscatorius	I	1990	2005		2	Decrease	LU	2	1	ICES, 2008 (WGFE)
Lophius piscatorius	II	1983	2003		1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Lophius piscatorius	II	1977	2001		1	northward shift	LU	1		Perry *et al*,. 2005
Lophius piscatorius	II	1990	2005		2	Increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Lophius piscatorius	II	1977	2005		2	Overall increase	LU	1		ICES, 2008 (WGFE)
Lophius piscatorius	III	1990	2005		1	No change	LU	0	1	ICES, 2008 (WGFE)
Lophius piscatorius	III	1977	2005		2	Overall increase in abundance	LU	1		ICES, 2008 (WGFE)
Lophius piscatorius	IV	1990	2005		2	No Change	LU	0	1	ICES, 2008 (WGFE)
Lophius piscatorius	II	1977	2005		1	Change in distribution from W to E	LU	0		ICES, 2008 (WGFE)
Lumpenus lampretaeformis	II	1977	2001		1	distribution southward shift	BO	2	1	Perry *et al*,. 2005
Lycodes terraenovae	I	2000			1	First record	BO	1		Astthorsson and Palsson, 2006
Macroparalepsis affnis	I	1997			1	First record	BO	1		Astthorsson and Palsson, 2006
Makaira nigricans	IV		2002		1	occurrence		0		Brander *et al*., 2003
Melanocetus johnsoni	I	1996			1	First record	AT	1		Astthorsson and Palsson, 2006
Melanogrammus aeglefinus	I	1977	2005		2	Increase	BO	1		ICES, 2008 (WGFE)
Melanogrammus aeglefinus	I	1990	2005		2	Increase	BO	1	1	ICES, 2008 (WGFE)
Melanogrammus aeglefinus	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press

Table 3.4.3.1.1 continued.

Melanogrammus aeglefinus	II	1977	2005	1	Change in distribution from S to N	BO	1		ICES, 2008 (WGFE)
Melanogrammus aeglefinus	II	1990	2005	1	Increase S	BO	2	1	ICES, 2008 (WGFE)
Melanogrammus aeglefinus	II	1977	2005	2	Overall increase	BO	2	1	ICES, 2008 (WGFE)
Melanogrammus aeglefinus	III	1990	2005	1	No change	BO	0	1	ICES, 2008 (WGFE)
Melanogrammus aeglefinus	III	1977	2005	2	Overall increase in abundance	BO	2		ICES, 2008 (WGFE)
Melanogrammus aeglefinus	IV	1990	2005	2	No Change	BO	0	1	ICES, 2008 (WGFE)
Merlangius merlangus	I	1977	2005	2	Decrease	LU	2		ICES, 2008 (WGFE)
Merlangius merlangus	I	1990	2005	2	No change	LU	0	1	ICES, 2008 (WGFE)
Merlangius merlangus	II	1983	2003	1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Merlangius merlangus	II	1990	2005	1	Increase S, decrease N	LU	0		ICES, 2008 (WGFE)
Merlangius merlangus	II	1977	2005	1	Increase S, decrease N	LU	0		ICES, 2008 (WGFE)
Merlangius merlangus	II	1901	1997	1	decreased abundance North Sea	LU	2		Rogers and Ellis, 2000
Merlangius merlangus	III	1990	2005	1	No change	LU	0	1	ICES, 2008 (WGFE)
Merlangius merlangus	III	1977	2005	2	Overall increase in abundance	LU	1		ICES, 2008 (WGFE)
Merlangius merlangus	IV	1990	2005	2	No Change	LU	0	1	ICES, 2008 (WGFE)
Merluccius merluccius	II	1983	2003	1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Merluccius merluccius	II	1990	2005	1	Increase N	LU	1	1	ICES, 2008 (WGFE)
Merluccius merluccius	II	1977	2005	1	Increase N, decrease S	LU	0		ICES, 2008 (WGFE)
Merluccius merluccius	III	1990	2005	1	Decrease N	LU	0	1	ICES, 2008 (WGFE)
Merluccius merluccius	III	1977	2005	2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Merluccius merluccius	IV	1990	2005	2	No Change	LU	0	1	ICES, 2008 (WGFE)
Michrochiru boscanon	IV		2000	1	1st occurrence		1		Brander *et al*., 2003
Micromesistius potassou	II	1977	2001	1	northward shift	AT	1	1	Perry *et al*,. 2005
Microstomus kitt	II	1983	2003	1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Molva molva	II	1983	2003	1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Mullus surmuletus	II	1925	2004	2	increased abundance North Sea	LU	1		Beare *et al*., 2004
Mullus surmuletus	II	1990	2005	2	Increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Mullus surmuletus	II	1977	2005	2	Overall increase	LU	1		ICES, 2008 (WGFE)
Mullus surmuletus	III	1980	2000	1	sharp increase	LU	1	1	Brander *et al*., 2003
Mullus surmuletus	III	1990	2005	1	Increase N	LU	1	1	ICES, 2008 (WGFE)
Mullus surmuletus	III	1977	2005	2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Mullus surmuletus	IV	1980	2000	1	sharp increase	LU	1	1	Brander *et al*., 2003
Mullus surmuletus	IV	1990	2005	2	No Change	LU	0	1	ICES, 2008 (WGFE)
Mustelus spp.	IV	1727	1997	1	deep reduction at Bassin d'Arcachon				Quero *et al*., 1998
Myoxocephalus scorpius	II	1901	1997	2	increased abundance North Sea	BO	2	1	Rogers and Ellis, 2000
Neonesthes capsensis	I	1998		1	First record		1		Astthorsson and Palsson, 2006
Oblada melanura	III		2000	1	1st occurrence		1		Stebbing *et al*., 2002
Parablennius incognitus	IV		2000	1	1st occurrence		1		Brander *et al*., 2003
Petromyson marinus	I			2	Increasing abundance	BO	1	1	Astthorsson and Palsson, 2006

Table 3.4.3.1.1 continued.

Phycis blennoides	I				1	Extended distribution	LU	1	1	Astthorsson and Palsson, 2006
Platichythys flesus	I	1999			1	First record		1		Astthorsson and Palsson, 2006
Platytroctes apus	I	1998			1	First record	AT	1		Astthorsson and Palsson, 2006
Pleuronectes platessa	I	1990	2005		2	Decrease	BO	2	1	ICES, 2008 (WGFE)
Pleuronectes platessa	I	1977	2005		2	Increase	BO	1		ICES, 2008 (WGFE)
Pleuronectes platessa	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Pleuronectes platessa	II	1990	2005		1	Increase N, decrease S	BO	1		ICES, 2008 (WGFE)
Pleuronectes platessa	II	1977	2005		1	Increase N, decrease S	BO	1		ICES, 2008 (WGFE)
Pleuronectes platessa	II	1977	2001		1	deeper distribution	BO	1		Perry *et al*,. 2005
Pleuronectes platessa	II	1901	1997		2	increased abundance North Sea	BO	2		Rogers and Ellis, 2000
Pleuronectes platessa	II	1970	2004		3	increased growth	BO	2	1	Teal *et al*., 2008
Pleuronectes platessa	III	1990	2005		1	Decrease N, increase S	BO	2	1	ICES, 2008 (WGFE)
Pleuronectes platessa	III	1977	2005		2	Overall increase in abundance	BO	2	1	ICES, 2008 (WGFE)
Pleuronectes platessa	IV	1990	2005		2	No Change	BO	0	1	ICES, 2008 (WGFE)
Pollachius virens	I	1977	2005		2	Decrease	BO	2		ICES, 2008 (WGFE)
Pollachius virens	I	1990	2005		2	Increase	BO	1	1	ICES, 2008 (WGFE)
Pollachius virens	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Pollachius virens	II	1990	2005		1	Increase N, decrease S	BO	1	1	ICES, 2008 (WGFE)
Pollachius virens	II	1977	2005		1	Increase N, decrease S	BO	1		ICES, 2008 (WGFE)
Pollachius virens	III	1990	2005		1	Increase N	BO	0	1	ICES, 2008 (WGFE)
Pollachius virens	III	1977	2005		2	Overall decrease in abundance	BO	1	1	ICES, 2008 (WGFE)
Pollachius virens	IV	1990	2005		2	No Change	BO	0	1	ICES, 2008 (WGFE)
Pomadasys incisus	IV		2000		1	1st occurrence		1		Brander *et al*., 2003
Pomatomus saltator	III	1969	1993	2	1	1st occurrence		1		Quero *et al*., 1998
Pomatomus saltator	IV	1969	1993	2	1	1st occurrence		1		Quero *et al*., 1998
Poromitra megalops	I	2001			1	First record	AT	1		Astthorsson and Palsson, 2006
Prionace glauca	I	1996			1	First record	AT	1		Astthorsson and Palsson, 2006
Pseudoscopelus altipinnis	I	1996			1	First record	AT	1		Astthorsson and Palsson, 2006
Raja clavata	I	1977	2005		2	Decrease	LU	2		ICES, 2008 (WGFE)
Raja clavata	I	1990	2005		2	Decrease	LU	2	1	ICES, 2008 (WGFE)
Raja clavata	II	1977	2005		1	Decrease N, increase S	LU	0		ICES, 2008 (WGFE)
Raja clavata	II	1901	1997		1	decreased abundance Irish Sea	LU	2	1	Rogers and Ellis, 2000
Raja clavata	II	1990	2005		2	Overall decrease	LU	2	1	ICES, 2008 (WGFE)
Raja clavata	III	1990	2005		1	Increase N	LU	1	1	ICES, 2008 (WGFE)
Raja clavata	III	1977	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Raja clavata	IV	1990	2005		2	No Change	LU	0	1	ICES, 2008 (WGFE)
Raja naevus	II	1983	2003		1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Raja radiata	II	1983	2003		1	Shift to shallow water	BO	2	1	Dulvy *et al*., in press
Raja sp.	IV	1727	1989		1	deep reduction at Bassin d'Arcachon				Quero *et al*., 1998
Ranzania laevis	IV		2000		1	massive occurrence		0	1	Quero *et al*., 1998
Rhinonemus cimbrius	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Rhinonemus cimbrius	II	1977	2001		1	northward shift	BO	1		Perry *et al*,. 2005

Table 3.4.3.1.1 continued.

Sarda Sarda	I	1998			1	First record	AT	1		Astthorsson and Palsson, 2006
Sardina pilchardus	II	1925	2004		2	increased abundance North Sea	LU	1		Beare *et al*., 2004
Sardina pilchardus	II	1990	2005		2	Overall decrease	LU	2	1	ICES, 2008 (WGFE)
Sardina pilchardus	II	1977	2005		2	Overall increase	LU	1		ICES, 2008 (WGFE)
Sardina pilchardus	III	1990	2005		1	Increase N	LU	1	1	ICES, 2008 (WGFE)
Sardina pilchardus	III	1977	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Sardina pilchardus	IV	1990	2005		2	No Change	LU	0	1	ICES, 2008 (WGFE)
Scomber scombrus	I				2	Increasing abundance	AT	1	1	Astthorsson and Palsson, 2006
Scomber scombrus	II	1925	2004		2	increased abundance North Sea	AT	0		Beare *et al*., 2004
Scorpaena porcus	III		1998		1	2nd occurrence (1st: 1994)		0		Stebbing *et al*., 2002
Scyliorhinus canicula	II	1983	2003		1	Shift to shallow water	LU	2	1	Dulvy *et al*., in press
Scyliorhinus canicula	II	1990	2005		1	Increase N, decrease S	LU	1	1	ICES, 2008 (WGFE)
Scyliorhinus canicula	II	1977	2005		2	Overall increase	LU	1		ICES, 2008 (WGFE)
Scyliorhinus canicula	II	1901	1997		2	increased abundance North Sea	LU	1	1	Rogers and Ellis, 2000
Scyliorhinus canicula	III	1990	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Scyliorhinus canicula	III	1977	2005		2	Overall increase in abundance	LU	1		ICES, 2008 (WGFE)
Scyliorhinus canicula	IV	1990	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Seriola carpenteri	IV	1985	1985	1	1	1st occurrence		1		Quero *et al*., 1998
Seriola dumerili	III	1969	1984	3	1	1st occurrence		1		Quero *et al*., 1998
Seriola dumerili	III	1984	1994		1	2nd occurrence (1st: 1951)		0		Stebbing *et al*., 2002
Seriola dumerili	IV	1969	1984	3	1	1st occurrence		1		Quero *et al*., 1998
Seriola rivoliana	III	1969	1993	6	1	1st occurrence		1		Quero *et al*., 1998
Seriola rivoliana	III		1999		1	2nd occurrence (1st: 1985)		0		Stebbing *et al*., 2002
Seriola rivoliana	IV	1969	1993	6	1	1st occurrence		1		Quero *et al*., 1998
Solea vulgaris	II	1983	2003		1	Shift to shallow water	LU	2	1	Dulvy *et al*., in press
Solea vulgaris	II	1977	2005		1	Decrease N	LU	2		ICES, 2008 (WGFE)
Solea vulgaris	II	1977	2005		1	Move inshore	LU	2		ICES, 2008 (WGFE)
Solea vulgaris	II	1977	2001		1	distribution northward shift	LU	1	1	Perry *et al*,. 2005
Solea vulgaris	II	1990	2005		2	Increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Solea vulgaris	II	1970	2004		3	increased growth	LU	1	1	Teal *et al*., 2008
Solea vulgaris	III	1990	2005		1	Increase N	LU	1	1	ICES, 2008 (WGFE)
Solea vulgaris	III	1977	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Solea vulgaris	IV	1990	2005		2	No Change	LU	0	1	ICES, 2008 (WGFE)
Sphoeroides pachygaster	III	1978	1990	12	1	1st occurrence		1		Quero *et al*., 1998
Sphoeroides pachygaster	IV	1978	1990	12	1	1st occurrence		1		Quero *et al*., 1998
Spondyliosoma cantharus	II	1925	2004		2	increased abundance North Sea		1		Beare *et al*., 2004
Sprattus sprattus	II	1990	2005		1	Decrease S, increase N	LU	1	1	ICES, 2008 (WGFE)
Sprattus sprattus	II	1977	2005		2	Overall increase	LU	1	1	ICES, 2008 (WGFE)
Sprattus sprattus	III	1990	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Sprattus sprattus	III	1977	2005		2	Overall increase in abundance	LU	1		ICES, 2008 (WGFE)

Table 3.4.3.1.1 continued.

Sprattus sprattus	IV	1990	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Squalus acanthias	I	1977	2005		2	Decrease	BO	2		ICES, 2008 (WGFE)
Squalus acanthias	I	1990	2005		2	Increase	BO	1	1	ICES, 2008 (WGFE)
Squalus acanthias	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Squalus acanthias	II	1990	2005		2	Decrease S	BO	1	1	ICES, 2008 (WGFE)
Squalus acanthias	II	1977	2005		2	Overall decrease	BO	1		ICES, 2008 (WGFE)
Squalus acanthias	III	1990	2005		1	Decrease N	BO	0	1	ICES, 2008 (WGFE)
Squalus acanthias	III	1977	2005		2	Overall decrease in abundance	BO	1		ICES, 2008 (WGFE)
Squalus acanthias	IV	1727	1997		1	deep reduction at Bassin d'Arcachon	BO	1		Quero *et al*., 1998
Squalus acanthias	IV	1990	2005		2	No Change	BO	0	1	ICES, 2008 (WGFE)
Squatina squatina	IV	1727	1996		1	deep reduction at Bassin d'Arcachon		2		Quero *et al*., 1998
Synodus saurus	IV		2002		1	occurrence		0		Brander *et al*., 2003
Synphodus ocelatus	IV		2000		1	1st occurrence		1		Brander *et al*., 2003
Tarpon atlanticus	III	1973	1993	7	1	1st occurrence		1		Quero *et al*., 1998
Tarpon atlanticus	IV	1973	1993	7	1	1st occurrence		1		Quero *et al*., 1998
Tetrapturus albidus	IV		2002		1	occurrence		0		Brander *et al*., 2003
Thunnus obesus	III		1985		1	occurrence		0		Stebbing *et al*., 2002
Trachinus vipera	II	1983	2003		1	No change	LU	0	1	Dulvy *et al*., in press
Trachurus trachurus	II	1925	2004		2	increased abundance North Sea	LU	1		Beare *et al*., 2004
Trachurus trachurus	II	1977	2005		2	Overall increase	LU	1		ICES, 2008 (WGFE)
Trachurus trachurus	II	1990	2005			Inconclusive	LU	0		ICES, 2008 (WGFE)
Trachurus trachurus	III	1990	2005		1	Increase N	LU	1	1	ICES, 2008 (WGFE)
Trachurus trachurus	III	1977	2005		2	Overall increase in abundance	LU	1		ICES, 2008 (WGFE)
Trachurus trachurus	IV	1990	2005		2	No Change	LU	0	1	ICES, 2008 (WGFE)
Trigla lucerna	II	1925	2004		2	increased abundance North Sea		1		Beare *et al*., 2004
Trisopterus esmarki	II	1983	2003		1	Shift to deeper water	BO	1	1	Dulvy *et al*., in press
Trisopterus esmarki	II	1977	2001		1	distribution southward shift	BO	2		Perry *et al*,. 2005
Trisopterus luscus	II	1983	2003		1	Shift to shallow water	LU	2	1	Dulvy *et al*., in press
Trisopterus luscus	II	1977	2005		1	Change in distribution from S to N	LU	1		ICES, 2008 (WGFE)
Trisopterus luscus	II	1990	2005		1	Increase N, decrease S	LU	1	1	ICES, 2008 (WGFE)
Trisopterus luscus	II	1977	2005		1	Increase N, decrease S	LU	1		ICES, 2008 (WGFE)
Trisopterus luscus	II	1977	2001		1	northward shift	LU	1		Perry *et al*,. 2005
Trisopterus luscus	II	1925	2004		2	increased abundance North Sea	LU	1		Beare *et al*., 2004
Trisopterus luscus	II	1901	1997		2	increased abundance North Sea	LU	1		Rogers and Ellis, 2000
Trisopterus luscus	III	1990	2005		1	Increase N	LU	1	1	ICES, 2008 (WGFE)
Trisopterus luscus	III	1977	2005		2	Overall increase in abundance	LU	1		ICES, 2008 (WGFE)
Trisopterus luscus	IV		2000		1	no observation	LU	0		Brander *et al*., 2003

Table 3.4.3.1.1 continued.

Trisopterus luscus	IV	1990	2005		2	No Change	LU	0	1	ICES, 2008 (WGFE)
Trisopterus minutus	II	1983	2003		1	Shift to deeper water	LU	1	1	Dulvy *et al*., in press
Trisopterus minutus	II	1925	2004		2	increased abundance North Sea	LU	1		Beare *et al*., 2004
Zenopsis conchifera	I	2002			1	First record		1		Astthorsson and Palsson, 2006
Zenopsis conchifera	III	1966	1995	34	1	1st occurrence		1		Quero *et al*., 1998
Zenopsis conchifera	III		1995		1	1st occurrence		1		Stebbing *et al*., 2002
Zenopsis conchifera	IV	1966	1995	34	1	1st occurrence		1		Quero *et al*., 1998
Zeus faber	I	2004			1	First record	LU	1		Astthorsson and Palsson, 2006
Zeus faber	II	1925	2004		2	increased abundance North Sea	LU	1		Beare *et al*., 2004
Zeus faber	II	1990	2005		2	Increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Zeus faber	II	1977	2005		2	Overall increase	LU	1		ICES, 2008 (WGFE)
Zeus faber	III	1990	2005		1	No change	LU	0	1	ICES, 2008 (WGFE)
Zeus faber	III	1977	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)
Zeus faber	IV	1990	2005		2	Overall increase in abundance	LU	1	1	ICES, 2008 (WGFE)

3.4.3.2 Approach taken to use of data

For the main sources of data we describe the logic that was applied to decide whether a specific observation might be a result of climate change, or not.

WGFE

In order to interpret observed changes in abundance and/or distribution based on the work of WGFE, we applied the same rigorous 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 3.4.3.1.1 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.

To interpret the changes for different species, we used the bio-geographical classification into Lusitanian, Boreal or Atlantic. For OSPAR areas 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 area 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 area I could be interpreted as a result of climate change.

Changes in distribution could only be assessed for OSPAR areas 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.

Literature

Shifts in distribution towards deeper water by marine organisms are comparable to the upward altitudinal responses of terrestrial organisms in response to climate change (Walther *et al.*, 2002; Parmesan and Yohe, 2003; Dulvy *et al.*, in press). We therefore scored any shift towards deeper water as climate driven. A shift towards shallow water was considered to contradict our expectations even though for warm-tolerant species this could be a second-order effect of niches becoming available after the shift of other species toward deeper water.

Beare *et al.*, 2004 analysed two research trawl surveys series, covering both the entire North Sea and the Scottish west coast for a period of 80 years (1925 to 2004) when combined. These data are considered highly informative regarding changes in fish populations over a long period. Results indicate that the North Sea has experienced waves of immigration by exotic, southern species (e.g., red mullet, anchovy and pilchard). The last such wave, which occurred after 1990, was the strongest and points to a change in the fish ecosystem of the North Sea.

Distributions of both exploited and non-exploited North Sea fish have responded markedly to recent increases in sea temperature, with nearly two-thirds of species shifting in mean latitude or depth, or both, over 25 years (Perry *et al.*, 2005). For species with northerly or southerly range margins in the North Sea, half have shown boundary shifts with warming, and all but one shifted northward. Species whose distributions shifted had faster life cycles and smaller body sizes than species showing no shift.

Rogers and Ellis, 2000 compare survey results from three areas around the British Isles in two periods: 1901–1907 and 1989–1907. In Stuart Bay (NW English Channel) and the Irish Sea, species diversity was the same in both periods, although the most abundant species were not the same. In English coastal regions of the southern North Sea, fish populations became more diverse as some commercial species became less abundant and populations of several non-target species increased. Changes were considered to be a response to commercial exploitation.

Quero *et al.*, 1998 present the Northward shift of first-time recording of several tropical species from southern Portugal coast to Bay of Biscay and waters north-west of Ireland. The northward shift of species such as *Zenopsis conchifer* and *Cyttopsis roseus* over a 30 years period is the best documented and quite convincing. Information on less frequent species is reduced to only the first occurrence in the area.

Stebbing *et al.*, 2002 make a documented list of southern species encountered in Cornwall (SW England) from 1960 to 2001. The data show that over the first 15 years no new southern species were recorded; thereafter the numbers have increased at an accelerating rate.

Brander *et al.*, 2003 analyse the connection between increases in sea temperature and changes in the abundance of commercial and non-commercial species. They observe a general increase of warm-water commercial gadoid and flatfish species, but like the warming trend, changes in distribution and abundance were by no means uniform and there was considerable inter-annual variability. Information on first occurrences in the area of species whose distribution was previously limited to the Mediterranean and/or NW Africa is also provided.

3.4.3.3 Tabulation

For the analysis of the table we applied several criteria to select records we considered informative and which should therefore be included.

- Confirmatory bias was avoided by only including records that came from analyses that involved a suite of species that were chosen without any prior expectation as to their sensitivity to climate effects. This also involved the exclusion of records of first occurrence.
- Following IPCC we excluded records for which the start date was before a specific date as we considered that processes other than climate change could have driven the observations. However we chose 1980 as opposed to 1970 for the cut-off date.
- Duplication was avoided by allowing one record per area, property and species. This implied that we excluded duplicates where the change of a particular property of the same species was recorded for different time periods or based on different monitoring programs. In case of duplicating time periods the most recent period was preferred as it is was assumed more likely that climate was the main driver of the observed changes. If duplicates contradicted each other in providing evidence for a climate effect, both were kept as this was considered to give the most conservative estimate of the proportion of cases changing according to expectation.

3.4.3.4 Observations from the tabulation

The results of these analyses show that in most cases, in all areas, both abundance and distribution have changed. Substantially more than half of these changes are in accordance with expectations from 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. Therefore further screening of the data and additional testing will be presented in Section 3.5.3.

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 area for two properties: abundance and distribution. Initially a third property, condition, which could include any other characteristic, was also considered. However for this third property only two records were found and this property was therefore not further considered. Two assessments were conducted: one on all the records, for the final assessment we only used the records that passed our selection criteria.

3.4.3.5 Case histories

Red Mullet

The red mullet *Mullus surmuletus* (Order Perciformes, Family Mullidae) is a benthic schooling species with adult body length typically 33–37 cm. It has a Lusitanian distribution in coastal waters from Norway, north Scotland and the Faeroes, south to the Strait of Gibraltar and into the Mediterranean and Black Seas, also along the coast of north-west Africa to Senegal and the Canary Islands. The red mullet feeds primarily on invertebrates and small fish, using the sensory barbels to locate prey. This species has a relatively rapid growth rate, and during the first 2 years of life similar for the two sexes, but thereafter the females grow faster than the males, and by 5 years are on average about 6 cm longer than males.

Most global red mullet landings are taken from the Mediterranean and Black Seas and a comparatively smaller fraction from the Atlantic Ocean. It is a relatively high-value non-quota species and in north-east Atlantic is a target species for French bottom trawlers with a mesh size of 70–99 mm. It is mainly exploited in the North Sea and Celtic Sea (Figure 3.4.3.5.1), in the inshore waters. Before 1975 red mullet was only significantly exploited along the Spanish coasts and in the Bay of Biscay by Spanish fleets. Between the mid 1970s until about 1990 landings were reported by France mainly in the Bay of Biscay and the English Channel. Recently, French landings from the North Sea and English Channel have increased substantially. UK and Dutch landings from the English Channel and the North Sea have also increased in the last decade.

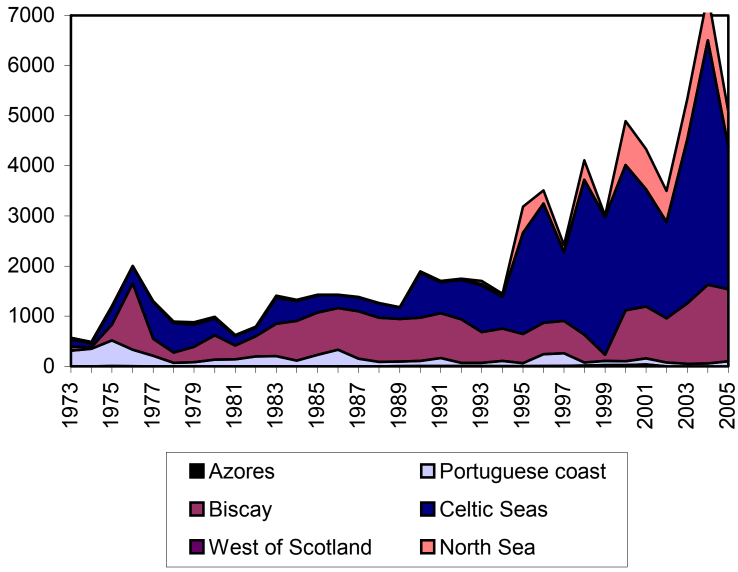

Figure 3.4.3.5.1 North-east Atlantic red mullet: trends in total landings by fishing region (in t). Data from ICES Fisheries Statistics.

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. Restrictions in the quota of other species might also have redirected fishing effort towards this species.

Surveys have also shown recent changes in distribution of mullet. Red mullet have recently become significantly more prevalent in North Sea bottom trawl surveys, with notable seasonal changes in distribution. During summer they have been mainly observed in the warmer, shallower waters of the southeastern North Sea, but during winter they have mainly been observed off north-east UK. 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, 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 will enhance its' ability to rapidly respond to climate warming by colonising new habitats.

Herring

The Atlantic herring *Clupea harengus* (order Clupeiformes, family Clupeidae) 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 3rd and 5th biggest fishery in the world (FAO statistics).

There are many stocks of herring in the North Atlantic. In the ICES area, Norwegian spring spawning herring and the North Sea herring are the biggest stocks. Like other pelagic fish, there are often large migrations between spawning and feeding areas, and discrete overwintering areas also exist for some stocks. The life span of herring is between 17–20 years (38–40 cm length) although as most species are heavily fished this rarely occurs. Herring in the Baltic are smaller in size. The main spring feeding time reduces in intensity during the build up to spawning and little feeding occurs over winter.

Atlantic herring are repeat spawners which deposit sticky benthic eggs on the substratum or each other. In the North Sea, herring use gravel beds that are generally between 20–40m depth, but in other areas seaweed or other substrates are used. Different herring stocks either spawn in spring or autumn.

The prey of herring varies by location, but juveniles generally feed on nauplii, microzooplankton, copepodites and small meroplankton. Adults feed on *Calanus,* Amphipoda and juvenile sandeels, and have been reported to eat their own eggs. The distribution of feeding shoals is correlated with zooplankton abundance and shows very strong affinity with the southerly incursion of the copepods *Calanus* and *Limacina* into the North Sea each year. Distribution of herring and their prey is influenced by the Atlantic inflow, and in years when the Calanus peak abundance is further north, herring catches are also further north.

Norwegian spring spawning herring dominate global catches but most stocks support a fishery. Herring is mainly exploited in a directed fishery for human consumption and is fished by a variety of fleets ranging from fixed gear, purse seiners, pelagic trawlers and freezer trawlers. Herring is traded fresh, pickled, frozen, smoked and canned. Sizable industrial fisheries also take herring as a bycatch in the NE Atlantic. Herring are often caught with sprat or mackerel. Herring is very sensitive to overfishing and collapses of stocks have occurred across the Atlantic.

Herring stocks are well known to have large changes in productivity. There seems to be a very clear link between herring productivity and temperature and this has allowed comparisons to be made of productivity against climate variability. The variability in recruitment and growth also differs between stocks and their subcomponents. Fluctuations 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 herring appears to exhibit patterns that may be associated with climatic cycles such as the Atlantic multidecadal oscillation. Changes in predator and prey abundances will affect herring production and distribution. The mechanism by which temperature has an association with recruitment is still unclear and more study is required about the impact of temperature on growth and recruitment.

3.4.3.6 Acknowledgements

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3.4.3.7 References

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3.4.4 Seabirds

3.4.4.1 Data sources and related information

The reports of the Working Group on Seabird Ecology (ICES, 2007; ICES, 2008) were decompiled to extract specific information from reported peer-reviewed material. WGSE supplied focussed information on the OSPAR areas. Additional peer reviewed material was obtained to supplement the available information supplied by the working groups in the time available.

3.4.4.2 Approach taken to use of data

For the main sources of data we describe the logic that was applied to decide whether a specific observation is expected to be caused by climate change.

Durant *et al*., 2003 factored the co-occurrence of food requirements and food availability for Atlantic puffins (*Fratercula arctica*) as a factor in fledgling success. Thus the expected response for this population was that the preferred prey was affected by change in temperature and subsequently availability of the prey determined breeding success.

Frederiksen *et al*., 2004 examined changes over time and correlations between black-legged kittiwakes (*Rissa tridactyla*) population parameters, 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, once again, condition was a factor of temperature mediated through prey availability.

Frederiksen *et al*., 2007 correlated black-legged kittiwakes (*Rissa tridactyla*) breeding productivity with available prey (sandeel) with temperature at five sites in OSPAR area I and II, thus providing the opportunity to see if the proposed relationship between temperature, prey availability and condition factor was sound at different sites.

Grobois and Thompson, 2005 investigated the winter climate conditions and survival of adult, male and female fulmar (*Fulmarus glacialis*), further investigating whether or not there were sexually dimorphic indirect or direct effects. Colder temperatures were expected to result in poor survival rates.

Harris *et al*., 2005 similarly investigated the winter climate conditions and survival of adult, male and female Atlantic puffins at five sites within the OSPAR area I–III, providing the opportunity to see if the proposed relationship between temperature, and survival (a condition factor) was sound at different sites.

Møller *et al*., 2006 considered that natal and breeding dispersal of the Arctic Tern (*Sterna paradisaea*) was responsive to temperature conditions. This allowed the opportunity to explore a common factor (temperature) on a different population parameter.

Sandvik *et al*., 2005 investigated the effect of climate on adult survival in five species of North Atlantic seabirds in OSPAR area I. Annual survival is, once again, related to temperature change meditated through prey availability, but in this case the response of different species to a common driver in the same area can be explored.

Thompson and Ollason, 2001 investigated the survival/increased population breeding performance over time in fulmar populations, warmer conditions were proposed to favour increased abundance.

Wynn *et al*., 2007. Investigated the distribution of the Balearic shearwater (*Puffinus mauretanicus*) in northeast Atlantic waters in several sites in the two OSPAR areas (III and II) correlating with a northwards range expansion with sea surface temperature.

The assessment of a response of seabirds to climate change, generally mediated through the trophic effects, is dependant upon the stated hypothesis in the peer-reviewed material, and whether or not the hypothesis is accepted. This reflects the complex multi-level response of different components of the ecosystem relevant to change in population dynamics of seabirds.

Many of these papers were identified from the ICES 2007–2008 WGSE reports.

3.4.4.3 Tabulation

The information derived peer-reviewed material extracted within the time available is shown in Table 3.4.4.3.1.

Table 3.4.4.3.1 Summary of information used to assess seabird species responses to climate change.

Table A.4. Summary of responses of fish species to climate change.

Taxon Arctic tern (*Sterna paradisaea*)	**OSPAR Area**	**Property** (1 - distribution; 2 - abundance; 3 - condition)	**Observed variation**	**Observed Variation**	**Observed change in relation to climate** (0 - no change; 1 - expected change; 2 - unexpected change)	**Latitude**	**Longitude**	**Source**
Arctic tern (*Sterna paradisaea*)	II	1	natal dispersal inc when temp inc	dispersed further when temp inc '+ve correlation with temperature	1			Møller *et al* ., 2006
Atlantic puffins(Fratercula arctica*)*	II	3	breeding dispersal decreased when temperature decreased	dispersed short distances with inc temp '-ve correlation with temperature	1			Møller *et al* ., 2006
Balearic shearwater (*Puffinus mauretanicus*)	I	3	annual survival with increased SST	+ve or -ve (can be due to changes in food availabilty)	1			Harris *et al* , 2005
Balearic shearwater (*Puffinus mauretanicus*)	II	2	abundance	evidence for progressive northwards range expansion	1			Wynn *et al* ., 2007
Bird Atlantic puffin (*Fratercula arctica*)	III	2	abundance	evidence for progressive northwards range expansion	1			Wynn *et al.* , 2007
Bird Atlantic puffin (*Fratercula arctica*)	I	3	breeding performance	severe winters = poor puffing recruitment due to low quality herring (prey item)	1	67°26' N	11°52' E	Durant *et al* ., 2003
Bird Atlantic puffin (*Fratercula arctica*)	I	3	annual survival / breeding success (-ve) with increased SST	-ve (mitigated by prey availability lower prey at higher temps)	1	66-68°N	10-14°E	Harris *et al* , 2005
Bird Atlantic puffin (*Fratercula arctica*)	I	3	annual survival / breeding success (-ve) with increased SST	-ve (mitigated by prey availability lower prey at higher temps)		70-72°N	29-34°E	Harris *et al* , 2005
Bird Atlantic puffin (*Fratercula arctica*)	II	3	annual survival / breeding success (-ve) with increased SST	-ve (mitigated by prey availability lower prey at higher temps)	1	55-57°N	0-3°W	Harris *et al* , 2005
Bird Atlantic puffin (*Fratercula arctica*)	II	3	annual survival / breeding success (-ve) with increased SST	-ve	2	59-61°N	0-3°W	Harris *et al* , 2005
Bird Kittiwake (*Rissa tridactyla*)	III	3	annual survival / breeding success (-ve) with increased SST	-ve (mitigated by prey availability lower prey at higher temps)	1	53-53°N	4-7°W	Harris *et al* , 2005

Table 3.4.4.3.1 continued.

Bird Norther Fulmar (*Fulmar glacialis*)	II	3	breeding success (-ve)	the population was unlikely to increase if the fishery was active or sea temperature increased,	1	56°11N°	2°33W	Frederiksen *et al* ., 2004
Bird Norther Fulmar (*Fulmar glacialis*)	II	2	change in abundance	severe winters = poor recruitment	2	59°8'N	3°8'W	Thompson and Ollason, 2001
Bird Norther Fulmar (*Fulmar glacialis*)	II	3	annual survival / breeding success (-ve)	warmer/wetter conditions unfavourable to female fulmar	1	59°8'N	3°8W	Grobois and Thompson, 2005
Bird Norther Fulmar (*Fulmar glacialis*)	II	3	annual survival	warmer/wetter conditions unfavourable to male fulmar	2			Grobois and Thompson, 2005
Black-legged kittiwakes (*Rissa tridactyla* L.)	II	3	breeding performance	severe winters = poor recruitment	2			Thompson and Ollason, 2001
Black-legged kittiwakes (*Rissa tridactyla* L.)	I	3	annual survival with increased SST	+ve or -ve (can be due to changes in food availabilty)	2			Sandvik *et al., 2005*
Black-legged kittiwakes (*Rissa tridactyla* L.)	II	3	breeding success/productivity			59° 30’–61°30’N	1°E–2° 30’W	Frederiksen *et al* ., 2006
Black-legged kittiwakes (*Rissa tridactyla* L.)	II	3	breeding success/productivity	-ve	1	58° 30’–59°30’N	1°–5°W	Frederiksen *et al* ., 2007
Black-legged kittiwakes (*Rissa tridactyla* L.)	II	3	breeding success/productivity	-ve	1	55° 30’–57°30’N	1°E–3°W	Frederiksen *et al* ., 2007
Black-legged kittiwakes (*Rissa tridactyla* L.)	II	3	breeding success/productivity	inc in breeding productivity but not correlated with SST	2	52° 30’–55°30’N	3°E–2°W	Frederiksen *et al* ., 2007
Black-legged kittiwakes (*Rissa tridactyla* L.)	III	3	breeding success/productivity	decrease in breeding productivity but not corrlated with SST	2	56°–59°N	5°–10°W	Frederiksen *et al* ., 2007
Brünnich's guillemots (*Uria lomvia* L.),	III	3	breeding success/productivity	decrease in breeding productivity but not corrlated with SST	2	51°–55°30’N	3°–8°W	Frederiksen *et al* ., 2007
Guillemots (*Uria aalge)*	I	3	annual survival with increased SST	+ve or -ve (can be due to changes in food availabilty)	2			Sandvik *et al., 2005*
Razorbills (*Alca torda* L.)	I	3	annual survival with increased SST	+ve or -ve (can be due to changes in food availabilty)	1	70°22' N	31°10'E	Sandvik *et al., 2005*
	I	3	annual survival with increased SST	+ve or -ve (can be due to changes in food availabilty)	1			Sandvik *et al., 2005*

3.4.4.4 Concluding thoughts

The majority of the material which could be analysed reports on condition factors, in this case mainly referring breeding success and annual survival. Ultimately, condition factors will subsequently link to abundance in the various seabird populations. Out of the cases investigated, albeit a small sample size, there is a demonstrable link elucidated between the proposed factor (abundance, distribution and condition) and a climate variable.

However, the most salient feature of the analysis is that the available outcomes best illustrate that the relationship between climate change and bird population dynamics is complex. For the same species, different populations throughout the OSPAR region, there are different responses to climatic trends. This issue is further complicated by differential responses to the same explanatory variable within a population at different stages of the life history. These are explored further in the case history below.

3.4.4.5 Case histories

3.4.4.5.1 Atlantic puffins in north Norway

Durant *et al.*, 2003 have demonstrated that the breeding success of Atlantic puffin *Fratercula arctica* in Røst, Northern Norway, to a large part is explained by the combined effect of local sea temperatures (i.e. within the Norwegian coastal current) in March–July and the size of first-year (0 group) herring they provide for their chicks in the same year. The repeated breeding failures have caused a severe drop in population size over several decades (Anker-Nilssen, 1992). In a more recent paper, Durant *et al.*, 2006 showed that the nestling period of these chicks, and hence the quality of the reproductive output of the population, can be equally well predicted by only using local data for sea temperatures and salinity in March, which is the period of first growth for larval herring drifting northwards along this coastline. Simple correlations between different time series for sea temperatures and an updated version of the data set on breeding success for the Røst puffins (Anker-Nilssen and Aarvak, 2006 and unpubl. data) suggest that temperatures sampled further away from the breeding site, at different depths, in different water masses and/or at different times of year are less able to uncover such relationships (Figure 3.4.4.5.1.1). This highlights the importance of selecting the most relevant descriptors of environmental change, i.e. those that are expected to be most closely linked to the underlying ecological processes (in this case the growth and survival of young herring). Usually, this will demand a closer cooperation between oceanographers and seabird ecologists than just picking from a (restricted) list of available data sets.

When repeating the analysis with the same set of environmental data series, but substituting fledging success with the rate of population change from year to year in the same colony (Anker-Nilssen and Aarvak, 2006), all significant relationships disappears (Figure 3.4.4.5.1.1). This emphasizes the unsuitability of breeding numbers as an indicator of the effect of climate change on this population. Not only are puffin numbers monitored early in the egg-laying period when herring is expected to be a less important prey, but as the age at first breeding in this population is 5–7 years (Anker-Nilssen and Aarvak, 2006), these analyses are also biased by a likely great variation in immature survival of different cohorts.

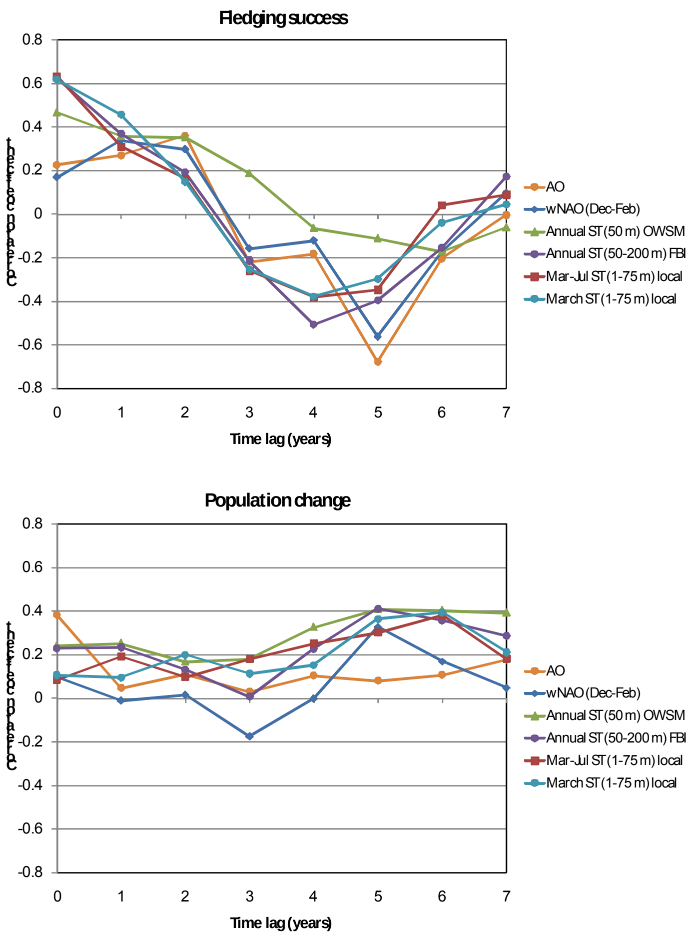

Figure 3.4.4.5.1.1 Degree of correlation between a selection of climatic variables and (a) the fledging success (upper) and (b) the ln-transformed change in annual breeding numbers of Atlantic puffins (lower) at Røst, northern Norway in 1979–2007. To test for indirect effects of trophic relationships 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).

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3.4.5 Marine mammals

3.4.5.1 Data sources and related information

Unfortunately, there is a general lack of reliable baseline information and long-term datasets on distribution, abundance and condition of marine mammals within the OSPAR area to perform the analyses outlined for the other ecosystem components.

3.4.5.2 Approach taken to use of data

WGECO notes that WGMME identified the lack of baseline information available on marine mammals in the Arctic-OSPAR area. Material from outside the OSPAR area was assessed to see if the analysis in the other sections could be applied using the approach outlined in the other areas. Overall, insufficient material was available to perform a comprehensive analysis (see case histories).

3.4.5.3 Tabulation

Below is outlined the possible effects of climate change (Table 3.4.5.3.1).

Table 3.4.5.3.1 Possible climate change effects on marine mammals within the OSPAR Region.

Species Common name	Observed or possible effects (reproduction and survival) as a result of changes in climate
OSPAR THREATENED AND DECLINING SPECIES	
Balaena mysticetus Bowhead whale	Possibly heat intolerance; effected by changes in prey distribution
Balaenoptera musculus Blue whale	Unknown
Eubalaena glacialis Northern right whale	Unknown
Phocoena phocoena Harbour porpoise	Unknown; in fjords increase of freshwater runoff can lead to unusual freezing events
SPECIES THAT ARE NOT LISTED AS OSPAR THREATENED AND DECLINING	
Dolphin	
Tursiops truncatus Bottlenose dolphin	Unknown
Large toothed whales	
Physeter macrocephalus Sperm Whale	Unknown
Baleen whales	
Megaptera novaeangliae Humpback Whale	Possibly affected by changes in prey distribution
Balaenoptera borealis Sei Whale	Possibly affected by changes in prey distribution
Balaenoptera physalus Fin Whale	Possibly affected by changes in prey distribution
Balaenoptera acutorostrata Minke Whale	Possibly affected by changes in prey distribution
Narwhals and Belugas	
Monodon monoceros Narwhal	Possibly heat intolerance; reduction in sea ice will effect survival and reproduction.
Delphinapterus leucas Beluga Whale	Possibly heat intolerance; reduction in sea ice will influence reproduction

Species Common name		Observed or possible effects (reproduction and survival) as a result of changes in climate
All pinnipeds		
Odobenus rosmarus Walrus		Pupping on ice floes; possibly change in prey species (from benthic to seals)
Phoca vitulina Harbour Seal		Change in sea level likely to affect availability of haulout and/or breeding sites. affected along with any that use ice for breeding/hauling out
Halichoerus grypus Grey Seal		Change in sea level likely to affect availability of haulout sites; increased rainfall may influence reproduction
Cystophora cristata Hooded Seal (Greenland stock)		Life history is strongly associated with pack ice, so would be vulnerable to reduction in ice extent and duration.
Phoca groenlandica Harp Seal		Life history is strongly associated with pack ice, so would be vulnerable to reduction in ice extend and duration.
Phoca hispida Ringed Seal		Life history strongly related to ice and snow conditions. Females build birth chambers in snow drifts on ice
Erignatus barbatus Bearded Seal		Life history is strongly associated with pack ice, so would be vulnerable to reduction in ice extend and duration.
Others		
Ursus maritimus Polar Bears		A decline in reproductive output and body mass in polar bears in Svalbard, was linked to both large-scale climatic variation and the upper trophic level in the Arctic marine ecosystem.

3.4.5.4 Observations

For the marine mammals within the OSPAR region, especially non-Arctic species, it is very difficult to demonstrate relationships between changes in distribution, abundance or condition and climate change/variation, due to both a lack of baseline data and a lack of relevant long-term datasets. The Arctic species whose habitat is dependant on ice extent and duration may show a disruption in breeding/reproductive output. This is evident in polar bears and possibly in seals that breed on ice (Ferguson *et al*., 2005; Fischbach *et al*., 2007; Regehr *et al*., 2007). The long term effects on population dynamics, especially relating to reproductive success (as a function of body condition, litter production, sub-adult survival) of Arctic species that are dependent on sustained ice coverage are presumed to be considerable.

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.

3.4.5.5 Case histories

ICES WGMME, 2007 identifies the following as possible responses to climate change:

1) A decline in reproductive output and body mass in polar bears in Svalbard, Norway, between 1988 and 2002, was linked to both large-scale climatic variation (Arctic Oscillation index) and the upper trophic level changes in the Arctic marine ecosystem. Although changes could also be as a result of an increase in population abundance in the area;
2) Within the OSPAR area, long-term changes in large-scale distribution in the bottlenose dolphin, common dolphin, and the white-beaked dolphin populations over the last 100 years may have occurred. These may be a result of changes in sea surface temperature (and linked with changes in the North Atlantic Oscillation index), and
3) Changes in the distribution of harbour porpoises have been reported in the last 10 years in the North Sea and English Channel, although the reasons for the southern shift in their distribution have not been fully investigated regarding what may have caused the (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 area.

3.4.5.6 References

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Regehr, E.V., Lunn, N.J., Amstrup, S.C., and Stirling, L. 2007. Effects of earlier sea ice breakup on survival and population size of polar bears in western Hudson bay. Journal of Wildlife Management, 71: 2673–2683.

3.4.6 Invasive species

3.4.6.1 Data sources and related information

A number of invasive species have had their range and often their abundance tracked for years to decades. This information was assembled by WGITMO (WGITMO 2007), wherein information on the sources of data for all cases is presented. For one monitoring study in northwestern Spain trends in a number of species were record quantitatively in a database (http://www.siam-cma.org/cligal/novedades/50.pdf) and these cases were taken into this report, along with a small number of additional data sets reported in WGITMO.

3.4.6.2 Approach taken to use of data

The information on invasive species was particularly hard to incorporate into the framework adopted for the other species. Monitoring intervals could not be recovered from most sources; rather usually an increasing tendency to observe a previously rare species eventually brought the species to the attention of experts who reported in various ways on its increasing abundance and range. Moreover, it is almost tautological that an invasive species will be observed to be increasing in abundance and range; otherwise it would be unlikely to attract attention in monitoring studies. All species were considered to have been expected to increase with changing oceanographic conditions, but in most cases the basis for this "expectation" seemed not to be independent of the actual observations that the species was increasing in abundance. Nor is it possible to form meaningful hypotheses about how many species would not show invasive patterns under some oceanographic conditions. The sampling universe cannot be specified. Consequently, these species were not included in any of the subsequent tabulations of patterns. Nonetheless, they illustrate the extent and magnitude of change in biota that occur, with oceanographic conditions often considered causally related to the observed increased.

3.4.6.3 Tabulation

The information from the study in Northwest Spain is presented in Table 3.4.6.3.1.

Table 3.4.6.3.1 Summary of information used to assess invasive species responses to climate change.

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Source
Balistes capriscus	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Caranx crysos	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Pseudocaranx dentex	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Gaidropsarus granti	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Physiculus dalwigki	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Pisodonophis semicinctus	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Lepidotrigla dieuzeidei	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Kyphosus spectator	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf

Taxon	OSPAR Area	Property (1 - distribution, 2 - abundance, 3 – condition)	Nature of variation	Expected change in relation to climate	Observed change in relation to climate (0 - no change; 1 - equals expected; 2 - not expected)	Source
Seriola rivoliana	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Fistularia petimba	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Pomatomus saltator	IV	1	More frequent in NW Spain	More records of tropical species	1	http://www.siam-cma.org/cligal/novedades/50.pdf
Crassostrea gigas	II;III;IV	1,2,3	Extended distribution and reproductive period	further northward shift	1	unavailable

3.4.6.4 Observations on the tabulation

All cases are reported as consistent with abundance and range of the species being affected by oceanographic conditions. As noted above, though, this inference of consistency may well be circular in most cases, so the quantitative results are not stressed. The narrative presentations of individual cases histories are considered much more informative about the risks of species invasions relative to climate change.

3.4.6.5 Case histories

Non-indigenous species

Three non-indigenous species were put forward as likely examples of range expansions that appear to be related to warming temperatures. (i) the Japanese oyster (*Crassostrea gigas*) which is an escaped aquaculture species (ii) a barnacle species (*Elminius modestus*) and (iii) the invasive *tomentosoides* strain of the green alga *Codium fragile*.

Crassostrea gigas reproduces in the wild and is exhibiting an extended reproductive period as observed along the Belgium and British coasts, in Dutch and German waters, and appeared along the Swedish west coast 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 oysters have been found on the south and west Irish coasts (Boelens *et al.*, 2005). Natural recruitment occurs in all areas of Europe where the species was introduced for aquaculture purposes. It was not expected to reproduce because temperatures in European waters were lower than those occurring in it native areas. This shows the danger of inferring temperature tolerance only from data on native range, since the native range may in fact be limited by other factors.

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

Codium fragile the invasive *tomentosoides* strain (Provan *et al*., 2008) grows in a variety of habitats (hard bottom and sandy areas with hard substrates e.g., *Crepidula*, rocks, shells,) and competes with kelp and seaweeds (http://www.algaebase.org/; Provan *et al*., 2008). It is expected to expand its range around the UK under warming scenarios. The references provided by WGITMO (ICES, 2007) do not contain information on observed changes in distribution in relation to temperature.

Fish records from Iceland

One of the fish species recorded for the first time in Iceland was the Sailfin dory (*Zenopsis conchifer*) which was found in 2002. This can be added to the records of its progressive occurrence further north along the European shelf break since the early 1960s (Figure 3.4.6.5.1). The range has extended from 37°N to 64°N over a period of 40 years.

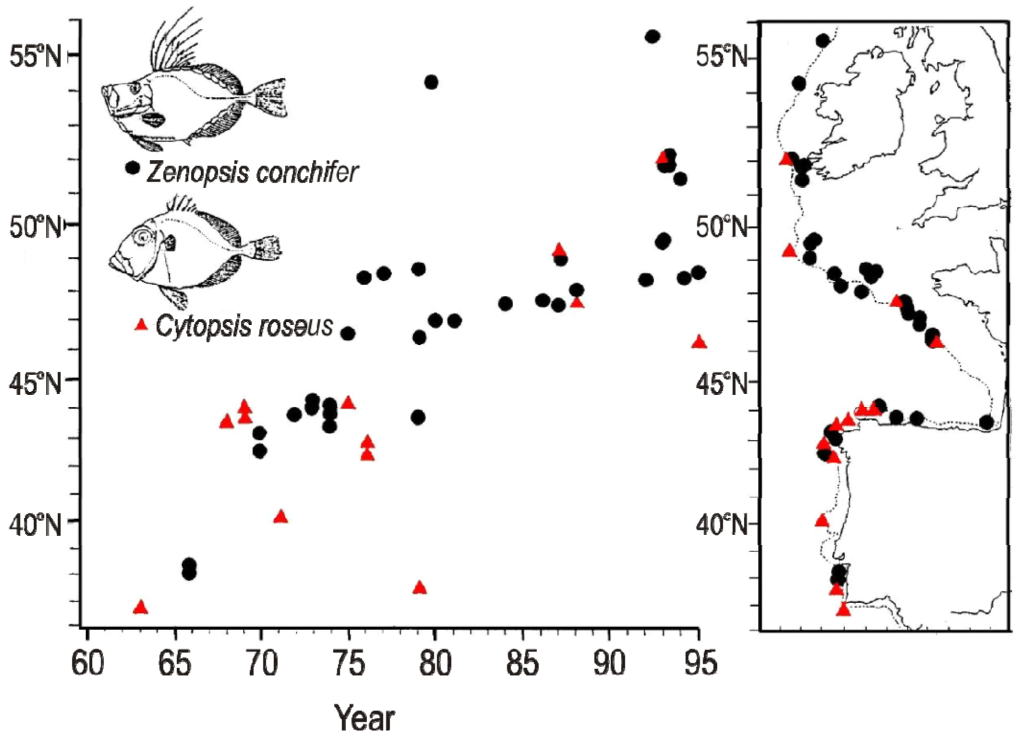

Figure 3.4.6.5.1 Movement north of Cytopsis roseus and Zenopsis conchifer from 1960ies to 1995. Figure redrawn from Quero *et al.*, 1998.

3.4.6.6 References

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Spencer, B.E., Edwards, D.B., Kaiser, M.J., and Richardson, C.A. 1994. Spatfalls of the non-native Pacific oyster, *Crassostrea gigas* in British waters. Aquatic Conservation and Freshwater Ecosystems, 4: 203–217.

3.5 Meta-analysis of overall evidence for effects

3.5.1 Rationale for selection of cases

As noted in Section 3.4, there were a number of reasons why some of the specific cases tabulated in the Section 3.5 summaries would be inappropriate for a scientifically legitimate evaluation of the extent and strength of evidence for effects of oceanographic conditions on species and ecosystems in the OSPAR area. Hence all the cases in 3.5 were subjected to a screening process to remove possible inappropriate cases. Screening considerations included:

a) Potential for confirmatory bias-papers or reports which stated that they had only reported cases that showed responses to oceanographic conditions were screened out. Not knowing how many species had been examined and not reported means 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) Dominance of another factor-cases chosen for reporting specifically because some pressure other than oceanography was affecting the species or population strongly, such that trends in the species or population would be directly informative about the effects of the other pressure were screened out. These cases would risk missing a true effect of climate, because some other pressure was aliasing its potential effects.

c) Duplicate records were removed. 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 analysis.

d) Inability to frame any *a priori* expectation of pattern-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. This justification included cases where an author may have made a prediction of an expected trend for the population, but the prediction was circular-using the observed trends in the population feature and the oceanography to predict what the pattern should have been. These cases were screened out as uninformative.

The aim of this screening process was to avoid as much as possible a bias toward the selection of "positive" records even if this reduced the number of records available for the analysis.

3.5.2 Rationale for hypothesis tested in the meta-analysis

As the term of reference requested 'the assessment of ***changes*** in the distribution and abundance of marine species' in our analysis we only considered records that showed a change. It is not appropriate to test hypotheses about what fraction of the total zooplankon, benthic, fish, and seabird species show some change. Even if it were possible to specify the full sampling universe for each taxon, only a unknown portion of all those species have been examined, and of those examined, it is unknown what fraction of results have been reported. However by screening our records rigorously for several potential sources of bias, the records screened may be the basis for at least coarse analyses of likelihoods of climate-related changes.

For the records that were screened in, the change of the property could only be in two directions: abundance can go up or down, the distribution could only shift Northward or Southward (e.g. EW movements were excluded) or towards deeper or shallower waters. Because our expectation of the effects of climate change implied a change in only one direction (e.g. an increase in abundance of Lusitanian, warm water species and a decrease in abundance of Boreal cold-water species, or a northward shift in distribution) and our screening process was intended to eliminate species where some known pressure other than climate or oceanographic conditions was driving a change in a particular direction, we assumed a null hypothesis that 50% of the cases should change according to our expectation. Furthermore, our logic is that if changes fail to exceed a 50% chance then there certainly was very little evidence to suggest climate as a cause of change. If the 50% chance was exceeded this leaves climate change as a likely cause but further analysis would be required to confirm this.

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", and several criteria had to be met before a match was inferred. If multiple criteria had to be met, then a match by chance is certainly less likely than when only a single criterion had to be met. Even if the a priori likelihood of meeting each criterion has not been determined independently, assuming a 50:50 likelihood of match or mismatch will set a conservative bound on testing for the presence of an effect of oceanographic conditions on distribution or abundance of benthic species.

One caveat to this is that in doing this we did not take into consideration that in some areas the residual water currents moving in a northerly direction may result in higher immigration rates in a that direction. Distributions that move northwards can arise through movement of both adult organisms and the influx of larvae from southerly populations. Distributions that shift southwards will as a rule only occur through adult fish movements. The value of 50% could therefore be subject to alteration based on the direction of the residual current. Without the knowledge to do this we retained the 50% value while acknowledging that further work on this might be required.

3.5.3 Results and Interpretation

The results for both all cases, and the cases remaining after the screening was applied, are presented in Tables 3.5.3.1–8.

Table 3.5.3.1 Occurrences of changes in zooplankton distribution that were in accordance with what is expected from climate change.

OSPAR AREA	SCREENED RECORDS		
	No change N	Change N	Expected %
I–V		17	100
II		3	100
II–IV		1	100
IV		1	100

Table 3.5.3.2 Occurrences of changes in zooplankton abundance that were in accordance with what is expected from climate change.

OSPAR AREA	SCREENED RECORDS		
	No change N	Change N	Expected %
I–V		1	100
II		9	44
IV		1	100

Table 3.5.3.3 Occurrences of changes in various zooplankton characteristics (other than abundance and distribution) that were in accordance with what is expected from climate change.

OSPAR AREA	SCREENED RECORDS		
	No change N	Change N	Expected %
II	7	61	100

Table 3.5.3.4 Occurrences of changes in benthos abundance that were in accordance with what is expected from climate change.

OSPAR AREA	SCREENED RECORDS		
	No change N	Change N	Expected %
II	4	32	66

Table 3.5.3.5 Occurrences of changes in benthos distribution that were in accordance with what is expected from climate change.

OSPAR AREA	SCREENED RECORDS		
	No change N	Change N	Expected %
II	9	40	65
IV	6	13	69

Table 3.5.3.6 Occurrences of changes in fish abundance that were in accordance with what is expected from climate change.

OSPAR AREA	SCREENED RECORDS		
	No change N	Change N	Expected %
I	1	13	62
II	0	15	67
III	1	12	92
IV	17	5	60

Table 3.5.3.7 Occurrences of changes in fish distribution that were in accordance with what is expected from climate change.

OSPAR AREA	SCREENED RECORDS		
	No change N	Change N	Expected %
I	0	2	100
II	1	42	79
III	9	9	89
IV	2	2	100

Table 3.5.3.8 Occurrences of changes in various seabird characteristics (including abundance and distribution) that were in accordance with what is expected from climate change.

OSPAR AREA	SCREENED RECORDS		
	No change N	Change N	Expected %
I		7	71
II		10	60
III		3	33

In each table the cases showing no change in the property being tabulated are separated from the cases where some change was observed. The percent of changes that were consistent with the expectations are also tabulated.

Looking across the tables, the first result is that cases where the change shows a trend are the rule, not the exception. Only for fish in Area IV did the number of cases with no trend outnumber the cases where some trend was present. For most of the other tables, the species which showed some trend predominated by a large amount over the species that showed no trend.

In all the rows where some trend was present, only for the 9 plankton abundance cases in area II were fewer than half the cases consistent with expectations. In 17 of the 18 taxon-ecological property (i.e. distribution, abundance or condition) combinations, in more than half the cases the trends in the property were consistent with the trend expected if the property was being affected by oceanographic conditions. As noted earlier, the decision whether or not the trends matched was an overall evaluation with insufficiently paired and calibrated data to estimate a precise statistical goodness of fit between the two series. Therefore it was assumed that there was a

50:50 probability of the two trends being considered to match, were the trends actually unrelated. If there is an overall 50:50 likelihood of matching trends by chance, the probability that 17 of 18 cases would have positive matches outnumber mis-matches is <0.001 (binomial test). For all the individual rows in Tables 3.5.3.1–3.5.3.8 where there are a total of 12 or more selected cases (so an expected value with a 50:50 likelihood of a match or mis-match is >5), chi-square tests indicate that there are significantly more positive matches than expected by chance in seven of the ten instances (P <0.01 or more in all cases) and one borderline case (0.05 < P <0.1).

Pooling all the cases that were screened in, across taxa and regions, 85% of the 246 matches are positive, significantly more than expected by chance (P <0.0001). If the rows of the tables are aggregated by taxon or by region, all results are still significant (all P for taxa pools by OSPAR area <0.01; all P for OSPAR areas pooled across taxa <0.01). The highly unbalanced numbers of selected cases by regions and taxa make the tabulation inappropriate for analyses of higher interactions among these factors. However, among taxa plankton stand out has having a particularly high proportion of positive matches. It is possible this reflects the ability of plankton to respond rapidly to changes in oceanographic, or possibly an undetected bias in the reporting of cases in the literature. Benthos on the other hand, has a lower proportion of positive matches than the other taxa. This may reflect less sensitivity to environmental conditions, or a tendency of the long-term monitoring programs to be associating with systems exposed to other strong drivers such as habitat perturbations or pollution. Differences in the proportions of positive matches were smaller among the OSPAR regions. However, the numbers of cases varied greatly among regions, and the OSPAR Area with an atypical (higher) proportion of positive matches was also the OSPAR Area with by far the most cases reported, so there could be an effect of differential power among the analyses.

3.6 Synthesis

3.6.1 Plankton

3.6.1.1 New insights from tabulation and meta-analyses

No new insights were gained from the tabulation in Section 3.5.1 but the manner in which this exercise was conducted reinforced the evidence that the observed changes are at least partly caused by the changing climate. Zooplankton inarguably undergo large-scale changes in distribution in response to warming/cooling and hydrography. With rapid life cycles and often high exposure to oceanographic conditions in the water column, population responses can be relatively fast. Also, being vulnerable to hydrographic transport processes, range may also be sensitive to changes in oceanographic conditions. WGZE-, ICES reports and peer-reviewed material offers compelling evidence that the North Atlantic and associated regions are undergoing change and it is apparent that zooplankton communities are sensitive and respond quickly to environmental changes.

The focus in the literature is on trends in functional groups and intermittently species-specific information on changes in abundance, distribution and condition with changes in climate. This analysis proved more difficult than anticipated given that trends in zooplankton with respect to climate change and variability often were reported at the functional group or genus level and the details of the species-specific changes are often held within grey literature. The functional group approach facilitates modelling and also aids understanding in complex marine system through simplification e.g., Edwards and Richardson, 2004 and ICES, 2006 on changes in functional groups' phenology, and Beaugrand *et al.*, 2002 identification of large scale abundance/distribution changes of biogeographical types.

Species-specific level information is, however, invaluable to understand the alterations in zooplankton community as a result of climate change and subsequent effects further up the trophic food web. This is typified by the mismatch between the copepods *Calanus finmarchicus* and *C. helgolandicus*, the former species is the more nutritionally valuable and its seasonal peaks of abundance differs from *C. helgolandicus* (Beaugrand *et al.*, 2003; Bonnet *et al.*, 2005). The copepods are of great importance to the fish recruitment as they represent an important prey item for larval fish (Munk, 1997; Gaard and Reinert, 2002). Annual fluctuations in abundance and phenology of these species translate clearly to the recruitment success of cod (*Gadus morhua*) in the North Sea (Beaugrand *et al.*, 2003). Species-level information is required to make these types of inferences.

3.6.1.2 Augmentation of Information from 2007

Temperature and hydrodynamic changes are strong drivers in changes in distribution, abundance, phenology and zooplankton community structure. There are defined and detailed evidence of changes in the dominant zooplankton genus/species (e.g. the copepods *Calanus helgolandicus, C. finmarchicus, C. hyperboreus, Centropages typicus*) in their spatio-temporal distribution in relation to temperature and hydroclimatic changes.

Change in abundance over large scales as a response variable is less easy to link to climate change, which perhaps reflects the seasonal nature of zooplankton productivity and rapid response to favourable, ambient conditions, e.g. stratification of the water column promoting phytoplankton blooms with subsequent zooplankton peaks in abundance (Clark and Frid, 2000).

It is naïve to assume that there is only a general warming trend towards the northern latitudes in the OSPAR area. In analysing the available data on the documented changes, identifying the mechanism of change in abundance and distribution in the higher latitudes is less clear. While there has been a decrease in the number of subarctic and Arctic species in some Arctic areas, the trend in others is reversed e.g. west of the mid-Atlantic ridge (Beaugrand *et al.*, 2002). In the area adjoining OSPAR I and V, in the Northwest Atlantic, there is a distributional move south of Arctic and subarctic species (Johns *et al.*, 2001) which links to cold temperatures in the Labrador-Newfoundland area influenced by the south-flowing Labrador Current. The coverage of the CPR varies, with some regions such as the North Sea having extensive coverage while in the higher latitudes coverage is less extensive effecting interpretation. Increasing coverage can only increase our level of knowledge of the changes in the system.

A great deal material on the effects of climate change on zooplankton is focused on the available data from the Continuous Plankton Recorder (CPR) survey. This is a valuable tool in mapping changes in the community structure. However, the CPR uses a relatively coarse mesh to sample zooplankton, and thus under-samples smaller copepods, and it only incidentally catches large phytoplankton cells and those which are in aggregations. There is, increasingly, documented material on the appearance warmer-temperature affinity zooplankton groups (e.g. meroplanktonic larvae of decapods or echinoderms, gelatinous filter feeders and gelatinous carnivorous) linked with temperature changes. But time series of sufficient length to fully elucidate the population dynamics of these organisms in a changing system do not exist. The changes in the abundance and distribution of gelatinous zooplankton are very difficult to quantify, mainly due to sampling problems: gelatinous zooplankton are difficult to sample due to fragile body forms and aggregation in sample nets.

Alternative sources of data, in addition to the CPR, should offer additional insight through offering more information on the greater plankton community, e.g. sampling that includes the micro-plankton component of plankton, a component that likely contributes to the majority of primary productivity, and other forms of zooplankton such as the aforementioned gelatinous species. It would be advantageous to synthesise other, local, zooplankton/phytoplankton sampling regimes (e.g. the The Helgoland time-series of mesozooplankton) with the CPR information.

The analysis of the Continuous Plankton Recorder (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 area. The working group concluded that these events in the plankton 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. 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 and fish species by more than 10° latitude northward has been recorded in the OSPAR 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. sub-artic species. This shift is particularly associated with the current running north along the shelf edge European continental margin (Beaugrand *et al*., 2002; Edwards *et al*., 2006). Additionally, in the OSPAR regions II, III and V an extension of the seasonal PCI has been recorded.
- **Secondary effects on higher trophic levels**: 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, whales), 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 *et al*., 2003; Edwards and Richardson, 2004; Richardson and Schoeman, 2004; ICES, 2006b; Frederiksen *et al*., 2006a).
- **Changes in the food-web structure**: Kirby *et al*., 2007 demonstrated that in the North Sea warmer conditions earlier in the year together with increased phytoplankton abundance occurred since the late 1980s, have determined the significant increase of meroplankton (i.e. temporary plankton

species), in particular echinoderm larvae of *Echinocardium cordatum.* The larvae may now impart a significant degree of control on the trophodynamics of the North Sea pelagic ecosystem by competitive exclusion of the holoplankton (i.e. permanent plankton species). This may significantly diminish the transfer of energy towards top pelagic predators (e.g. fish) while increasing the same transfer towards the benthic component.

- It is recognised that the Continuous Plankton Recorder (CPR) time series is an invaluable tool, without it, much of the insight into zooplankton population dynamics and trophic effects over time would be missing. Extending the CPR coverage will aid understanding of marine systems.
- Additionally, information from the static stations which use a variety of sampling methodologies can only increase our understanding. Different approaches have validity-in this case sampling different components of the phytoplankton and zooplankton community.
- The following zooplankton species categories should be selected for more intensive investigation:
    - dominant zooplankton genus/species that have shown significant changes in their spatio-temporal distribution in relation to hydroclimatic changes (e.g. the copepods *Calanus helgolandicus, C. finmarchicus, C. hyperboreus, Centropages typicus*);
    - zooplankton groups that have increased due to hydroclimatic changes (e.g. meroplanktonic larvae of decapods or echinoderms, gelatinous filter feeders and gelatinous carnivorous);
    - non native plankton species that have expanded their distribution possibly in relation to hydroclimatic changes (e.g. the cladoceran *Penilia avirostris*).

3.6.2 Benthos

3.6.2.1 New insights from Tabulation and Meta-analyses

The very large majority of benthic species and communities did show patterns of change in range and abundance over time, and the majority of these patterns were consistent with the expected changes if the species responded to oceanographic conditions. Compared to the other taxa examined, though, a slightly smaller proportion of benthic species showed evidence of some influence of oceanographic conditions than did plankton, fish or seabirds. However it is considered more likely that many of the benthic species whose abundances and ranges were being monitored were selected specifically because the species were sensitive to some other factor, such as habitat perturbations or pollution, than because benthic species are less likely to be affected by the state of the ocean.

Many benthic species are relatively long-lived, with life histories that allow both individuals and populations to integrate the effects of short term variation in oceanographic conditions over longer time periods. This would make their abundances and ranges actually less sensitive to variation in oceanographic conditions than for plankton and possible even for fish (as most fish are more mobile and may move to seek out preferred conditions.

Many of the strongest signals in the benthic data series, in fact, were very large changes in abundance in response to anomalously cold winter conditions. Several such responses were seen in both the Nordeney and the La Coruna data sets (and the

NSBP project was not designed to provide information on those short term population responses). This suggests strongly that oceanographic conditions do affect benthic populations and communities, but when the oceanographic signal is small, these effects may be masked by responses of the benthic populations and communities to other factors such as water quality and disturbance. Possibly only when the oceanographic pressure is strong, or when monitoring of the benthic populations is associated with careful study and monitoring (or stringent control) of other pressures, can the effects of oceanographic conditions be identified reliably in the responses of many of these benthic species.

3.6.2.2 Interpretation and synthesis

As discussed above, benthic species and communities may well be sensitive to at least anomalous oceanographic conditions, 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. Two of the stronger types of evidence of oceanographic effects on benthos may be:

a) the numerous cases where anomalous winter conditions led to die-offs of species commonly associated with relatively warmer waters or outbreaks of species commonly associated with relatively colder water, and

b) the numerous 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.

These both are consistent with an interpretation that oceanographic conditions do matter to benthos, but the signal needs to be large before it is likely to be detected. This situation could make the benthic biota a particularly high risk community for impacts of climate change, as incremental changes might be particularly hard to detect without very careful study, yet major changes in abundance could happen fairly abruptly for a small further increment in the pressure, beyond the range characteristic for the area. This situation suggests that more targeted work might be appropriate to improve our ability to detect responses of benthic species and populations to changing oceanographic conditions.

There would be value to more monitoring of sites selected because the effects of other pressures were considered small.

There would value to developing more complete classifications of benthic species by preferences or tolerances for different oceanographic conditions in ways that were not completely circular with the uses that would then be made of the classifications.

WGBE summarized a number of pathways by which changes in oceanographic conditions could be expected to affect benthic populations and communities. These include:

- Temperature itself will influence the distribution of 'northern' and 'southern' species.
- Primary production is influenced by temperature and the direction and flow of marine currents (e.g. via the transport of nutrients). The amount of primary production reaching the benthic system strongly influences the trophic structure of the communities in question.

- Hydrodynamics (e.g. current velocities, stratification of water layers, wave climate) determine the transport of larvae and influence the sediment composition, which reflects food availability to the benthos.
- Changes in precipitation can affect the distribution of suspended particulate matter, changes in the salinity variability, and changes in nutrient run-off. These both affect nutrient availability to benthos and increase the risk of hypoxia events in estuaries rich in organic matter.
- The increase in acidification of the deep sea with climate change is becoming well documented, and poses a threat to corals and other benthos, particularly species requiring calcium or carbonate for shells.

Thus, changes in both factors of interest to OSPAR (temperature and hydrodynamics) will affect species composition directly or indirectly with regard to sediment preference and the trophic structure of the benthic communities. All these pathways off potential effects highlight opportunities for directed research, and the WGBE report contains more than 20 hypotheses that could be tested with experiments or well designed monitoring.

3.6.3 Fish

3.6.3.1 New insights from tabulation and meta-analyses

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 area IV) and 100% (OSPAR area 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 77% (OSPAR area II) to 100% (OSPAR areas I and IV).

Many demersal and pelagic species changed abundance and distribution in all areas and while many of these changes are in accordance with what can be expected from climate change, others cannot. 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 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 & lesser-spotted dogfish).

The southward shift of warm-tolerant Lusitanian species is consistent with climate change acting: (i) through the warming and increasing availability of shallow habitats in the southern North Sea and (ii) through North Atlantic Oscillation-linked inflows of warm water into the NE North Sea. It is also apparent that warming is some cases has meant that species once considered strays are 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.

No new insights were gained from this exercise but the more comprehensive and structured manner in which this exercise was conducted reinforced the evidence that the observed changes are at least partly caused by the changing climate.

3.6.3.2 Interpretation and synthesis

The abundance is discussed in terms of changes in species abundance and/or distribution and not in changes in properties of fish communities. Changes in fish species abundance linked to changes in the temperature and hydrodynamics have been observed throughout the OSPAR regions (Table 3.6.3.2.1). These observations are potentially confounded by fishing effects. 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. In OSPAR Region I, the gadoids-haddock, saithe and whiting-have shown a large increase in abundance. In OSPAR Region V, which was not included in the analysis for lack of data, no large changes are expected because variation in annual recruitment has a relatively minor effect on the standing biomass. In OSPAR Region II and III, species at their northern limits in the North Sea (southern species) have increased in abundance, e.g. sea bass and stripped red mullet. In OSPAR Region III herring abundance decreased with increasing temperatures while sardine abundance is thought to have increased.

Table 3.6.3.2.1 List of species that showed a consistent and expected response to climate in OSPAR Region I.

Latin name	Common name	Association
Alosa fallax	Twaite shad	Lusitanian
Barbantus curvifrons	Palebelly searsid	Atlantic
Belone belone	Garfish	Lusitanian
Brotulotaenia crassa	Violet cuskeel	Atlantic
Chaunax suttkusi	-	Atlantic
Diaphus effulgens	Headlight fish	Atlantic
Dolichopteryx longipes	Brownsnout spookfish	Atlantic
Entelurus aequoreus	Snake pipefish	Lusitanian
Haplophryne mollis	-	Atlantic
Lamprogrammus shcherbachevi	-	Atlantic
Lycodes terraenovae	-	Boreal
Melanocetus johnsoni	Humpback anglerfish	Atlantic
Melanogrammus aeglefinus	Haddock	Boreal
Petromyson marinus		
Phycis blennoides	Greater forkbeard	Lusitanian
Platytroctes apus	Legless searsid	Atlantic
Poromitra megalops	-	Atlantic
Prionace glauca	Blue shark	Atlantic
Pseudoscopelus altipinnis	-	Atlantic
Sarda Sarda		
Scomber scombrus	Atlantic mackerel	Atlantic
Zeus faber	John dory	Lusitanian

Table 3.6.3.2.2 List of species that showed a consistent and expected response to climate in OSPAR Region II.

Latin name	Common name	Association
Anarhichas lupus	Wolffish	Boreal
Arnoglossus laterna	Scald fish	Lusitanian
Buglossidium luteum	Solenette	Lusitanian
Callionymus spp.		
Eutrigla gurnardus	Grey gurnard	Lusitanian
Glyptocephalus cynoglossus	Witch	Boreal
Hippoglossoides platessoides	Long-rough dab	Boreal
Lepidorhombus whiffiagonis	Megrim	Lusitanian
Leucoraja naevus	Cuckoo ray	Lusitanian
Limanda limanda	Dab	Boreal
Lophius piscatorius	Anglerfish	Lusitanian
Micromesistius potassou		
Microstomus kitt	Lemon sole	Boreal
Molva molva	Common ling	Boreal
Mullus surmuletus	Striped red mullet	Lusitanian
Pollachius virens	Saithe	Boreal

Raja naevus		
Rhinonemus cimbrius		
Sprattus sprattus	Sprat	Lusitanian
Squalus acanthias	Spurdog	Boreal
Trisopterus minutus	Poor cod	Lusitanian
Zeus faber	John dory	Lusitanian

Table 3.6.3.2.3 List of species that showed a consistent and expected response to climate in OSPAR Region III.

Latin name	Common name	Association
Allocyttus verrucosus	Warty oreo	Atlantic
Belone svetovidovi	-	Lusitanian
Capros aper	Boar fish	Lusitanian
Caranx crysos	Blue runner	Lusitanian
Chaunas spp.		
Cyttopsis roseus		
Dibranchus atlanticus	Atlantic batfish	Atlantic
Diretmoides parini		
Engraulis encrasicolus	European anchovy	Lusitanian
Heptranchias perlo	Sharpnose sevengill shark	Atlantic
Hoplostethus cadenati	Black slimehead	African
Mullus surmulletus		
Oblada melanura	Saddled seabream	Lusitanian
Pomatomus saltator	Bluefish	Atlantic
Raja clavata	Thornback ray	Lusitanian
Sardina pilchardus	Pilchard	Lusitanian
Scyliorhinus canicula	Lesser-spotted dogfish	Lusitanian
Solea vulgaris		
Sphoeroides pachygaster	Blunthead puffer	African
Sprattus sprattus	Sprat	Lusitanian
Tarpon atlanticus		
Thunnus obesus	Bigeye tuna	Atlantic
Trachurus trachurus	Horse-mackerel	Lusitanian
Trisopterus luscus	Bib	Lusitanian
Zenopsis conchifer		

Table 3.6.3.2.4 List of species that showed a consistent and expected response to climate in OSPAR Region IV.

Latin name	Common name	Association
Aluterus monoceros	Unicorn leatherjacket	Atlantic (African)
Bothus podas	Wide-eyed flounder	African
Cacharhinus obscurus		
Chaunas spp.		
Cyttopsis roseus		
Galeoides decadactylus	Lesser African threadfin	African

Grammicolepis brachiusculus	Thorny tinselfish	Atlantic
Hoplostethus cadenati	Black slimehead	African
Lichia amia	Leerfish	Lusitanian
Makaira nigricans	Atlantic blue marlin	Atlantic
Michrochiru boscanon		
Mullus surmulletus		
Parablennius incognitus	-	Lusitanian
Pomadasys incisus	Bastard grunt	African
Pomatomus saltator	Bluefish	Atlantic
Scyliorhinus canicula	Lesser-spotted dogfish	Lusitanian
Seriola dumerili	Greater amberjack	Lusitanian
Seriola rivoliana	Almaco jack	Lusitanian
Sphoeroides pachygaster	Blunthead puffer	African
Sprattus sprattus	Sprat	Lusitanian
Synodus saurus	Atlantic lizardfish	Lusitanian
Synphodus ocelatus		
Tarpon atlanticus		
Tetrapturus albidus	Atlantic white marlin	Atlantic
Zenopsis conchifer		
Zeus faber	John dory	Lusitanian

In OSPAR Region I, for several species that were not from Arctic origin and increased in abundance we assumed this to be climate driven. In Regions II, III and IV climate effects resulted in the changes in range of a species within a certain area. In OSPAR area II a strong relationship with climate-biogeography was found for several species exhibiting boreal-cold temperature as well as Lusitianian-warm water distributions. As a typical example of the former, the southern range boundary of wolffish retracted northward in response to local warming. In contrast the abundance of a typical example of the latter, Red mullet, increased strongly while its distribution was observed to be shifting northward. When the relationship between body size and climate-distribution was assessed, it was observed that smaller species such as scaldfish and solenette spread out and larger species retracted during warmer years changing their distribution within the North Sea. Thus it was considered that species habitat occupancy and latitudinal and depth distributions are changing in response to interannual variation in several measures of temperature and/or hydrography. However, it should be realized that there is no single biogeographical measure that consistently responds to a single measure of temperature or hydrography across the range of species. There is considerable heterogeneity in individual species' response to the various measures of climate variability, although there is scope to determine the underlying ecological factors, such as lifestyle (pelagic/demersal), trophic level and particularly body size. Comparative studies highlight a substantial proportion of species that do not appear to change distribution in response to climate variability. Finally, it was noted that the effect of temperature will be minimal if fishing pressure increases sufficiently to suppress all biotic interactions. This raises two questions:

- What other aspects of their population biology may be responding to climate variation?
- To what degree are species distributional responses to climate variability constrained by a strong association with the physical habitat?

3.6.4 Seabirds

3.6.4.1 New insights from tabulation and meta-analyses

The tabulation and the meta-analyses highlight that the connection with the climate change is not always clear and is generally mediated through trophic effects. This corroborates existing inferences on the effects of climate change on seabirds.

It is apparent that it is important to understand the underlying mechanism driving the observed change in a seabird population. Climate variability (inter-annual and variability on sub-decadal scales), not just the influence of longer term increase in temperature and hydrodynamics, will impact on seabird populations. However, the extent of climate variability and how it affects prey abundance and distribution can be difficult to disentangle from other effects on seabirds such as fisheries effects (e.g. changes in discard patterns). Irons *et al*. (in press) (unavailable for analysis-reported by WGSE) studying reproductive success of guillemots illustrated that there is evidence that the magnitude of a shift in sea surface temperature, regardless of whether the temperature changes were positive or negative, are more important than direction. 'Extreme events' and their effects, especially long term, on seabirds (and other functional groups) need to be assessed.

The most salient feature of the analysis is that the available outcomes best illustrate that the relationship between climate change and bird population dynamics is complex, both in terms of direct effects on metabolism, and indirect effects, usually mediated through prey population dynamics/trophic effects. Within the North Atlantic (OSPAR I–V) the observed trend is that there is a warming phase. Even for the same species, but different populations throughout the OSPAR region, there are different responses to this trend. This is neatly shown by the effect of sea surface temperatures (SST) on the abundance of pelagic fish that are important for Atlantic puffins (Harris *et al*., 2005). Depending on the area, different populations of Atlantic puffins feed predominantly on either herring or sandeel. 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). However, a positive relationship between sea temperature during winter and recruitment of 0-group (first-year) herring has been documented at higher latitudes in the Norwegian and Barents Seas (Toresen and Østvedt, 2000; Sætre *et al*., 2002). Thus an expectation that warmer temperature will consistently decrease the availability of prey, indirectly negatively affecting bird population dynamics is unsophisticated.

Notwithstanding, even when the mechanism of change in climate on a higher predator is presented based on the knowledge of the potential indirect and direct effects the outcome is not always as predicted (e.g. Thompson and Ollason, 2001). Additionally, many explanatory variables can influence the population dynamics of a bird species. Temperature variation may only explain a small proportion of the observed variation in the face of stronger influences such as, for example, fisheries effects determining the abundance of available prey.

This issue is further complicated by differential responses to the same explanatory variable within a population at different stages of the life history. Møller *et al*., 2006 investigated the natal and breeding dispersion of the Arctic tern (*Sterna paradisaea*) in response to the same driver. Increasing temperature, results in a different response in different behaviours, whereby natal dispersion range increased and breeding dispersion range decreased.

3.6.4.2 Interpretation and synthesis

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

- In some circumstances, a warming trend advances 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 non-optimum 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), 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; Nisbet *et al*., ms; Wernham *et al.*, 2002).

There is a substantial body of evidence linking changes in seabird demography and population dynamics to changes in ocean climate (Table 3.6.4.2.1). Most of these studies assume that climatic effects are indirect, i.e. mediated through trophic effects. This assumption is strongly based on theoretical consideration, although it is rarely possible to elucidate all steps of the causal chain. Although a coherent mechanistic hypothesis for how climate change affects seabirds can be constructed, it is not possible to test all elements of the hypothesis with existing data since spatially explicit relevant to the topic under question does not exist. Research is therefore often limited to analyses of the relationships between climatic variables and seabird demography, sometimes skipping several trophic levels.

Table 3.6.4.2.1 Links between climate change and seabirds (trends identified by WGSE).

SEABIRD PARAMETER	SPECIES	REGION	CLIMATE VARIABLE	SIGN OF CORRELATION WITH WARMING	SOURCES
Breeding range	Lesser black-backed gull	U.K.	Sea temperature	Positive	Mitchell *et al.* 2004
	Northern gannet	U.K.	Sea temperature	Positive	Mitchell *et al.* 2004
Non-breeding range	Lesser black-backed gull	U.K.		Positive	Wernham *et al.* 2002, Mitchell *et al.* 2004
	Common guillemot	Shetland	Sea temperature, sandeels		Heubeck *et al.* 1991
Reproductive success	Northern fulmar	Orkney (North Sea)	NAO index	Negative (hatching); positive (fledging)	Thompson and Ollason 2001
	Atlantic puffin	Røst Norwegian Sea	Sea temperature	Positive	Durant *et al.* 2003
	Atlantic puffin	Røst Norwegian Sea	Salinity	Negative	Durant *et al.* 2006
	Greater black-backed gull	Newfoundland	Sea temperature	Positive	Regehr and Rodway 1999
	Herring gull	Newfoundland	Sea temperature	Positive	Regehr and Rodway 1999
	Black-legged kittiwake	Newfoundland	Sea temperature	Positive	Regehr and Rodway 1999
	Leach's storm-petrel	Newfoundland	Sea temperature	Positive	Regehr and Rodway 1999
	Black-legged kittiwake	Isle of May (North Sea)	Sea temperature	Negative	Frederiksen *et al.* 2004b
Annual survival	Northern fulmar	Orkney (North Sea)	NAO index	Negative	Grosbois and Thompson 2005
	Black-legged kittiwake	Isle of May (North Sea)	Sea temperature	Negative	Frederiksen *et al.* 2004b, 2006
	Atlantic puffin	North Sea, Irish Sea	Sea temperature	Negative	Harris *et al.* 2005
	Atlantic puffin	Røst Norwegian Sea	Sea temperature	Positive	Harris *et al.* 2005
	Atlantic puffin	Norway (Barents Sea)	Sea temperature	Negative	Sandvik *et al.* 2005
	Common guillemot	Norway (Barents Sea)	Sea temperature	Negative	Sandvik *et al.* 2005
	Black-legged	Norway	Sea	Positive	Sandvik *et al.*

SEABIRD PARAMETER	SPECIES	REGION	CLIMATE VARIABLE	SIGN OF CORRELATION WITH WARMING	SOURCES
	kittiwake	(Barents Sea)	temperature		2005
Population change	Common guillemot	Circumpolar	Sea temperature	For both species: populations increase with small changes and decrease with large changes	Irons *et al.* in press
	Brünnich's guillemot	Circumpolar	Sea temperature		Irons *et al.* in press
	Black-legged kittiwake	Isle of May (North Sea)	Sea temperature	Negative	Frederiksen *et al.* 2004b
	Northern gannet	Newfoundland	Sea temperature	Positive	Montevecchi and Myers 1997
Nesting (laying or hatching) date	Black-legged kittiwake	Isle of May	NAO index	Positive	Frederiksen *et al.* 2004a
	Common guillemot	Isle of May	NAO index	Positive	Frederiksen *et al.* 2004a
	Atlantic puffin	St. Kilda	Sea temperature	Positive	Harris *et al.* 1998
	Atlantic puffin	Røst (Norwegian Sea)	NAO winter Index	Negative	Durant *et al.* 2004b
	Common guillemot	Isle of May (North Sea)	Sea temperature	Negative	Harris and Wanless 1988
	Razorbill	Isle of May (North Sea)	Sea temperature	Negative	Harris and Wanless 1989
	European shag	Isle of May (North Sea)	Wind	Negative	Aebischer and Wanless 1992
Fledging date	Common guillemot	Baltic Sea	Air temperature	Negative	Hedgren 1979
Foraging cost	Common guillemot	Isle of May (North Sea)	Stormy weather	Positive	Finney *et al.* 1999
	Northern fulmar	Shetland (North Sea)	Wind speed	Negative	Furness and Bryant 1996

3.6.5 Marine Mammals

3.6.5.1 New insights from tabulation and meta-analyses

This was not possible due to the lack of long term or strong time series of abundance data, or even trend indicators, for endemic Arctic marine mammals and other groups.

3.6.5.2 Augmentation of Information from 2007

WGECO recognises the challenges faced by WGMME in terms of the difficulty of working with and censusing small populations. The reports which are available remain mainly correlative and subjective in attributing climate change as causal agent.

WGECO notes that population genetics models generally show that there is an increased susceptibility, as result of low population sizes and hence reduced genetic diversity. This can mean that the population has little ability to adapt to changing external conditions such as caused by climate change. Such effects would be manifest over relatively long time periods (generations). In contrast, reduced-with respect to the virgin state-populations are likely to be restricted to the core, optimal habitat. As such decreased suitability, for example through warming, of large areas of the original range may not be apparent in the size of the population. However, once the area of suitable habitat loss increases to such an extent that it intersects the range of the small population then the decline will be catastrophic and rapid. These two scenarios have different management implications.

Changes in distribution and abundance are considered to be driven by bottom up effects (prey organism abundance and distributions affected by changes in hydrodynamics and temperature). The effects of changes in phenology in prey species (plankton and fish) are unquantified with respect to marine mammal population dynamics. Additionally, in the case of the Arctic species (both permanent residents and visitors whose life cycle is linked to the higher latitudes), loss of habitat i.e. extent and duration of ice (Heide-Joergensen and Lydersen, 1998; Härkönen *et al*., 1998; Stirling *et al*., 1999), is considered important but again this is difficult to quantify.

A set of statistical models as appropriate analytical tools need to be developed to assess changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics, and sea temperature to address the topic of effects of climate change.

The main identified marine mammal ecological indicator species predominantly include those in close association with Arctic sea ice/cold temperature-to-polar seas influenced by sea ice. They are: Polar bear; Ringed seal; Hooded seal; Harp seal; Bearded seal; Beluga whale; Bowhead whale; Narwhal). Those species which undertake large scale migrations (sperm whale and baleen whales) may also be possible indicator species (Learmonth *et al*., 2006; Simmonds and Isaac, 2007) and those species which are identified in conservation legislation (e.g. harbour porpoise and bottlenose dolphin).

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 most affected by climate change;
- Although Arctic species must have the highest priority for monitoring, WGMME notes that monitoring non-Arctic water species (e.g., harbour porpoise, *Phocoena phocoena* and bottlenose dolphins, *Tursiops truncatus*) also have merit. Additionally, the conservation of both harbour porpoises and bottlenose dolphins is specifically considered under the Habitats Directive through the establishment of marine protected areas (MPA). Impacts of climate change (i.e. on the prey species via changes in currents creating a shift in retention, concentration areas) could make an area previously important for either porpoises or bottlenose dolphins unsuitable in future years. Therefore monitoring of the habitat use of these species may provide a useful indicator of affects of climate change;
- 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), and

- 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.

3.6.6 Invasive species

3.6.6.1 Interpretation and synthesis

Published literature on documented climate change impacts on non-native species is sparse. Conclusive evidence is further limited by limited spatial and long-term sampling. Although the range expansions of certain introduced barnacles and algae are probably related to warming, the expansion of other vagrant species (species found at the edge of their tolerance range) is probably not related to climate change. Nevertheless, it is difficult to interpret the difference between vagrant species and introduced species with expanding ranges. Authors have, for example, differed in their interpretation of the range changes of Lusitanian species (Heinz-Dieter and Gutow, 2004; Hiscock *et al.*, 2004; Southward *et al.*, 2004; Kerckhof, pers. comm.). Information on the native range and potential range of many species is also often lacking, i.e. species' physiological tolerance is often greater than their distribution in their native range. The native range of a species is limited usually by physical and interactions, while successful introduced species may face fewer predators, disease and competitors. Thus, the potential range (i.e. the temperature and salinity tolerances) of a species may be greater than the observed native range. Finally, it is difficult to separate out those species found at the edge of their tolerance range (vagrants) that expand and contract with climate fluctuations.

A list of example non-indigenous species that are established (i.e. they are reproducing in the new location), appear to show range expansion, and/or show changes in reproductive periods over the last several years includes algae (*Codium fragile* (a green alga); *Sargassum muticum* (a brown alga)), molluscs (slipper limpet *Crepidula fornicata*, Japanese oyster *Crassostrea gigas*), barnacles (*Megabalanus tintinnalulum, Balanus amphitrite, Solidobalanus fallax, Elminius modestus*) and bryozoans (*Bugula neritina*). There are some caveats on this list. Astthorsson and Palsson, 2006 noted that over 22 species of fish normally recorded further south have been found recently in Icelandic waters. These species were categorised as annually recorded species, first time records, and others. Species that are now recorded annually include the twaite shad *Alosa fallax*; mackerel *Scomber scombrus*; sea lamprey *Petromyzon marinus* and garpike *Belone belone*. Nine species have been recorded recently for the first time are flounder *Platichthys flesus*, blue shark *Prionace glauca*, violet cuskeel *Brotulotaenia crassa*, blackdevil angler fish *Melanocetus johnsonii*, pink sabertooth *Evermannella balbo*, palebelly searsid *Barbantus curvifrons*, *Lycodes terraenovae* (an eelpout), *Poromitra megalops*, and *Chaunax suttkusi*. Some of these fish were seen in more than one location or over several years. Other species extending their ranges are the snake pipe fish *Enterlurus aequoreus*, greater fork beard *Phycis blennoides*, and blue antimora *Antimora rostarata*. Of all these species, only *Chaunax suttkusi*, *Petromyzon marinus*, and *Platichthys flesus* are believed to be introduced species.

Some Lusitanian species have spread into the Eastern Channel and into the south-eastern North Sea (Heinz-Dieter and Gutow, 2004) and are considered by some authors as indicators of warming; however many of these species are considered vagrants by other authors (Herbert *et al.*, 2003; Hiscock *et al.*, 2004; Southward *et al.*, 2004; Kerckhof, pers. comm.). The following species are believed to be Lusitanian vagrants: red algae *Mastocarpus stellatus* and two crab species *Liocarcinus depurator* and

Diogenes pugilator. Other species that are possibly expanding their ranges, but not clearly related to climate change include four species of red alga *Asparagopsis armata*, *Antithamnionella ternifolia*, *Bonnemaisonia hamifera* and *Neosiphonia (=Polysiphonia) harveyi*; three species of polychaete *Hydroides dianthus*, *Hydroides ezoensis* and *Ficopomatus enigmaticus*; a crab *Eriocheir sinensis*; and a tunicate *Styela clava*. Seven species of amphipods on floating seaweeds were reported in samples taken from 1998–2000, but none appears to have become established in the North Sea. The tunicate *Botrylloides violaceus* is reported to be expanding its range due to warmer temperatures (Stachowicz *et al.*, 2002).

3.6.7 References

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3.7 Integration and conclusions

In Section 3.3 we explained why it will be difficult to partition the trends due to climate change from simply patterns of "typical" climate variability. However for several reasons it is also very difficult to unambiguously detect the impacts of either "normal" environmental variation or climate change on individuals, populations, and communities. First, or marine species in the OSPAR area many other factors affect their abundances and distributions. Commercial fishing and habitat disturbance are two of the most prominent other pressures, for fish and benthos respectively. Both of those pressures have also show trends over the past few decades, and populations of many marine species reflect direct responses to those non-climate-related anthropogenic pressures. Second the effects of oceanographic factors may be direct (increases or decreased mortality, transport to new areas or arrival at different times, but many effects may be indirect, mediated, for example by a climate-related change in the food available to predators. Thirdly many fish, marine mammals, sea birds and some benthos are long-lived, such that effects of oceanographic conditions may be buffered at the population scale and integrated over time even at the scale of the individual. Fourth, 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 are likely to be at least different in magnitude, and possibly even in sign.

Despite all these limitations, both the narrative and the analytical information examined by ICES still demonstrated effects of oceanographic conditions in the majority of cases. If the effects are that widespread, they are important to take seriously. All types of species showed such effects and effects were found in the OSPAR areas. Effects varied from weak (probably undetectable) to very strong, particularly when the environmental conditions were exceptionally cold or warm.

Having said that effects were widespread, it is acknowledge that the analyses conducted by ICES are weaker than the meta-analyses conducted by the IPPC, which had substantially more resources for data extraction, data processing, analyses, and reporting. With the time available, and relying on exclusively on experts volunteered by regional laboratories, it simply proved impossible to replicate the rigorous data extraction and statistical pattern fitting analyses conducted by the IPCC. However, the data extraction methods were at least objective and cases were screened to minimize bias in selection. The analytical approaches that were adopted were simple enough that they did not require strong assumptions to be made about the data or the relationships between the indicators of population status and the oceanographic conditions. Hence the results are considered reliable, even if they are not elegant. The conclusion is inescapable that oceanographic conditions do influence the marine biota for the OSPAR area. There was evidence for the influence of oceanographic conditions in the large majority of all types of species, and sometimes these influences were large.

Even if the evidence in this report is not considered convincing proof of the importance of oceanographic conditions for marine biota, the wealth of examples cannot be dismissed as artefacts of simply chance. Rather, the precautionary approach dictates that it is necessary to take seriously the possibility that these populations will respond as the climate changes. These responses will not necessarily dominate population dynamics in the face of fishing pressure, habitat alteration etc, but they should be a part of planning, risk assessment, and precautionary management. As discussed in the various parts of the report addressing the tabulated results, the tabulations are extensive enough to provide some guidance into the types of species and communities most likely to be affected, and the types of climate and oceanographic events most likely to cause large effects.

The OSPAR request asked if the documented responses were "more than expected" to be associated with "normal oceanographic variation? ICES can't answer that part of the question with the information available. In fact it would still probably not be possible to provide an unqualified answer to that the question even with more time and money. It is likely that analytical results will remain highly uncertain even with better data and in-depth analyses. ICES has already contributed a great deal to the large scientific literature on species-environment relationships of marine ecosystems and there has been some accommodation of these relationships in management due to a number of ICES Expert Groups(SGPRIMS, SGGROMAT, SGRECVAP). It is the step of partitioning causality for change among oceanographic conditions and the several other causes listed at the beginning of this section that will be very hard to complete rigorously.

An important question implicit in the concern about "more than the change expected due to normal variation" is if there is a "tipping point" with regard to the effects of climate> That is, is there an amount of change such that when it is exceeded by even a small incremental amount, species and even communities may undergo dramatic changes in abundance and distribution, relative to past rates of change for similar incremental changes but within the more typical range of oceanographic variation. That is a good question but not one likely to be answerable for marine marine ecosystem, even ones as comparatively data rich and well studied as OSPAR 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.

With a definitive answer unlikely in the near future, it is necessary to be precautionary in the face of this plausible risk of "tipping points" in species and communities strategies. Several actions can contribute to building the necessary precaution into policy and management, and to provide the science support that would be needed. Science needs to monitor and analyse results in ways that take advantage of spatial patterns in both hydrographic and species occurrences, and build consistent time series. Each of the Expert Group reports contributing to Sections 3.5 and 3.6 also lay out research agendas to reduce our uncertainty about relationships of oceanography and climate with species and populations, and thereby reduce our uncertainty about the potential responses of the ecosystems to climate change.

Management and Policy need to be precautionary relative to known and controllable threats, such as fishing and habitat impacts. The threats of climate change impacts provide another reason to keep populations as resilient as possible to the potential pressures associated with climate change. This means keeping abundances and age structures from being depleted, productivity high, and habitats healthy. With current or improved management, much opportunity for progress on these fronts remains. These are wise management goals for dealing with the threat of climate change to OSPAR ecosystemst, even if we cannot establish if these "tipping points" are likely to be encountered for the majority of marine species.

4 Draft environmental impact of marine fisheries for the 2010 OSPAR QSR

ToR b) Prepare a draft final assessment of the environmental impact of marine fisheries as a contribution to the Quality Status Report 2010, with reference to the scoping work completed by WGECO in 2007.

WGECO2007 noted the potential value of presenting the information by RAC area but in the end we have followed the previous QSRs and present the regional information by OSPAR Region.

A word of caution: WGECO has risen to the task of completing a draft for the OSPAR QSR and fitting what it considered the important information into the structure produced by OSPAR and scoped by WGECO in 2007. We believe the statements made are accurate and defensible, however they are often generalisations and the QSR style does not allow the use of references in text nor protracted explanations and qualifications. This is therefore a break with WGECOs normal, scientifically rigorous writing style.

The last 10 years have seen 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 2–5. We envisage that these will feature as 'boxes' in the final QSR text and so contain information pertinent to more that just the region in which the box appears.

WGECO, 2007 noted the value of integrating information on EcoQOs and 'Threatened and Declining Species' into the account. The latter is taken up under our consideration of the 'Impact of fisheries on the state of the marine environment' but given the continuing issues surrounding EcoQOs (see Section 5 of this report) we have not reported specifically on them.

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 Quality Status Report (QSR) 2010. ICES in turn tasked WGECO with the responsibility for preparing a draft final assessment of the environmental impact of marine fisheries as a contribution to the QSR. In addressing this ToR WGECO consulted the framework proposed by ICES to OSPAR and was able to compile information on most aspects suggested. However, we were unable to find any information to add concerning the impacts of fishing on item vi) Genetic effects and effects on the phenotype. The guidance provided to WGECO suggested that two expert groups in ICES (WGAGFM, SGFIAC) could provide the relevant input for the QSR 2010. In reviewing their ToRs for 2007 and 2008 it was noted that they had not been asked for this input. We suggest that those WGs be tasked with providing the missing information for 2009.

4.1 NE Atlantic QSR 2010

4.1.1 Introduction

Previous Quality Status Reports have reported on the state of fish stocks and fisheries in the region. However, 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 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 therefore appropriate to consider the 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, 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 deepwater 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.

4.1.2 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 there has also been the appreciation that in order to have healthy fish stocks you need 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 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 1972 World Conference on Human Environment.
- The 1982 United Nations Law of the Sea Convention.
- The 1992 United Nations Conference on Environment and Development and its Agenda 21.
- The 1992 Convention on Biological Diversity.
- The 1992 Habitats Directive.
- The 1995 United Nations Fish Stocks Agreement.
- The 1995 FAO Code of Conduct for Responsible Fisheries.

- The 2001 Reykjavik Declaration.
- The 2002 World Summit on Sustainable Development.
- UN 2006 General Assembly to ensure protection of vulnerable marine ecosystems.
- The 2007 Committee on Fisheries of the UN FAO on IUU and protecting the marine environment.

The fishery policy documents relevant for the OSPAR area express similar objectives. The Common Fisheries Policy (CFP) 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 Directive 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 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."

"Managing fish stocks at Maximum Sustainable Yields will provide a better future for the European fishing community and ensure its contribution to Europe's food security; this should be achieved by 2015 in line with international commitments."

The Bergen declaration 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 ecosystem management. The complex process of translating international agreements into operational and sustainable regional management continues to evolve. In the 2007 State of the World Fisheries Report 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 NEAFC was the first RFMO to initiate such a review process.

In response to the 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;
- Information sharing between NEAFC and NAFO on the IUU vessels list in the respective areas;
- 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 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;
- Stakeholder involvement.

(Source: http://ec.europa.eu/fisheries/cfp/2002_reform_en.htm)

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.

In 2006 the EC and Greenland renewed their 1985 Fisheries Policy agreement. The agreement sets out arrangements for EC fishing within the Greenlandic EEZ in exchange for capacity building (including financial support) of a sustainable Greenlandic fisheries sector. In 2006 the EC and Norway adopted an Agreed Record of Conclusions which formalizes fisheries agreements between the two parties on a variety of governance issues.

(Source: http://www.oceanlaw.net/projects/current/pdf/cdiflp2007.pdf)

International Commissions such as the ICCAT, the IWC, and NAMMCO have continued to work towards sustainable management and conservation goals through scientific investigation, monitoring, and management plans (with varying levels of success).

4.1.3 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 principle drivers on fisheries activities are the market price paid for fish on landing, the cost of fuel and the need to operate within the regulator regime. While the price of fish on landing has varied it has not shown strong trends over the long term but has been trending downwards in recent (Figure 4.1.3.1). 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 lead to some changes in the wholesale and landed prices. Global fuel prices (Figure 4.1.3.2), 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.

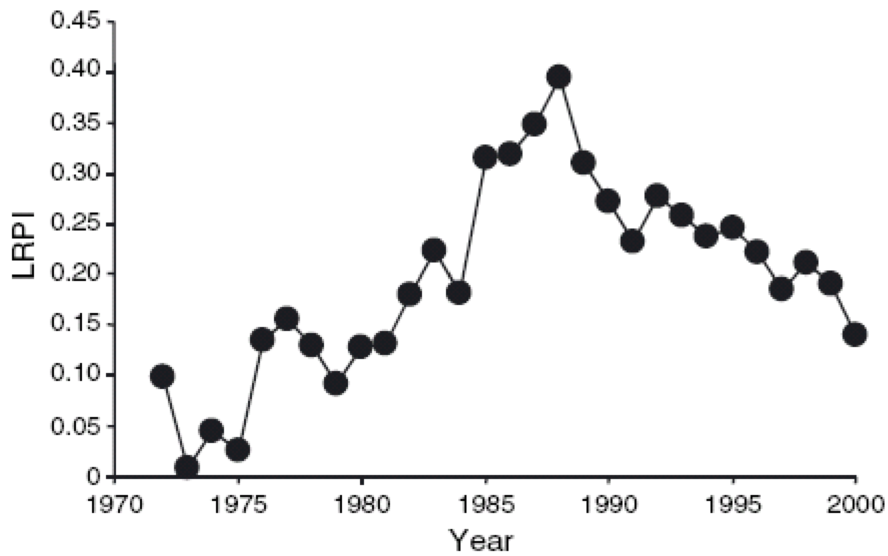

Figure 4.1.3.1 Pattern of change in the price of 26 species of fish captured by UK vessels in the Celtic Sea (ICES area VIIe–k) over a 30-year time series, expressed as a 'log-relative-price-index' (LRPI). Prices are expressed in £ kg^{-1}. (Pinnegar *et al.*, 2006).

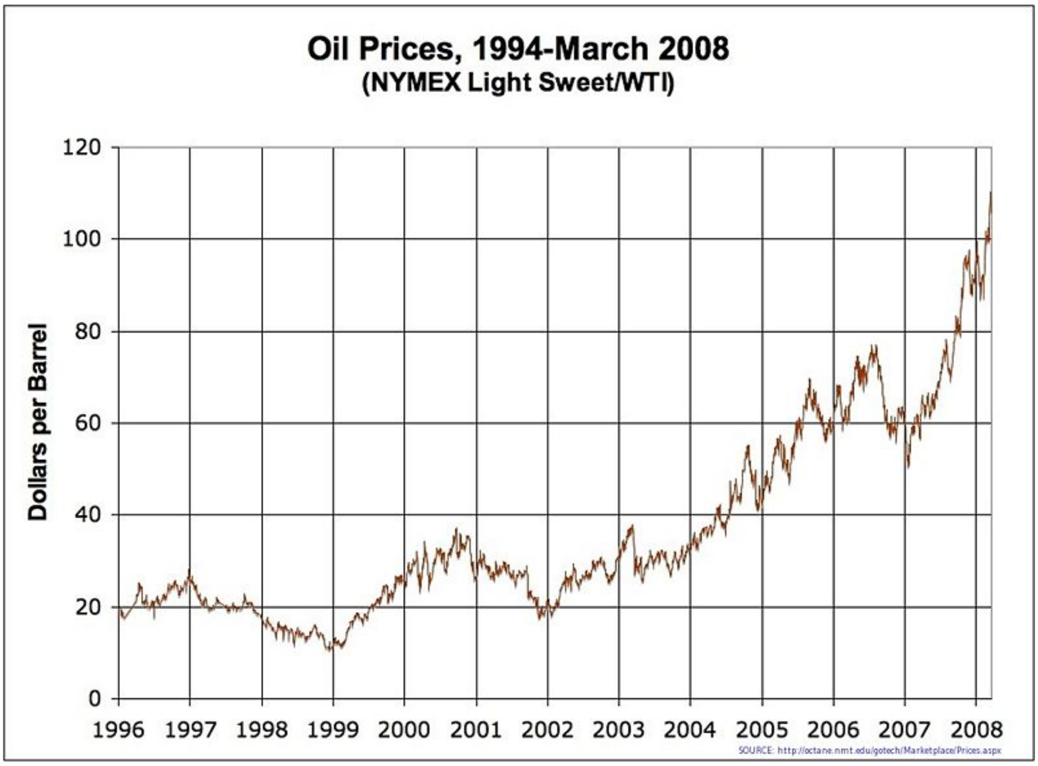

Figure 4.1.3.2 Global price of crude oil 1996–2008. (http://octance.nmt.edu/gotech/Marketplace/prices.aspx).

In order to ensure stability and security of marine food supplies it is critically important that fishing is managed in a sustainable way to avoid overexploitation of the fish stocks and to rebuild those stocks that are believed to be overexploited to levels capable of supporting a higher yield. Many target species are now not within their 'Safe Biological Limits'. In 2006 approximately 20% of the fish taken from EC managed waters (Regions I, II and III) was from stocks outside of safe biological limits (Table 4.1.3.1).

Table 4.1.3.1 A summary of the state of stocks supporting significant EC landings in 2006. The regional information relates to NEAFC regions, also defined in EC 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). Source: ICES 2007 Answers to non-Ecoregion specific Special Requests. EC DG Fish. Request: Status of fish stocks managed by the Community in the North-East Atlantic.

http://www.ices.dk/committe/acom/comwork/report/2008/Special%20Requests/EC%20Stock%20status%20report%20January%202008.pdf

FISHERY TYPE	STOCKS OUTSIDE SAFE BIOLOGICAL LIMITS SUPPORTING SIGNIFICANT LANDINGS	% OF EC LANDINGS FROM STOCKS OUTSIDE SBL
Benthic	Plaice, angler fish (Region 2) Sole, angler fish, *Nephrops* (Region 3)	42
Demersal	Cod, whiting, hake (Region 2) Hake (Region 3) Deep water species (Regions 1, 2, 3)	51
Diadromous	Salmon, sea trout (Region 2)	100
Industrial	Sandeel, Norway pout (Region 2)	33
Pelagic	Herring (Iva Region 2) Anchovy (Biscay Region 3) Mackerel (Regions 1, 2, 3)	13
Overall		21

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 increase 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 grown in oceanic areas.

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 its 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. A number of such initiatives have been applied in European fisheries in the last 10 years and some case studies are described in the Regional accounts.

4.1.4 Impacts of fisheries on the ecosystem

Commercial fishing has direct and indirect effects on the marine ecosystem which can be summarized as:

1. removal of target species;
2. mortality of non-target species (fish and invertebrates), birds and marine mammals, through their incidental catch in fishing gear;
3. physical disturbance of the sea bottom through some demersal fishing gear and therefore an adverse impact on benthic habitats and communities;
4. shifts in community structure; and
5. indirect effects on the food web.

4.1.4.1 Trends in spawning stock biomass of commercial fish stocks

Total landings in the OSPAR area have remained at approximately ten million tonnes per year since the 1980s (Figure 4.1.4.1). 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. The Regional breakdown of landings is given in Figures 4.1.4.2.6 and shows that across the whole NE Atlantic the patterns are similar. Pelagic landings show high variability and demersal landings show less variability but have trended downwards in every region.

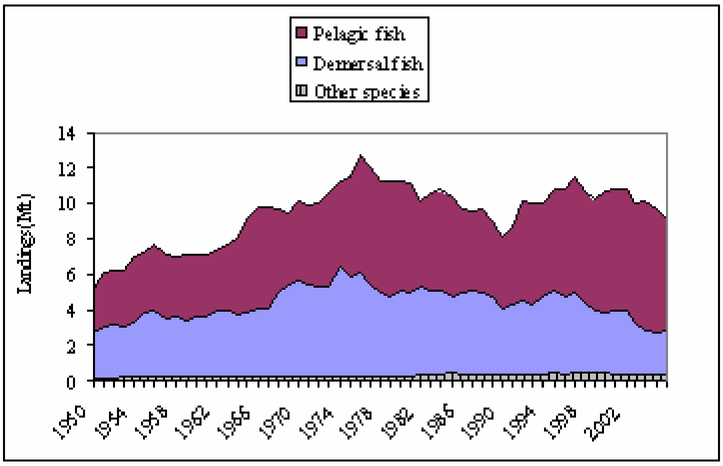

Figure 4.1.4.1 Landings in the Northeast Atlantic (ICES Area) of demersal stocks (D), pelagic stocks (P) and other species (crustaceans, squids, tunas, and tuna-like species). Data from the ICES Statlant database and includes stocks from the Baltic Sea (subdivisions 22–32) which are not in the OSPAR region.

Region I

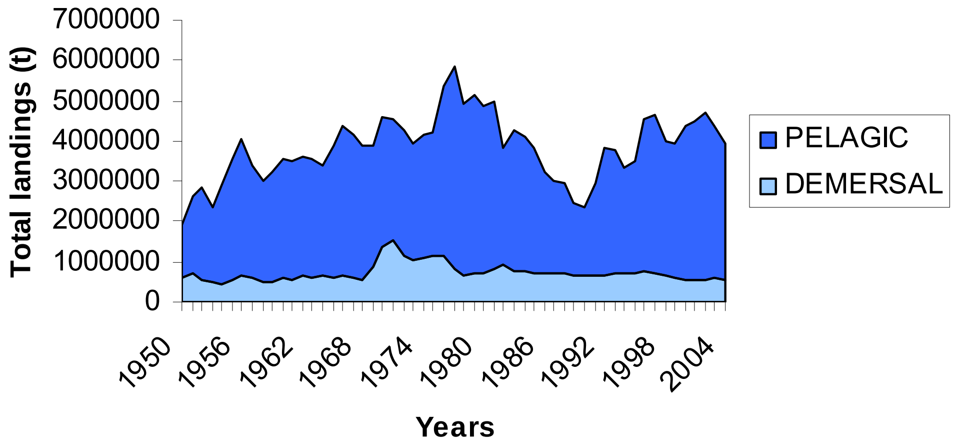

Figure 4.1.4.2 Total landings for the Greenland Sea, Faroe Plateau, Norwegian Sea, Iceland shelf, Barents Sea (sourced from www.seaaroundus.org).

Region II

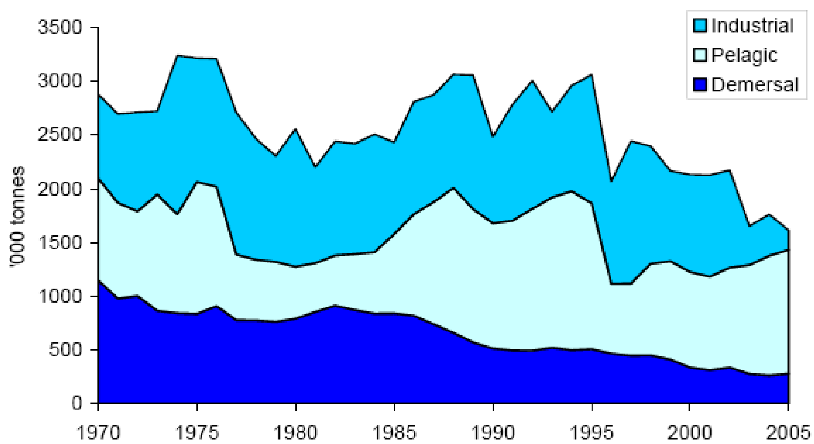

Figure 4.1.4.3 Landings (and discards) of industrial, pelagic, and demersal fisheries in the North Sea and Division IIIa (ICES, 2007).

Region III

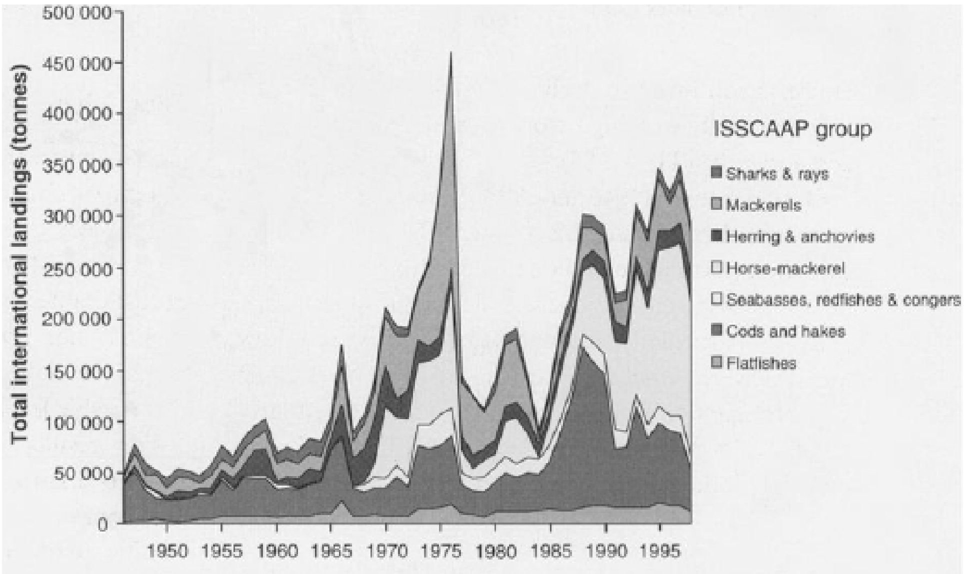

Figure 4.1.4.4 Celtic sea landings (Pinnegar *et al.*, 2002).

Region IV

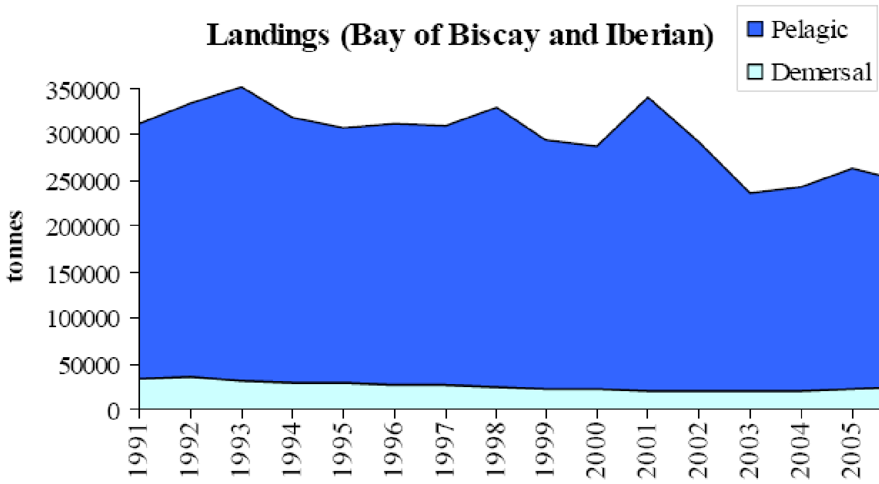

Figure 4.1.4.5 Catches by year of fish and *Nephrops* stocks assessed by ICES in the Bay of Biscay and Iberian waters. The stocks have been grouped into pelagic and demersal (ICES, 2007).

Region V

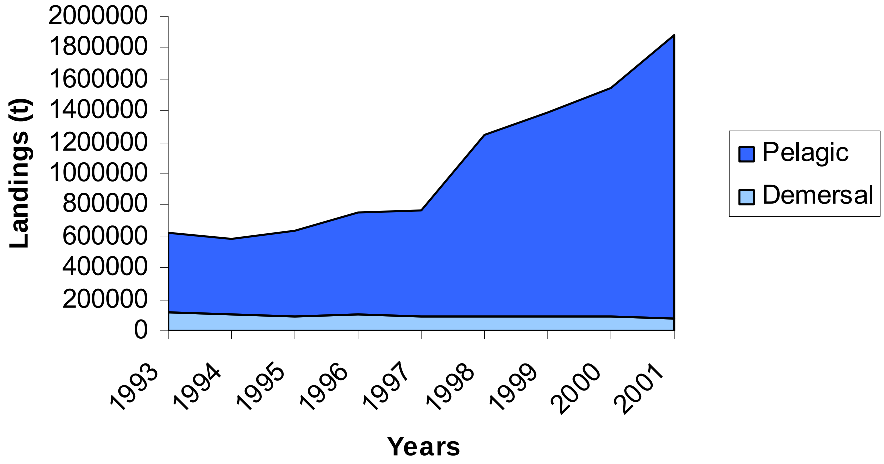

Figure 4.1.4.6 Total landings from OSPAR Region V of the 9 principal fish species exploited. Data from ICES and ICCAT databases.

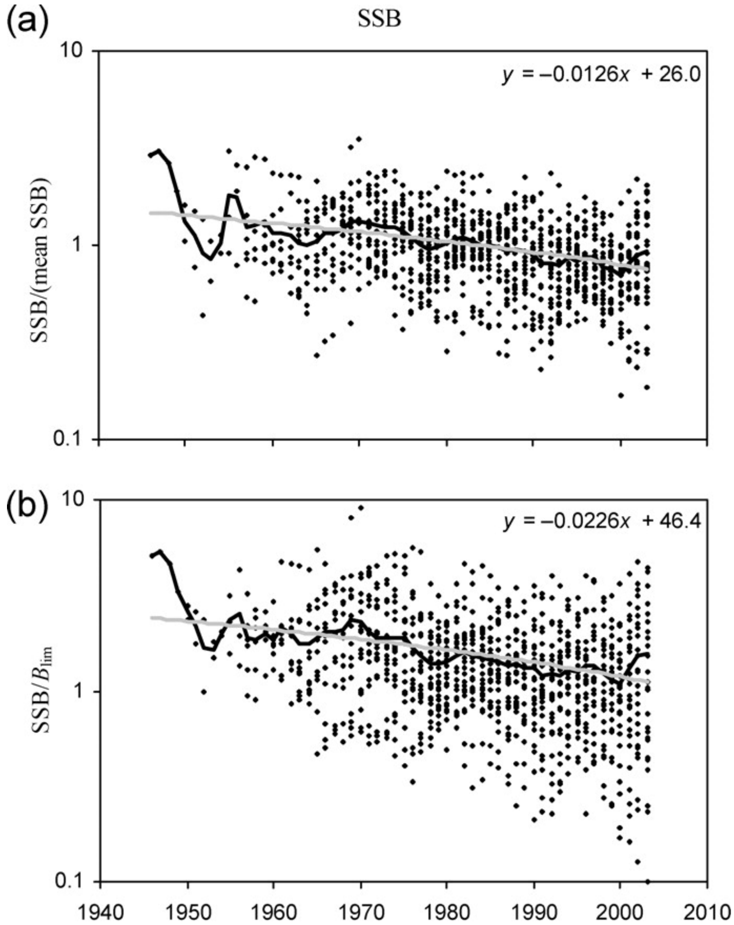

Figure 4.1.4.7 Standardized Spawning Stock Biomass (SSB) for demersal stocks by year by (a) annula mean SSB; (b) ratio of SSB to the biomass limit value (B_{lim}). The black line reflects the mean values by year, and the grey line is the linear regression (parameters are given in each panel) (Sparholt *et al.*, 2007).

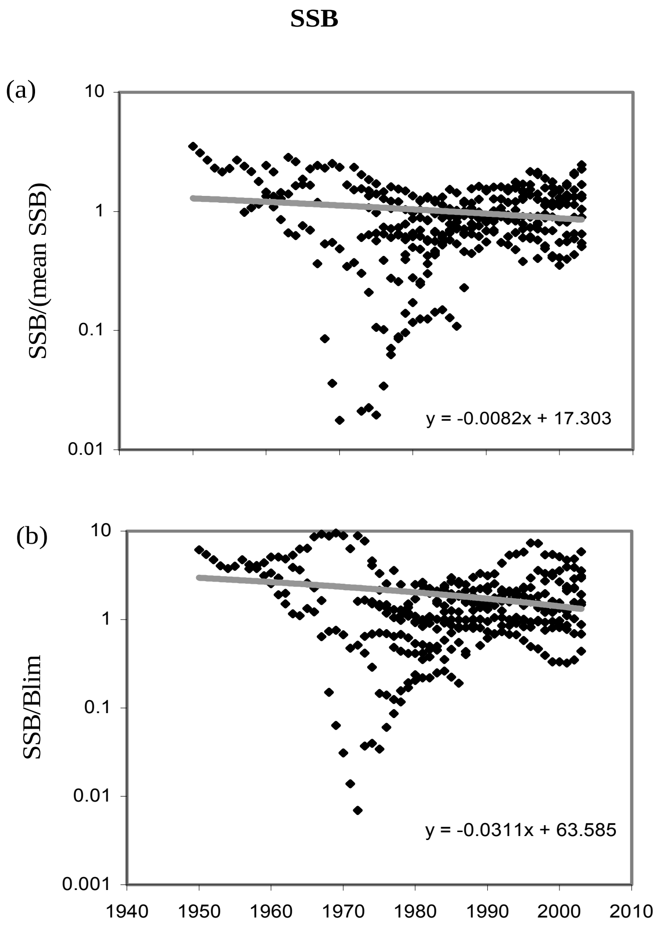

Figure 4.1.4.8 Standardized SSB for pelagic stocks by year by (a) mean SSB; (b) SSB/B_{lim}. The grey line is the linear regression (parameters are given in each panel) (Sparholt *et al.*, 2007).

The standardised SSB of demersal stocks show a negative linear regression trend throughout the time series, with mean values showing a decrease from a plateau in the 1970s, this even more evident following the standardisation of SSB using B_{Lim} (Figure 4.1.4.7). The standardised SSB of pelagic stocks show a sharp decline in the 1970s associated with a number of stock collapses and subsequent rebuilding (Figure 4.1.4.8). 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.

Across all OSPAR areas overfishing continues to be an issue with declining trends in demersal fish populations continuing. This is most pronounced in the Bay of Biscay (Region IV). French fishing effort of both towed and fixed gears for demersal species has increased in this area since 1999, and indicators for 51 fish populations and the whole fish community document a steady decline attributed to overfishing. 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. While in the North Sea (Region II) declining trends in indicators for 13 fish populations have been reported. 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. Spawning biomass of sandeel in the North Sea was at the lowest level observed in 2004 as a result of a targeted industrial fishery.

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 III) by the deep water fisheries carried out in this area. 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 macrophthalma*), and orange roughy (*Hoplostethus atlanticus*) as well as deep sea squalids (sharks) and Macrouridae. 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 seamounts populations of "giant" redfish on seamounts of the northern mid-Atlantic Ridge.

However, some stocks show some positive trends. 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. Also, the spawning stock of Greenland halibut in Region I is low from a historical perspective, but has increased slowly since 1996.

4.1.4.2 Bycatch of target and non-target species

In all five OSPAR regions some fisheries generate large amounts of discards, representing up to 50% of 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 *Crangon* 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, in addition to being a waste of living marine resources, 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 or the Iberian areas. The most successful programmes for implementing selective gears and reducing discards were those developed in close collaboration with the industry. These efforts should be further encouraged.

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. 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 was replaced by the trawl fishery, although in later years this bycatch appears to have reduced considerably. However, at least four species of seabird (northern gannet *Morus basanus*, 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, on the order of 800,000 blue sharks were caught, with a substantial proportion discarded. An estimated 24,358 dolphins were captured during these years by these fleets, of which about half were common dolphins and half were striped dolphins.

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.

4.1.4.3 Physical disturbance of the seabed

The physical impact of bottom tending gear on the benthos remains a concern, particularly with respect to the destruction of coral reefs. In the Norwegian Sea (Region I), destruction of deepwater 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 damaged or negatively impacted. 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 (*Lophelia pertusa*) on the shelf and bank slopes, prompting the Faroese authorities to close three coral areas for trawling in 2004. This species also forms large bioherms or reefs on the offshore banks (Rockall and Hatton) in Region V 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 Vasiere" grounds. Such changes to the physical habitat have the potential to cause substantial and long-term changes to benthic ecosystems, including negative impacts on burying animals such as *Nephrops*. 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.

4.1.4.4 Shifts in community structure

The three largest and economically 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 which have 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 other has repercussions to all. Years with good recruitment of herring and cod typically have resulted in poor capelin recruitment and have subsequently given rise to 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. Herring were very abundant in the early 1960s, collapsed and then have increased since 1970 to a historical high level in the last decade. 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. It appears that cod do not readily substitute herring for capelin in their diets. There is also evidence that change in the distribution of capelin which has resulted in less overlap with cod may be leading 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. In addition to catching target species, deepwater fisheries bycatch unwanted species that are either too small or unpalatable. Discarding rates are often high (in the order of 50%) and the bulk of the discarded catch is made of smoothheads (Alepocephalidae) because of their high abundance.

4.1.4.5 Indirect effects on the food web

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 trophic structure over 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. 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. There is general agreement that the size structure of the fish community has also changed significantly with a decrease in the relative abundance of large piscivorous fishes such as cod and hake coincident with an increase in smaller pelagic species which feed at a lower trophic level. 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, may have longer term consequences given the fish community shift towards smaller pelagic species feeding on zooplankton. There is some evidence that suggests 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. 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).

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. In the North Sea (Region II) data suggests that fishing activity overall has declined by approximately 28% since 1999. The resultant overall decline in fish discards may have also impacted seabird communities. Certainly, over the past decade, 12 out of 28 seabird species show an increasing trend, 4 others including the northern fulmar and black-legged kittiwake show a decreasing trend, while another 4 appear stable.

4.1.5 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 4.1.5.1 illustrates a number of these approaches with examples for a variety of types of measure.

Table 4.1.5.1 A variety of fisheries management measures introduced into European fisheries management in the last 10 years and an indication of their effectiveness.

FISHERY MEASURES:	AIM:	EFFECTIVENESS:	EVIDENCE:
CFP 2002	The 2002 reform of the CFP aimed at ensuring the sustainable development of fishing activities from an environmental, economic and social point of view. http://ec.europa.eu/fisheries/cfp_en.htm	Over 20% of 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, physical impacts on the sea floor.	ICES Advice
Cod Recovery Plan	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." http://128.227.186.212/fish/InNews/cod2004.htm	SSB has declined from 250,000t in 1970s to 40,000 in 2006. The limit value below which the productivity of stock is considered to be impaired is 70,000t. North Sea cod effort has declined by 25% since 2000 F has been in declined since 1999/2000 but remains above the value needed to rebuild stocks in the required time frame.	ICES Advice
Sandeel management	To leave a SSB = B_{pa} after a year of fishing	Compliance with Harvest Rule achieved after 3 years	ICES Advice
GBTM – cetacean pingers	Reduce mortality on small cetaceans in EC waters to below the ASCOBAN levels of 'unacceptable' mortality	Pingers are not widely used. Those pingers in use target only 1 species, the harbour porpoise.	Very limited monitoring of the effectiveness of these measures seems to have occurred. Monitoring was a requirement of the

Fishery measures:	Aim:	Effectiveness:	Evidence:
			Regulation.
Hake recovery plan	To increase SSB of northern Hake to within safe biological limits	Met the SSB of 140,000t achieved in 2006 and 2007.	ICES Advice
GBTM - Mesh size increases and square mesh panels	Decrease by-cacth mortality and discarding of non-target species and undersize targets	Some reduction of discards in modified gear has been observed.	This report
Bay of Biscay anchovy closure in 2005.	Rebuild stocks of anchovy following a recruitment failure	Only slight signs of stock recovery apparent in 2006 and 2007	From scientific fishing in 2007; see this report
Closed areas to protect corals in Regions I and V; including Council Regulation (EC) no 602/2004 of 22 March 2004	To protect vulnerable habitats and coldwater corals.	Fishing has virtually ceased in more than ten closed areas. No monitoring has occurred of the state of coral reefs	WGDEC
Closed areas in EU Atlantic and North Sea waters	Variety of fish stock conservation measures and in one case for biodiversity conservation	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.	STECF SGMOS 07-03 report
EC data collection regulations	Regulation establishing the Community Programme for the collection, management and use of data (including ecosystem considerations) in the fisheries sector	Council Regulation (EC) No 199/2008 only recently established	Scientific, Technical and Economic Committee for Fisheries

4.1.6 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 which are abundant in seafood the fisheries sector will remain under pressure to deliver high quantities of material. Managing the fishery within ecologically sustainable limits, meeting societal objectives for the conservation of biodiversity against this moral, social and economic imperative will be a growing challenge for fisheries management. OSPAR will work in partnership with Regional Fisheries Management Organisations to deliver ecologically sustainable fisheries and ensure adequate provisions are made for biodiversity conservation.

Fisheries recovery plans are delivering better stock health for those stocks covered by them and gear based technical measures have made a contribution to reducing the environmental impact of some fisheries. Regulatory and market incentives both can lead to an improvement of fishing practice.

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.

OSPAR should:

- Work with RFMOs to develop ecosystem based fisheries management plans.
- There remains considerable heterogeneity in the level of knowledge about fisheries resources, fisheries impacts and ecosystem status across the OSPAR regions. OSPAR should continue to work with RFMOs to develop a more detailed and more consistent data coverage to underpin evidence based management.
- Continue the development of integrated marine management plans and assessment techniques, for example through the setting of ecological quality objectives and integrated assessments.
- Work to ensure that the QSR process in future meets the needs of those countries required to make an initial assessment of their marine waters under the EC Marine Strategy Framework Directive.

4.1.7 Further Reading

The Common Fisheries Policy (CFP) Council Regulation Nr 2371/2002.

The Marine Strategy Framework Directive 9388/2/2007.

The Maritime Policy Blue book COM (2007) 574 final. An Integrated Maritime Policy for the European Union.

Ministerial declaration of the fifth international conference on the protection of the North Sea, Bergen Norway.

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4.2 Regional QSR I: Arctic

4.2.1 Introduction

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 North East Arctic cod has been healthy since 2002 and fishing mortality has been reduced, but surveys indicate that recent year classes are 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 NEA haddock and NEA saithe are high, and recent recruitment appears 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 Faeroes, the haddock and saithe stocks are in good shape, 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, due to a too small spawning stock. The exploitation of polar cod in the Barents Sea has been very low since the 1970s. The Iceland-Greenland-Jan Mayen capelin stock reached a peak in 1996/97, but has since declined.

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..

4.2.2 The development of fisheries management and policy since 1998, and an assessment of their effectiveness

Although the Iceland 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 is alleviated by the compulsory use of a Nordmøre grid since the mid-1990s, as well as a shrimp sorting grid and 40 mm square-mesh codend in areas of juvenile shrimp.

In Norway, 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 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 waters. A Norwegian program 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.

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. The need for such activity is probably larger than what is currently carried out, given the fish mortality observed in retrieved nets.

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 most of the Icelandic fleets operates under this system (WGDEEP).

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 with the objective to protect 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, in a given area, there are several consecutive quick closures the Minister of Fisheries can close the area for a longer time forcing the fleet to operate in other areas. Such semi-permanent closures took place at several places along the south-southeast area for tusk in 2003 (Figure 4.2.2.1). 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 aiming at protect juveniles. Figure 4.2.2.1 shows map of such legislation that was in force in 2004. Some of them are temporarily, but others have been closed to fisheries for decades (WGDEEP 2008).

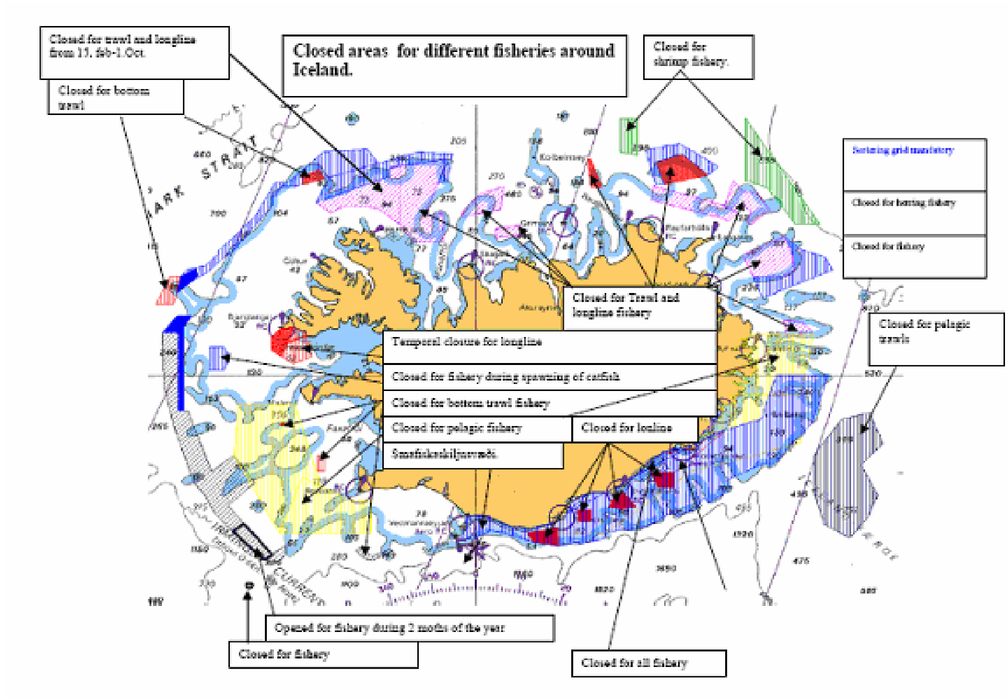


Figure 4.2.2.1 Overview of closed areas around Iceland. The boxes are of different nature and can be closed for different time period and gear type (see text for further detail) (WGDEEP 2008).

4.2.3 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 4.2.3.1). The gross tonnage of the trawler fleet has remained rather stable in the last decade at around 100 000 tonnes, but their main engine power has decreased by 25% or from 200 000 to 150 000 kW. In Icelandic deep sea fisheries the most significant development in recent years is the increasing size of pelagic trawls and with increasing engine power the ability to fish deeper with them. There have also been substantial improvements with respect to technological aspects of other gears such as bottom trawl, longline and handline (WGDEEP 2008).

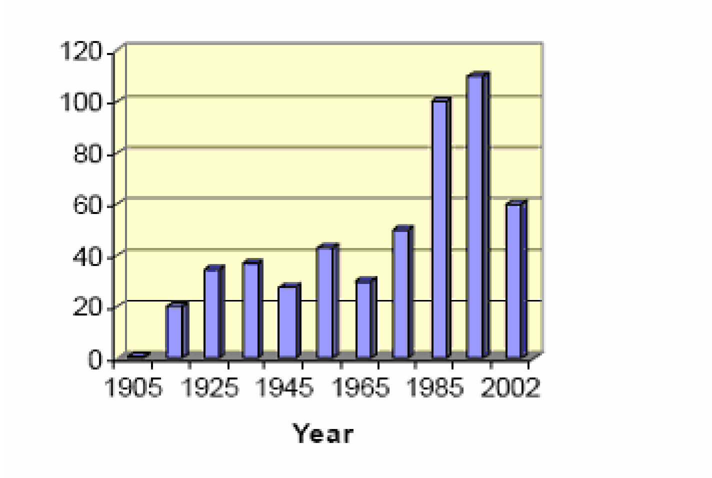


Figure 4.2.3.1 Number of Icelandic trawlers during the period 1905–2002 (Garcia *et al.*, 2006).

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 25 000 tonnes or less in recent years. The offshore shrimp fishery led to a great increase in trawling effort targeting cod and Greenland halibut on the continental slopes and in deeper muddy areas off the northern part of the country where bottom trawling had been relatively sporadic until then Trawling effort measured in standardized trawling hours has decreased by some 50% in the last decade.

Icelandic *Nephrops* catches reached a historical maximum of 6000 tonnes in 1963, but they decreased quickly to some 1500 tonnes a year in the last decade. This fishery exerts localized and severe impact due to the use of 80 mm codend mesh on grounds inhabited partly by juvenile haddock, whiting and witch (Figure 4.2.3.2). Fishing effort measured in number of trawling hours decreased by some 60–70% in the last decade compared to the early 1970s.

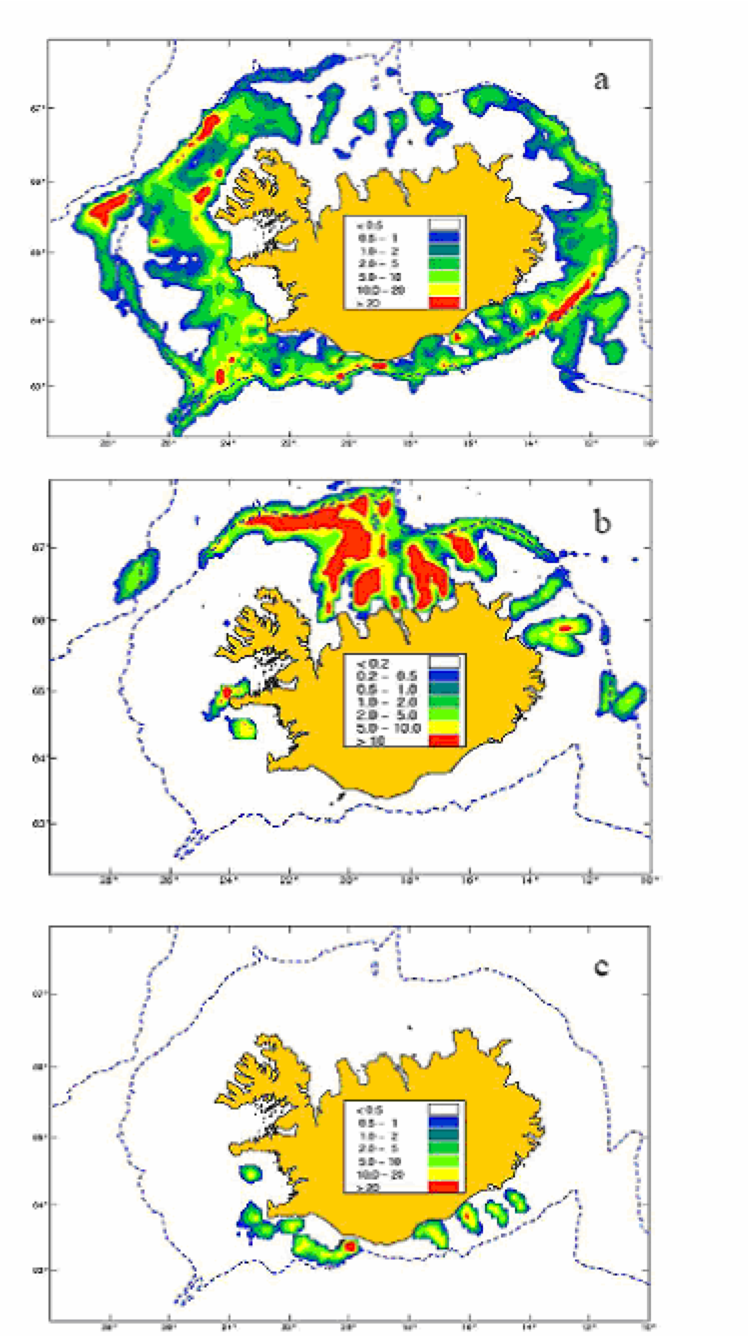


Figure 4.2.3.2 Distribution of total otter trawling effort (tow duration) in Icelandic waters targeting a) demersal fish b) shrimp and c) *Nephrops* between 2000 and 2004. The 300 m depth contour is shown (Garcia *et al.*, 2006).

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. Impacts of the fishery are difficult to estimate but cannot be ruled out. Thus, all local scallop fisheries had been suspended by the year 2003. In Breiðafjörður, West Iceland, the stock is at present (2006) estimated at 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 4.2.3.3), especially since early 1990 as a result of technological advances and the significant decreases in stock sizes of commercial fish species. It is likely that fishing has had a considerable negative impact on benthic habitats and species since the early 20th century.

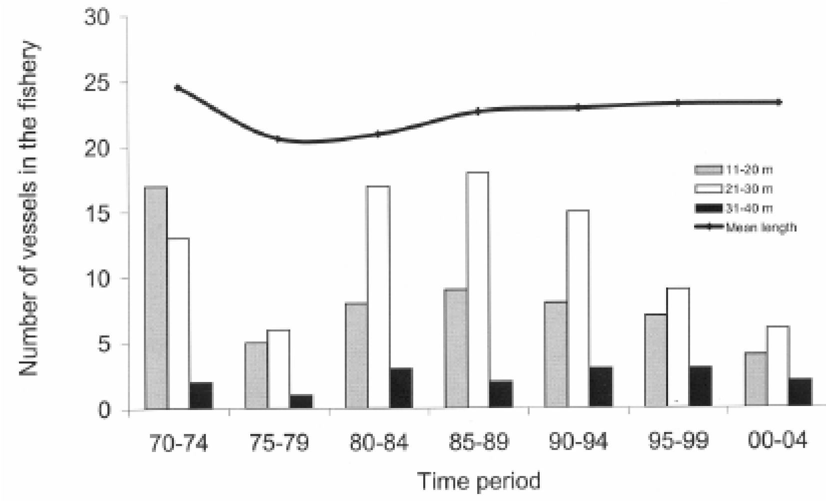


Figure 4.2.3.3 Number of vessels in the Icelandic scallop fleet and mean length of vessel 1970–2004, grouped in 5 year intervals (Garcia *et al.*, 2006).

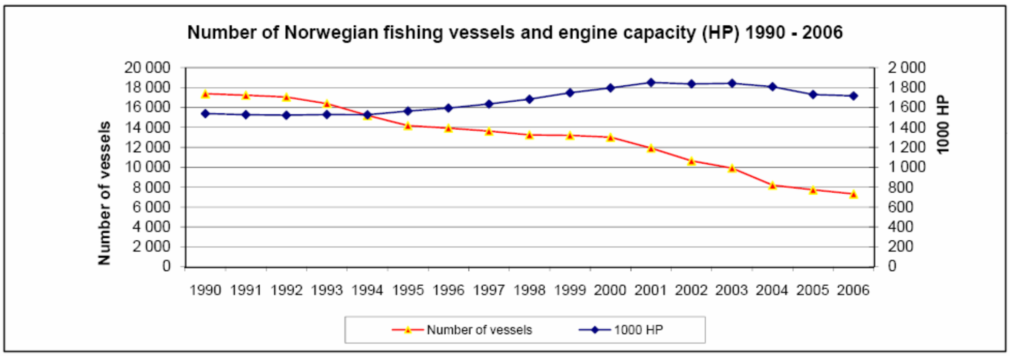


Figure 4.2.3.4 Number of Norwegian fishing vessels and aggregated engine capacity 1990–2006.

The Norwegian fishing fleet has been reduced in number of vessels since 1998, but the fishing capacity, measured in tons or horsepower, has been maintained (Figure 4.2.3.4). 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 4.2.3.5 and 4.2.3.6).

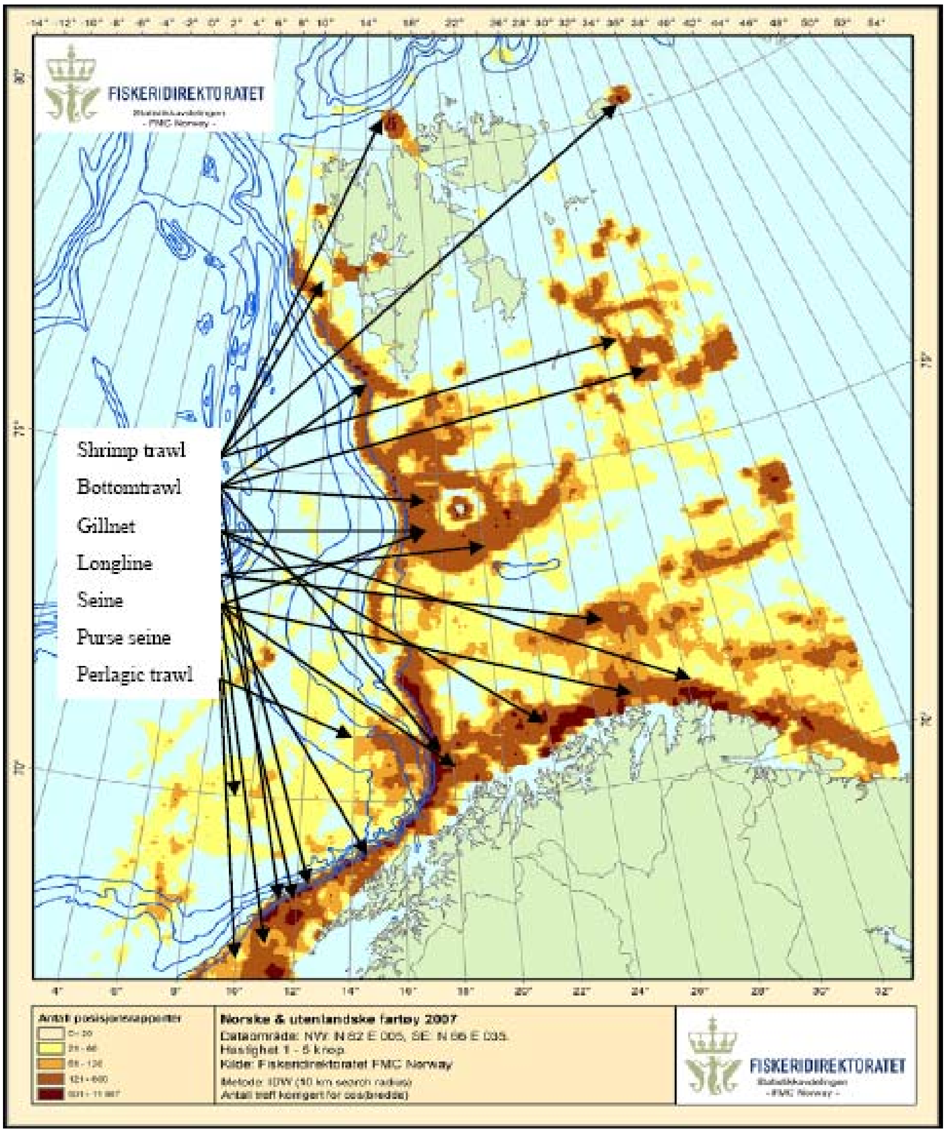


Figure 4.2.3.5 Distribution of fishing effort in the Barents Sea in 2007, based on Norwegian VMS data (vessels moving slower than 6 knots). Darker colour indicates a higher number of position reports.

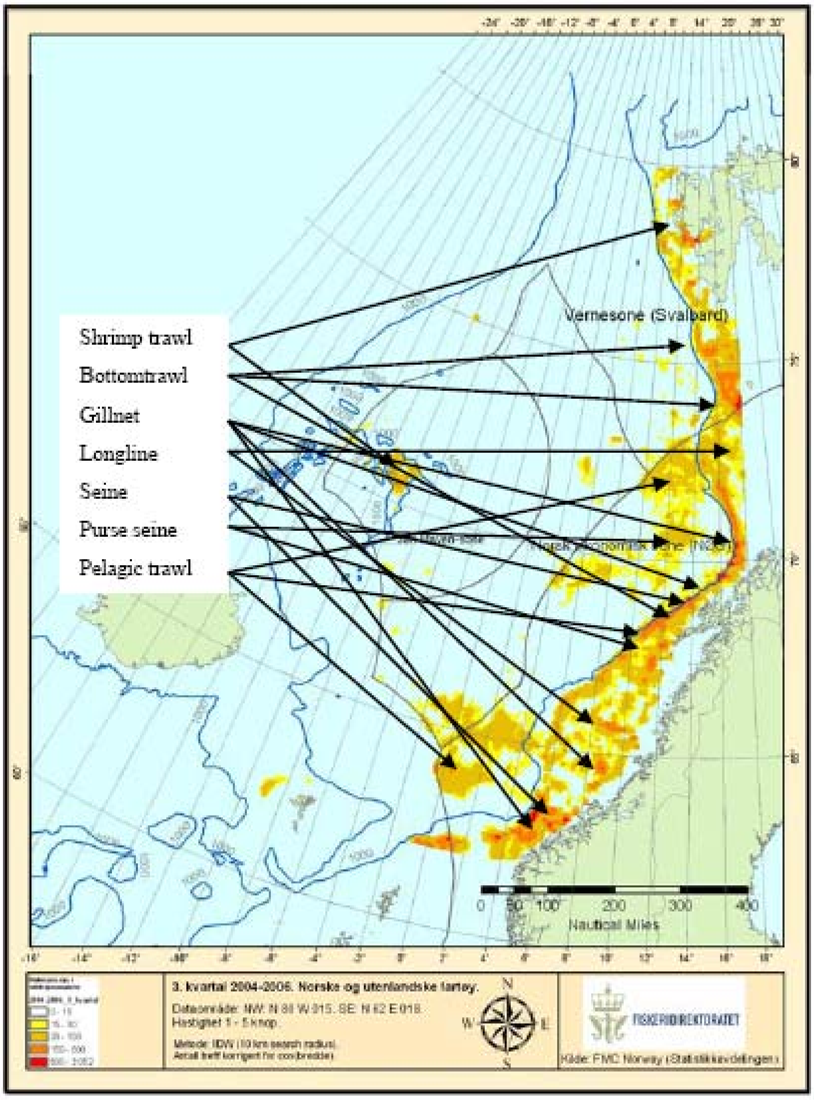


Figure 4.2.3.6 Distribution of fishing effort in the 3rd quarter in the Norwegian Sea, aggregated over the years 2004–2006, based on Norwegian VMS data (vessels moving slower than 5 knots). Darker colour indicates a higher number of position reports.

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 area, on banks and associated with ridges (Figures 4.2.3.5 and 4.2.3.6). 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 deepwater fleet has reduced its effort in other areas.

The waters around the Faroe Islands are in the upper 500 m dominated by the North Atlantic current, which to the north of the islands meets the East Icelandic current. Clockwise current systems create retention areas on the Faroe Plateau (Faroe shelf) and on the Faroe Bank. In deeper waters to the north and east is deep Norwegian Sea water, and to the south and west is Atlantic water. From the late 1980s the intensity of the North Atlantic current passing the Faroe area decreased, but it has increased again since. The productivity of the Faroese waters was very low in the late 1980s and early 1990s. This applies also to the recruitment of many fish stocks, and the growth of the fish was also poor. From 1992 onwards the conditions have returned to more normal values, which is also reflected in the fish landings. There has been observed a very clear relationship, from primary production to the higher trophic levels (including fish and seabirds), in the Faroe shelf ecosystem, and all trophic levels seem to respond quickly to variability in primary production in the ecosystem.

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 redcrab and blue ling. More recently exploratory trap fisheries for deep-sea red crab have been performed.

4.2.4 Impacts of fisheries on the ecosystem

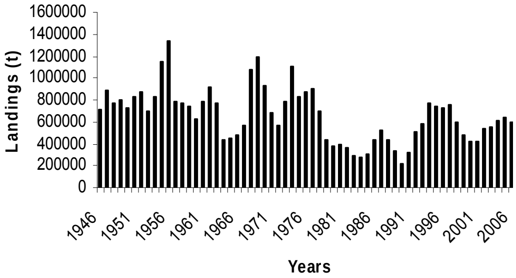
Commercial fishing has direct and indirect effects on the marine ecosystem which can be summarized as:

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.

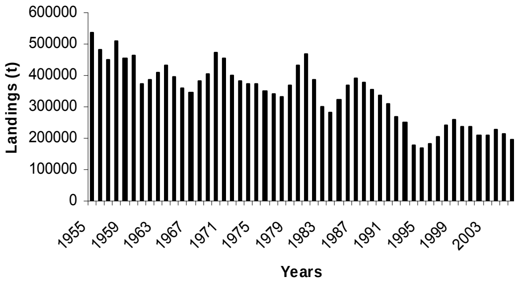
In OSPAR Region I the most critical issues regarding the impact of fisheries relate to Points 1, 2, 3 and 5.

4.2.4.1 Trends in commercial fish stocks

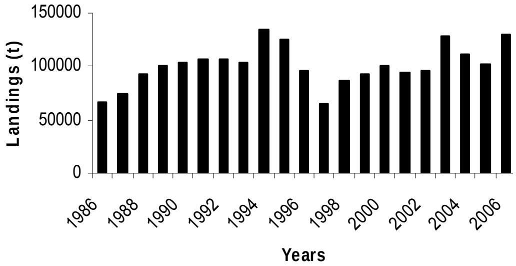
The most important impacts of fishing are likely to be on the fish stocks themselves. Fishing will usually change the age structure of a stock (fewer old and large individuals), and as the fishing mortality increases the spawning stock is likely to become smaller, and based on fewer year classes. This reduces a stock's resilience to both natural and human pressures. Figures 4.2.4.1.1.a to e show landings and mean fishing mortality for a number of the important stocks which are fished in OSPAR Region 1.



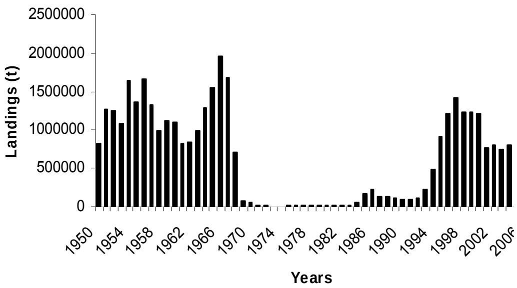
North-East Arctic cod (Sub-areas I and II).



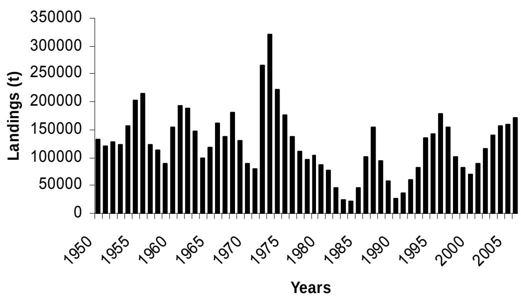
Icelandic cod (Division Va).



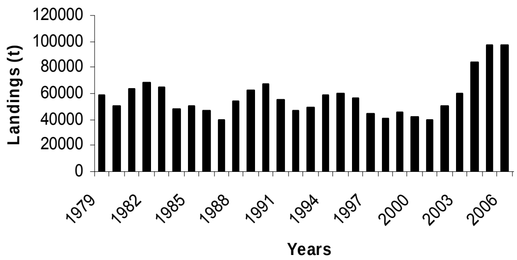
Icelandic summer-spawning herring (Division Va).



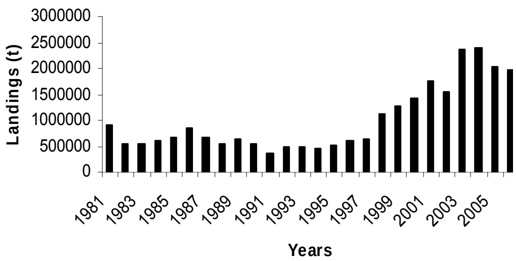
Norwegian spring-spawning herring.



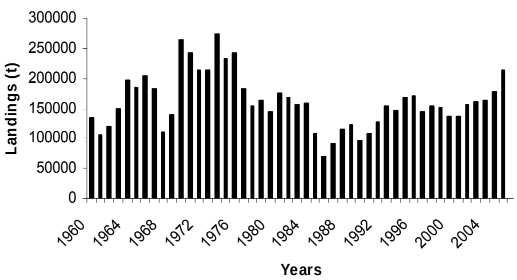
North-East Arctic haddock (Sub-areas I and II).



Icelandic haddock (Division Va).

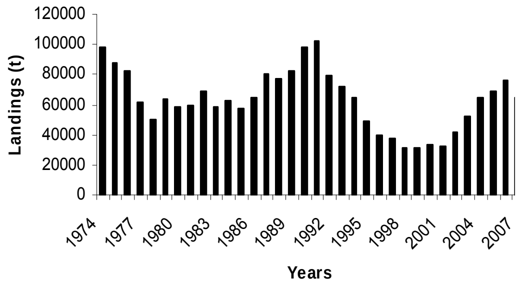


Blue whiting combined stock (Sub-areas I–IX, XII and XIV).

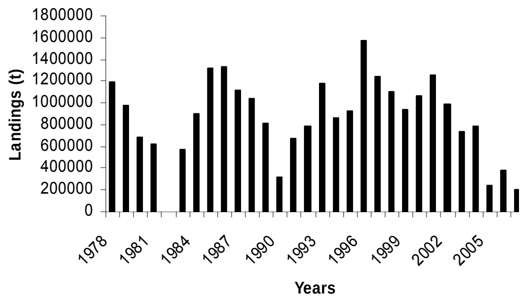


North-East Arctic saithe (Sub-areas I and II).

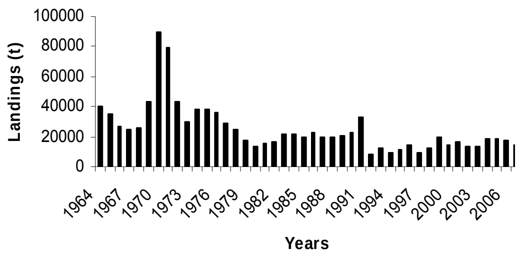
Figure 4.2.4.1.1a Total landings (tonnes) for a number of the important stocks which are fished in OSPAR Region 1.



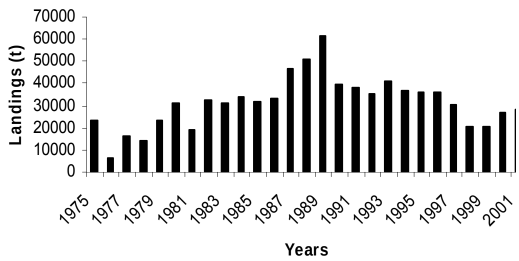
Icelandic saithe (Division Va).



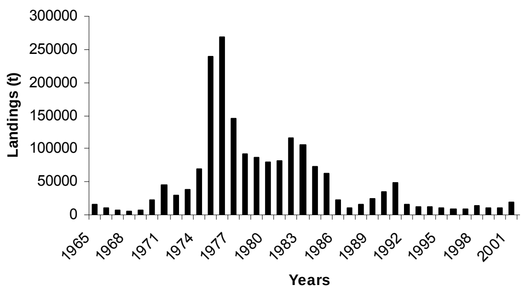
Capelin, Iceland-East Greenland-Jan Mayen Area(V XIV IIa west 5°W) 5°W)ssessment).



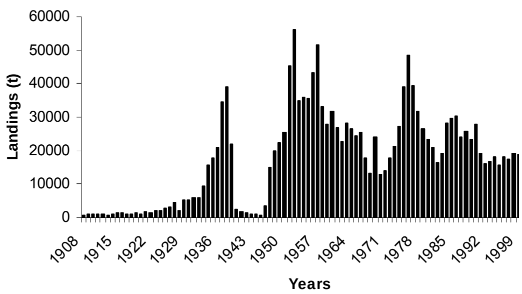
Greenland halibut in Sub-areas I and II.



Greenland halibut in Sub-areas V and XIV.

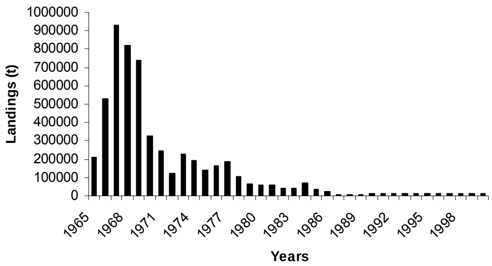


Sebastes mentella in Sub-areas I and II.

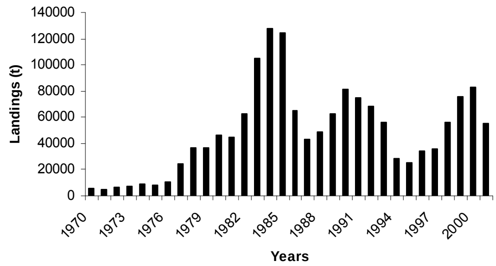


Sebastes marinus in Sub-areas I and II.

Figure 4.2.4.1.1b Total landings (tonnes) for a number of the important stocks which are fished in OSPAR Region 1.

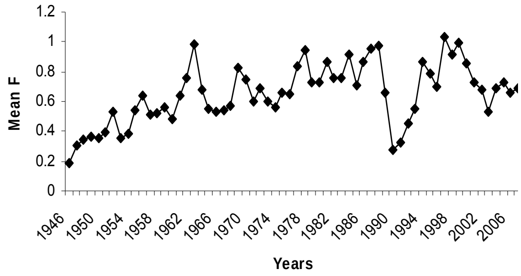


Mackerel in the North Sea Area (Fishing Areas IIa, IV and IIIa).

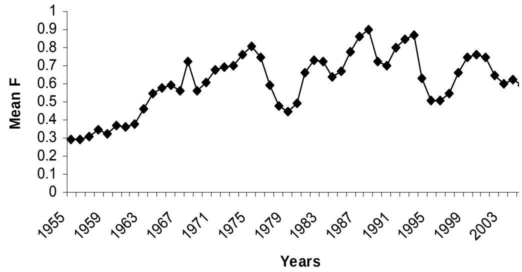


Northern shrimp (*Pandalus borealis*) in ICES Subareas I (Barents Sea) and IIb (Svalbard) Waters).

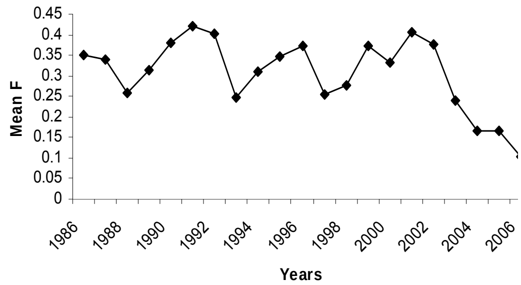
Figure 4.2.4.1.1c Total landings (tonnes) for a number of the important stocks which are fished in OSPAR Region 1.



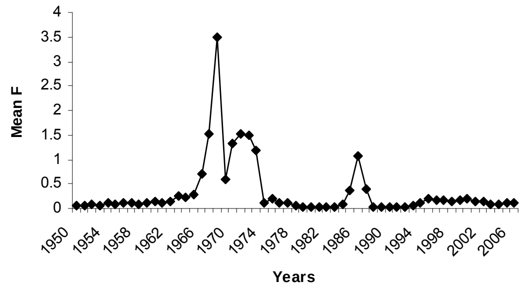
North-East Arctic cod (Sub-areas I and II).



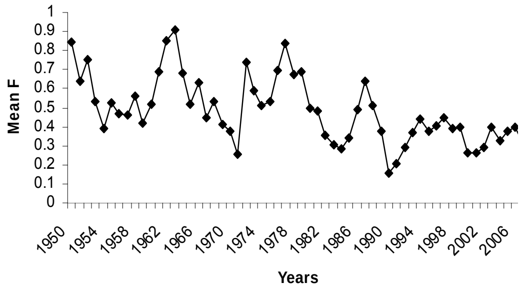
Icelandic cod (Division Va).



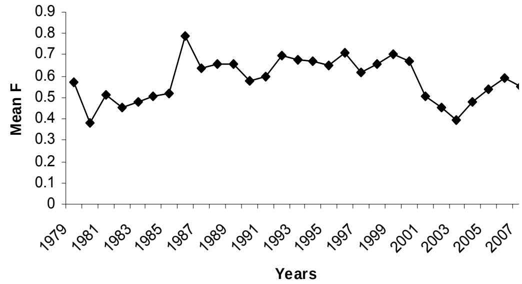
Icelandic summer-spawning herring (Division Va).



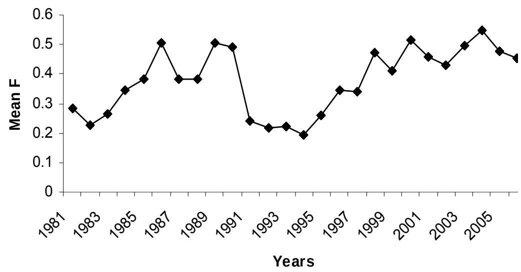
Norwegian spring-spawning herring.



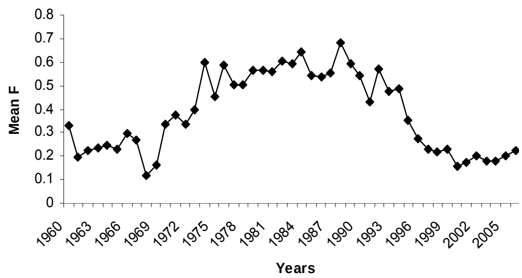
North-East Arctic haddock (Sub-areas I and II).



Icelandic haddock (Division Va).

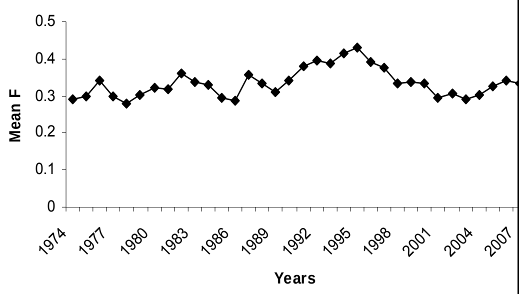


Blue whiting combined stock (Sub-areas I–IX, XII and XIV).

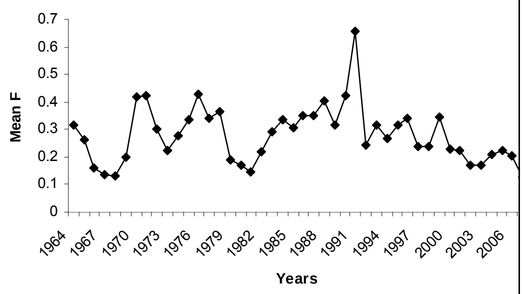


North-East Arctic saithe (Sub-areas I and II).

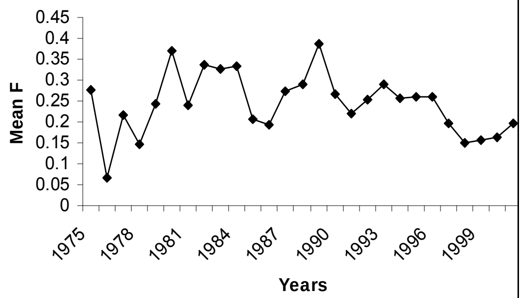
Figure 4.2.4.1.1d Fishing mortality (Mean F) for a number of the important stocks which are fished in OSPAR Region 1.



Icelandic saithe (Division Va).



Greenland halibut in Sub-areas I and II.



Greenland halibut in Sub-areas V and XIV.

Figure 4.2.4.1.1e Fishing mortality (Mean F) for a number of the important stocks which are fished in OSPAR Region 1.

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 Figure 4.2.1.1a and d). The stock has gradually been rebuilt since the 1980s.

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 that there are considerable catches of Norwegian coastal cod and redfishes *Sebastes mentella* and *S. marinus* in the mixed fisheries for NEA Cod.

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 in periods although 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 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.

Northern shrimp off East Greenland in ICES Div. XIVb and Va is assessed as a single population. The fishery started in 1978 and, until 1993, occurred primarily in the area of Stredebank and Dohrnbank 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 4.2.4.1.1c).

A multinational fleet exploits the stock. During the recent ten years, vessels from Greenland, Denmark, the Faroe Islands and Norway have fished in the Greenland 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 by 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 increased rapidly to about 15 500 tons in 1987 and 1988, but declined thereafter to about 9000 tons in 1992 and 1993. Following the extension of the fishery south of 65°N catches increased again to about 13 800 tons in 1997. Catches from 1998 to 2003 have been around 12 000 tons (Figure 4.2.1.1c), but have since decreased. Catches decreased in 2005 to 8000 tons and in 2006 further to about 5100 tons. 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 or, so far, in 2007.

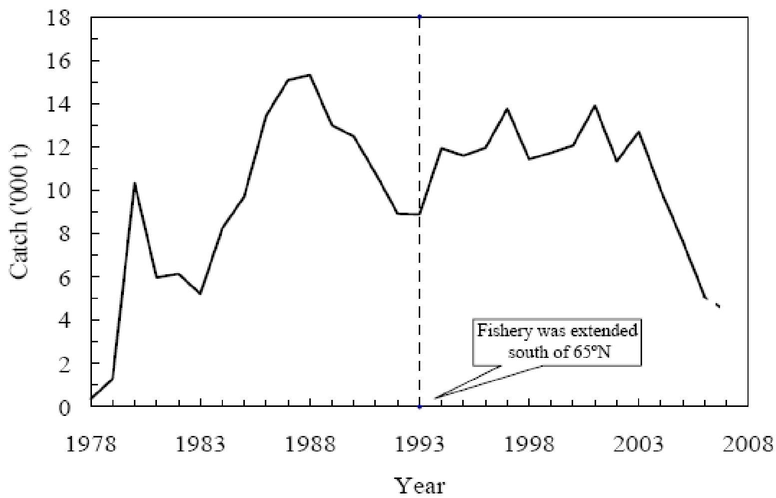


Figure 4.2.4.1.2 Total catch of Shrimp in Denmark Strait and off East Greenland: (2007 catches until October 2007).

The Greenland fishing fleet, (catching 40% of the total 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.

4.2.4.2 Bycatch of target and non-target species

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. In 2004 Norway initiated a monitoring program on bycatches of marine mammals in fisheries.

4.2.4.3 Physical disturbance of the seabed

The physical impact of bottom tending gear on the benthos remains a concern, particularly with respect to the destruction of coral reefs. In the Norewegian Sea, destruction of deepwater 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 damaged or negatively impacted. Up to the mid 1900s it was common for fishermen as well as scientists to catch large 'Bubblegum Tree Coral' *Paragorgia arborea* (up to 4m tall) in bottom gear. This situation has changed and large individual colonies of *Paragorgia arborea* are now rarely reported or seen. The depletion of the populations of *Paragorgia arborea* is of great concern especially because of the disappearance of old individuals that can be more than one hundred years old. Concern is likewise expressed for *Primnoa,* which is also slow-growing and long-lived. The lack of detailed information on the distribution of coral species (soft corals and stony corals) emphasizes the urgent need for coherent mapping of species and habitats in all parts of the study area except Iceland (Garcia *et al.*, 2006).

During ROV surveys of reef areas off Norway and Iceland lost longlines, gillnets and other types of fishing equipment have been observed on the seabed. Lost nets can be seen ghost fishing and also covering parts of the coral colonies. One direct effect on the corals is breakage, but the effect of the net covering coral colonies is not known. Although these fishing techniques obviously cause breakage and disturbance of corals, it is assumed that the extent of the damage is limited compared to the effect of bottom trawling.

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.

4.2.4.4 Shifts in community structure

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 areas of corals (*Lophelia pertusa*) on the shelf and bank slopes, prompting the Faroese authorities to close three coral areas for trawling in 2004.

In sandy bottoms of high seas fishing grounds trawling disturbances have not produced large changes in the benthic assemblages as these habitats may be resistant to trawling due to natural disturbances 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.

The three largest and economically 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 top predators which have 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 other has repercussions to all. Years with good recruitment of herring and cod typically have resulted in poor capelin recruitment and have subsequently given rise to weak capelin stock size. Abundance of demersal species off 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.

In Iceland, capelin abundance has been oscillating on roughly a decadal period since the 1970s, producing a yield of >1600 Kt at the most recent peak. In recent years the stock size of capelin has decreased from about 2000 Kt in 1996/97 to about 1000 Kt in 2006/07. Herring were very abundant in the early 1960s, collapsed and then have increased since 1970 to a historical high level in the last decade. This inverse relationship between abundance of capelin and herring is well documented as the young herring are predators on capelin larvae.

Due to somewhat unstable environmental conditions, individual marine resources in Greenland are often characterized by extreme stock variability, even more so than in Iceland and the Barents Sea. The most important marine species has traditionally been cod, and more recently shrimp. Logbooks from ships in the offshore fleet show a southward shift of effort during the period 1975–2003.

Depending of the relative strength of the two East Greenland currents, the Polar Current and the Irminger Current, the marine environment experiences extensive variability with respect to temperature and speed of the West Greenland Current. The general effects of such changes have been increased bioproduction during warm periods as compared to cold ones, and resulted in extensive distribution and productivity changes of many commercial stocks. Historically, cod is the most prominent example of such a change.

In recent years temperature has increased significant in Greenland water to about 2°C above the average for the historic average, with historic high temperatures registered in 2003 (50 years time series). Recently increased growth rates for some fish stocks as indicated from the surveys might be a response of the stock to such favourable environmental conditions. As has been observed with the Icelandic cod stock an important interaction between cod and shrimp and a historic large shrimp biomass is in West Greenland water in present time would make feeding conditions optimal for fish predators.

4.2.4.5 Indirect effects on the food web

The impacts of experimental trawling have been studied on a high seas 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.

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. It appears that cod do not readily substitute herring for capelin in their diets. There is also evidence that change in the distribution of capelin which has resulted in less overlap with cod may be leading to a marked detrimental impact on cod growth.

4.2.5 Conclusions and priorities for action

A number of fish stocks in the Barents Sea and Norwegian Sea are at a low level, at least partly due to fisheries:

- The spawning stock of Greenland halibut is low in a historical perspective, but has increased slowly after 1996.
- The golden redfish (*Sebastes marinus*) shows a major stock decline both in surveys of fishable biomass and in commercial catch rates, and current regulation measures are insufficient to rebuild the stock.
- The deep-sea redfish (*S. mentella*) has shown recruitment failure in surveys for more than a decade. The only year classes that can contribute to the spawning stock are those prior to 1991, as the following 15 year classes are extremely poor. Strict regulations are necessary to rebuild the stock. Area closures and low bycatch limits are in force in Norwegian waters, and measures to prevent high catches and bycatches in the pelagic trawl fisheries in the Norwegian Sea seem necessary.
- - Data from the fisheries show that the catch-per-unit of effort for ling and tusk has declined by 70% since the 1970s. ICES recommended in 2004 that the fishing effort for ling and tusk should be reduced by 30% with reference to the 1998 level. For blue ling, ICES recommended that directed fisheries should be banned and spawning areas with high aggregations should be closed.

In the southwestern part of the Arctic area, the stocks of Greenland halibut and redfish also are reduced - probably mostly as a result of fishing:

- ICES in 2007 advised that the biomass of Greenland halibut in subareas V, VI, XII and XIV is near a historical low in most areas.
- The golden redfish *S. marinus* in ICES Divisions Va, Vb, VI and XIV is classified by ICES 2007 as having reduced reproductive capacity, although survey indices indicate that pre-fishery recruits in East Greenland have increased in recent years. (Also relevant for the Celtic Sea region).
- For the demersal deep-sea redfish *S. mentella* in in subarea IV, ICES 2007 advises that there should be no directed fishery until there are clear signs of improvement of the adult stock size. (Also relevant for the Celtic Sea region).
- For the pelagic S. mentella in the Irminger Sea and adjacent areas, a survey in 2007 indicates that the stock is low compared to the early 1990s.

While knowledge of the status of most stocks is well described the data available for deep water species and for many of the ecosystem components in higher latitudes is limited. It should be a high priority to develop the necessary international agreements to set in place robust procedures for the gathering and interpretation of the necessary data to allow a full assessment of the fisheries and their ecosystem impacts.

4.2.6 Further reading

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4.3 Regional QSR II: Greater North Sea

4.3.1 Introduction

The North Sea is highly productive and the fish resources of the region have been exploited for millennia. At the peak of the fishery in the 1980s the North Sea provided almost 10% of the global fish catch, and even after the collapse of many of the traditional fish stocks the North Sea still yielded 2.3–2.5 million tonnes per year, or almost 3% of the global catch.

Traditionally 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). Since the 1980s there has also been a significant industrial fishery focussing mainly on Norway pout and sandeels.

4.3.2 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 volume. In this section we consider those measures with a purely regional basis.

The major driver 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 (*The cod recovery plan*). As cod generally occur alongside other species, notably haddock, whiting and in places *Nephrops* these management measures have impacted on these other fisheries.

Much effort has been invested recently in recovery of the North Sea cod. Analysis of data and previous advice shows that the recovery of cod needed cuts of at least 60% in the rate of fishing mortality, from the high levels experienced in 2000. The key to achieving recovery over a period of about a decade, short of complete closure of the North Sea, is through reduction in F through reduced effort. Technical measures, while having a role to play, can only provide a modest reduction in *F*.

In 2001, the EU implemented a 10-week closed area for part of the North Sea. However, following the ICES advice for a cessation of all directed fishing on cod, the Council of Ministers agreed further measures to achieve cod recovery, but which also maintained access to fish stocks that were healthy, such as the North Sea haddock. For 2003, a cod 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, it set TAC levels that were predicted to give a 30% annual increases in spawning stock biomass.

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 of North Sea cod within the next decade. The EC regulation for cod has recently been amended in order 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.

For cod in the North Sea, Eastern Channel, and Skagerrak, the current ICES advice implies a reduction of total removals to less than half the amount of estimated removals for 2006.

Sandeel landings in the North Sea dropped abruptly in 2003/4 to around 350 000 tonnes and have remained low. In 2007 a TAC of 170 000 were set for the whole of the North Sea. Because there is no agreement between EU and Norway on how to share the sandeel, the TAC was overfished by 21%. 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 protect nesting 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 is still at a low level and is considered to have had reduced reproductive capacity since 2001. In order to rebuild the sandeel stock, ICES recommends exploratory fishing to be carried out in April 2008 to determine the abundance of I-group sandeel as a basis for setting a TAC for the rest of 2008. ICES suggests a maximum TAC of 400 000 tonnes and that the fishery should end no later than 1 August to protect young-of-the-year sandeel.

In the North Sea since 1998, gear changes have 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 fishermen in certain countries to adopt more selective gears.

In the period from the mid 1990s to 2002/2003, 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 fishing effectively even over the hardest of bottom. Similar designs have also been employed by Scottish fishermen 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 fishermen 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 fishermen 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 fishermen reverting back to seining and pair trawling/seining. In 2006 it was estimated that approximately 20 twin-rig vessels (16–30 m) 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 use much heavier seine rope (40 mm–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 look likely to continue as fuel prices continue to rise.

Changes in the beam trawling fisheries prosecuted by the Dutch, 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, 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 with smaller circumference, smaller mesh trawls for targeting herring. In Scotland pelagic trawling began as a pair fishing method, however, with the arrival 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, improve water flow within the gear and also to improve fish quality through reduced damage against the mesh.

There has been no gear development in the industrial fisheries for sandeel and Norway pout. 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 English Channel area. There has also been a shift of effort by deepwater gillnetters, targeting monkfish from Area VI and VII into the northern North Sea 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 ghost net issues as have been observed in western waters. The other 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 latterly 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 jigging 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 gears 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 of differing mesh sizes, materials and positioning within the trawl have been extensively tested (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 trialed. Despite this research, very few of these designs have been adopted into legislation and voluntary uptake remains low in the absence of real incentives. Latterly though with the adoption effort restriction management in the North Sea by the EU, as a way to maintain or increase fishing opportunities, fishermen have increasingly moved to selective gears. For instance in Sweden as a result of extra effort and also national legislation requiring the use of species selective *Nephrops* trawls, there 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, Belgium and UK fleets (see Section 4.4.4.2.). 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, 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.

The harbour porpoise is the most commonly encountered and widely distributed cetacean species in the North Sea but there are few sightings south of 47ºN. Overall abundance of harbour porpoises in the North Sea and adjacent areas has not changed between the two SCANS surveys (1994 and 2005). Harbour porpoise distribution, however, has undergone a southward shift with a two-fold increase in the number of porpoises in the southern North Sea strata while porpoise numbers in the northern North Sea strata have halved. Bycatch of harbour porpoises remains a problem in gillnet fisheries in the North Sea. 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.). The regulation provided technical specifications for the efficiency of the acoustic deterrent devices, while there was also a requirement for scientific studies or pilot projects to increase knowledge about the effects over time of the use of acoustic deterrent devices. Since its inception a number of practical, technical and economic issues have arisen that have largely negated effectiveness of this regulation. According to ICES, 2008 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 cetaceans has also continued to be a problem in the Channel bass fishery prosecuted by French and Scottish pelagic trawlers. Research into possible mitigation measures is ongoing mainly looking at acoustic deterrent devices and excluder grids or panels. Some promising results have been found but the work remains in a developmental phase. Observer data from other pelagic fisheries in the North Sea suggest cetacean bycatch is primarily restricted to the bass fishery with only isolated incidental captures noted in the other pelagic fisheries.

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 in this case i.e. the gear modifications highlighted can provide a partial solution to discarding problems in 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 since the legislations introduction 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.

4.3.3 Fishing activities in OSPAR Region II Greater North Sea

The amount of fishing effort expended in the North Sea has declined by around 25% since 2000 (Figure 4.3.3.1; Figure 4.3.3.2). Both otter and beam trawling show similar patterns of decline with the greatest change occurring in 2002 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).

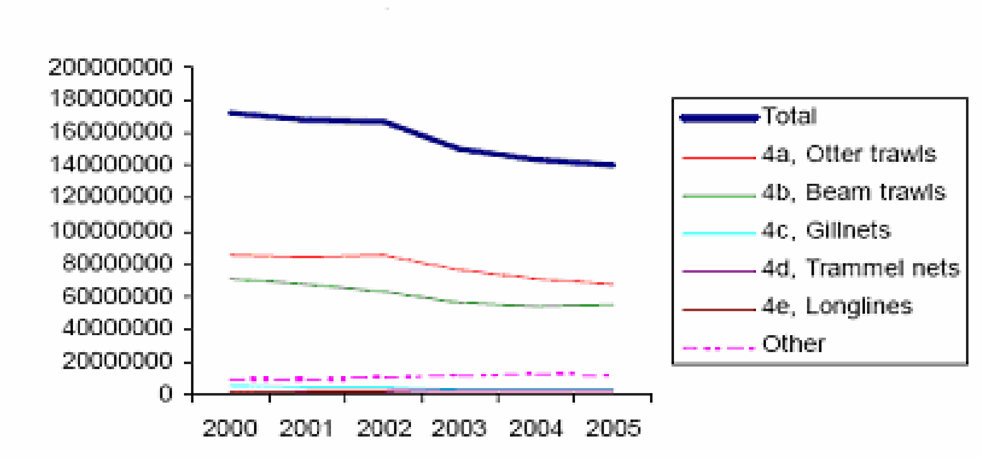


Figure 4.3.3.1 Trends in nominal fishing effort (kW*days at sea) in the North Sea by major gear type. (From STECF 2006).

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.

Roundfish are caught in otter trawl and seine fisheries, with a 120 mm minimum mesh size (Figure 4.3.3.1). 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.

There have recently been some changes in demography that are important for management. The centre of 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.

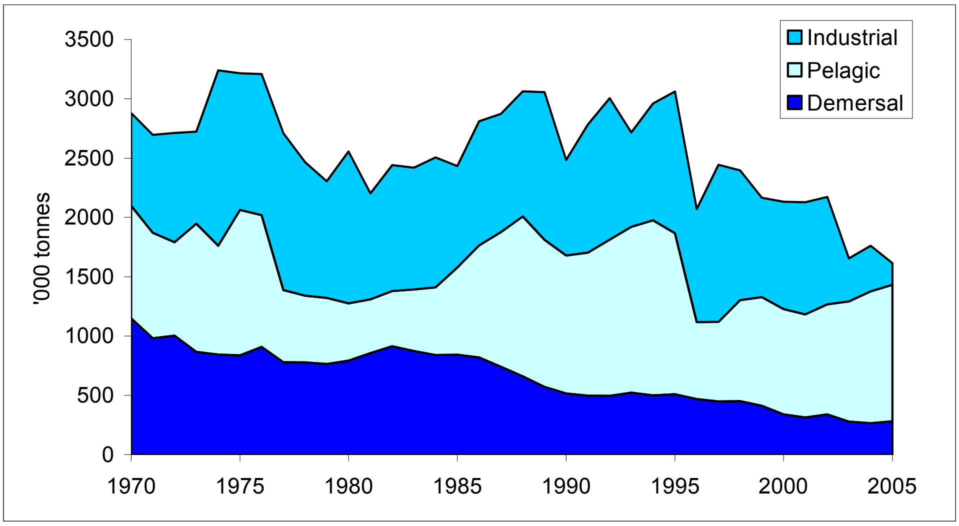


Figure 4.3.3.2 Landings (and discards) of industrial, pelagic, and demersal fisheries in the North Sea and Division IIIa (ICES, 2007).

4.3.4 Impacts of fisheries on the ecosystem

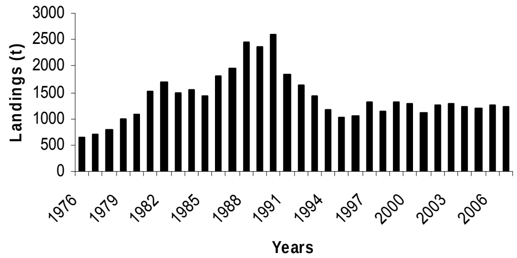
Commercial fishing has direct and indirect effects on the marine ecosystem which can be summarized as:

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.

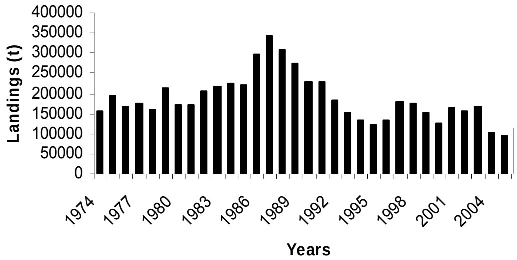
4.3.4.1 Trends in commercial fish stocks

Fishing mortality is generally high for several demersal stocks in the North Sea, but for some stocks there are now indications that fishing mortality has been decreasing in recent years. This is consistent with the observed decrease in fishing effort due to days-at-sea regulations and decommissioning in the major fleets. Since 2000 there has been a decline in landings and discards of industrial, pelagic, and demersal fisheries in the North Sea and Skagerak (Figure 4.3.4.1).

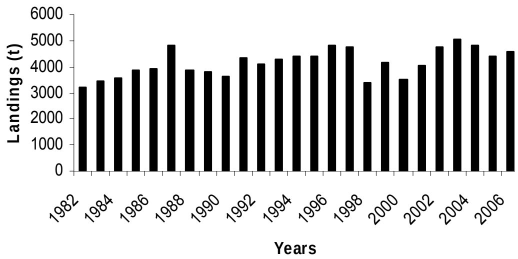
Assessments of cod (*Gadus morhua*) in the North Sea, Skagerrak, and eastern English Channel, (North Sea cod), show trends in spawning-stock biomass (SSB), the mature component of the stock, declining from a peak of 250 000 t in the early 1970s to current levels of about 40 000 t (Figure 4.3.4.1). The stock is well below the limit reference level of 70 000 t, below which ICES considers productivity of the stock to be impaired.



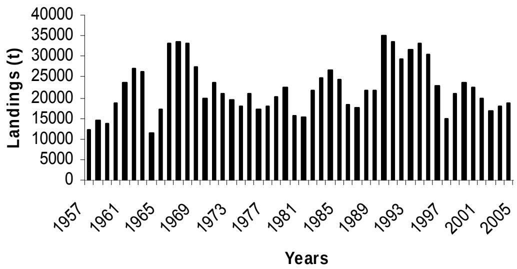
Plaice in Division VIIe (Western Channel).



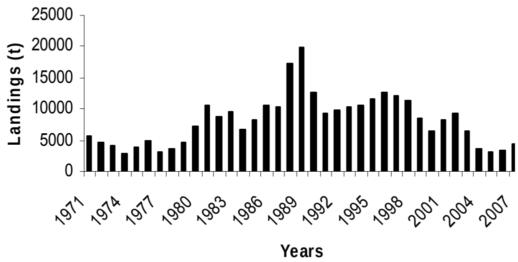
Plaice Sub-area IV (North Sea).



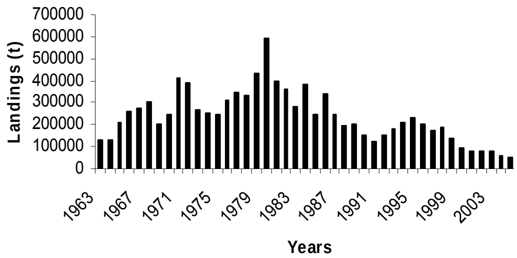
Sole in Division VIId (Eastern Channel).



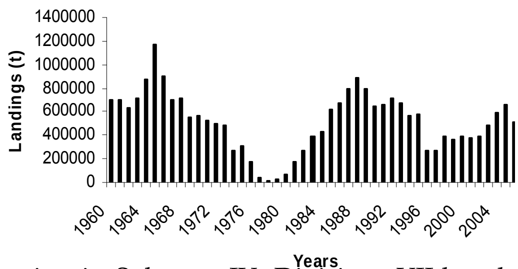
Sole in Sub-area IV (North Sea).



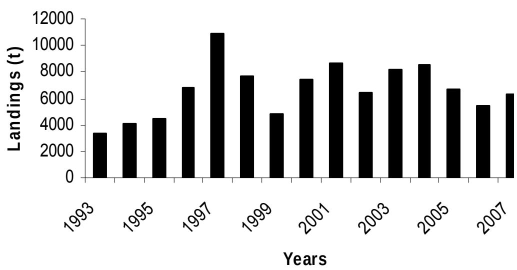
Cod in Divisions VIIe–k.



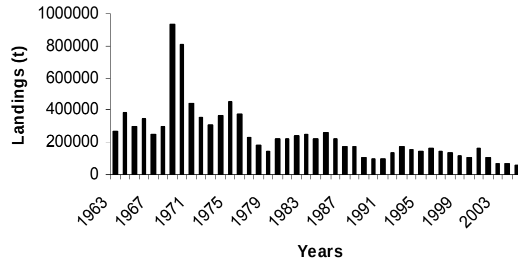
Cod in Sub-area IV, Divison VIId and Division IIIa (Skagerrak).



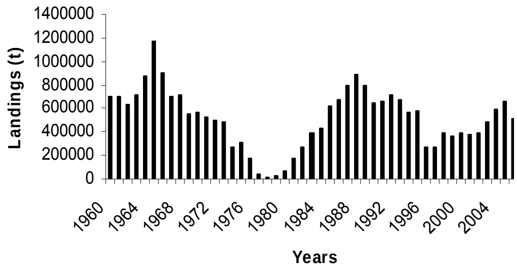
Herring in Sub-area IV, Divisions VIId and IIIa (autumn-spawners).



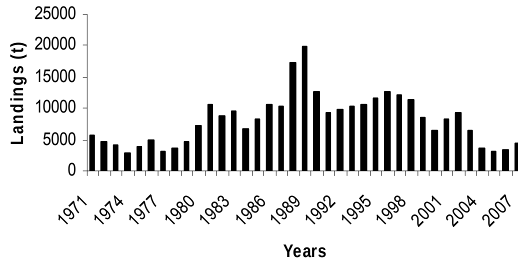
Haddock in Divisions VIIb–k.



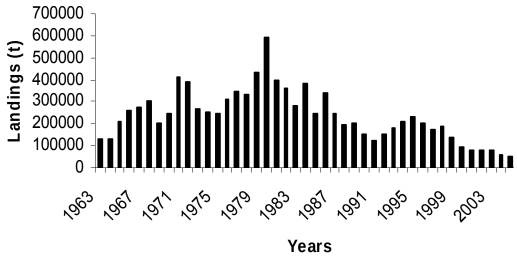
Haddock in Sub-area IV (North Sea) and Division IIIa.



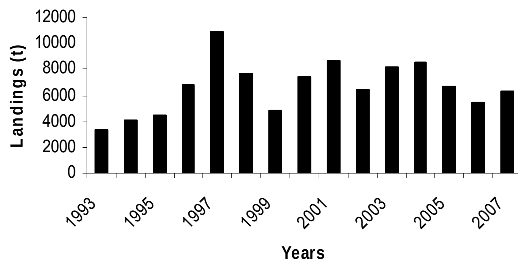
Herring in Sub-area IV, Divisions VIId and IIIa (autumn-spawners).



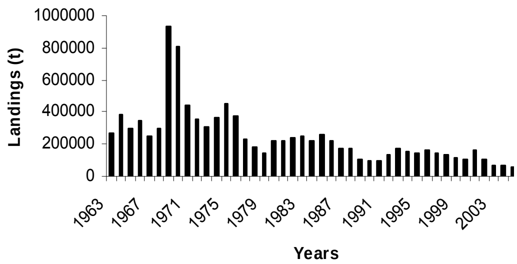
Cod in Divisions VIIe–k.



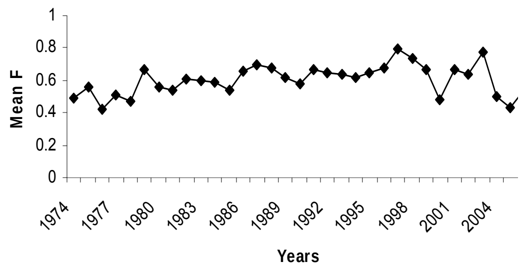
Cod in Sub-area IV, Divison VIId and Division IIIa (Skagerrak).



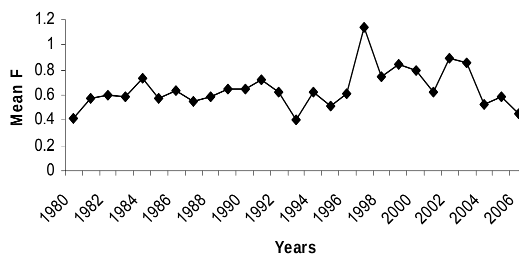
Haddock in Divisions VIIb–k.



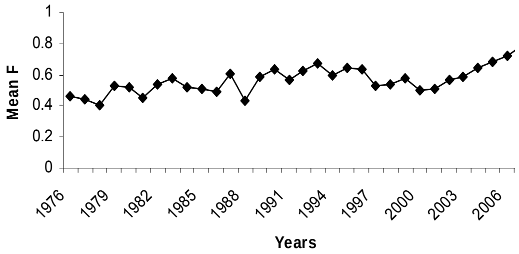
Haddock in Sub-area IV (North Sea) and Division IIIa.



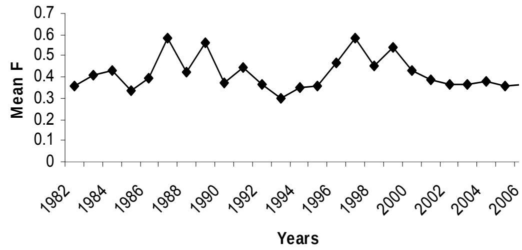
Plaice Sub-area IV (North Sea).



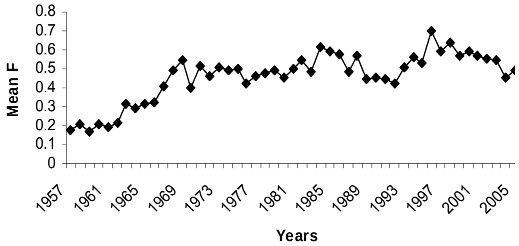
Plaice in Division VIId (Eastern Channel).



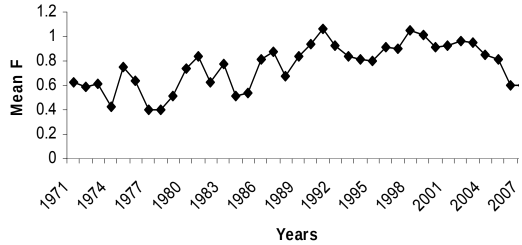
Plaice in Division VIIe (Western Channel).



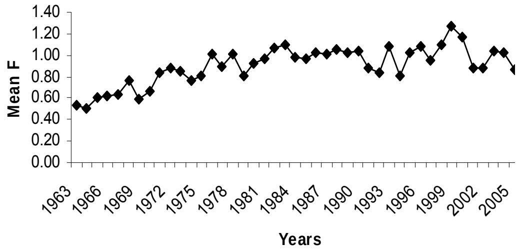
Sole in Division VIId (Eastern Channel).



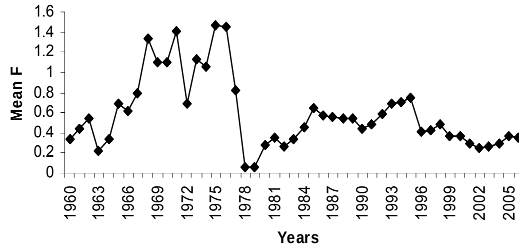
Sole in Sub-area IV (North Sea).



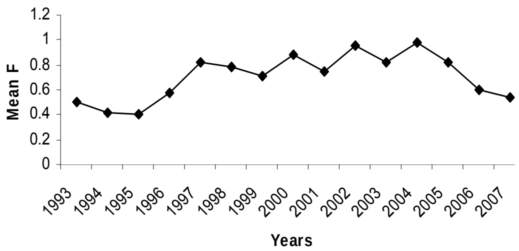
Cod in Divisions VIIe–k.



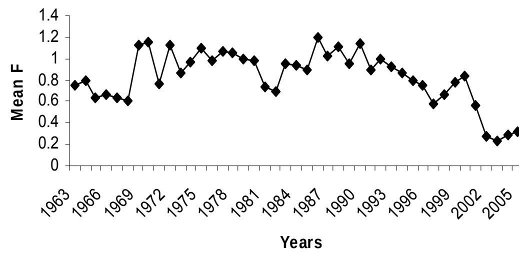
Cod in Sub-area IV, Division VIId and Division IIIa (Skagerrak).



Herring in Sub-area IV, Divisions VIId and IIIa (autumn-spawners).



Haddock in Divisions VIIb–k.



Haddock in Sub-area IV (North Sea) and Division IIIa.

Figure 4.3.4.1 Total landings (tonnes) and fishing effort (Mean F) for important demersal and pelagic stocks in Area II the Greater North Sea.

The stocks of cod in the North Sea, Eastern Channel, Skagerrak, and in Kattegat, and sole in the North Sea have spawning-stock biomass that are at reduced reproductive capacity and/or experience fishing mortality that results in unsustainable harvesting of the stock (Figure 4.3.4.1). There is also concern about the status of the North Sea whiting stock, and the overexploitation of North Sea herring where ICES recommends landings are reduced.

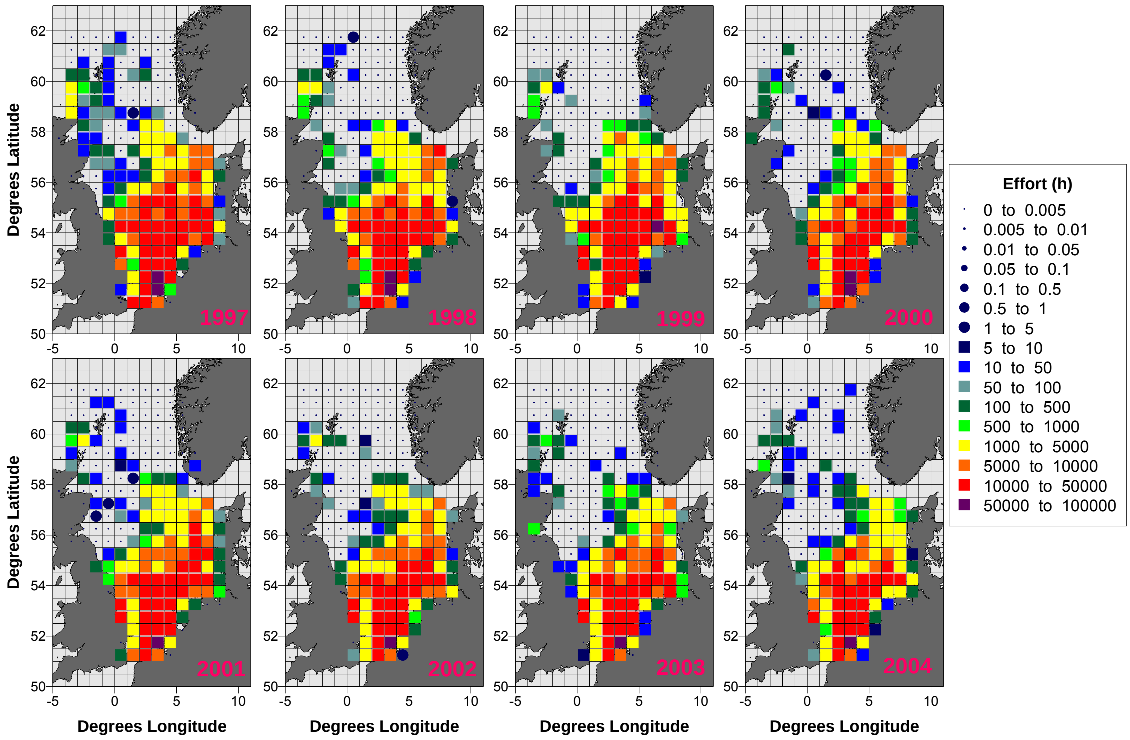


Figure 4.3.4.2 Spatial distributions of fishing effort (hours-fishing) using beam trawl by the nine major fishing nations operating in the North Sea in each of the years between 1997 and 2004.

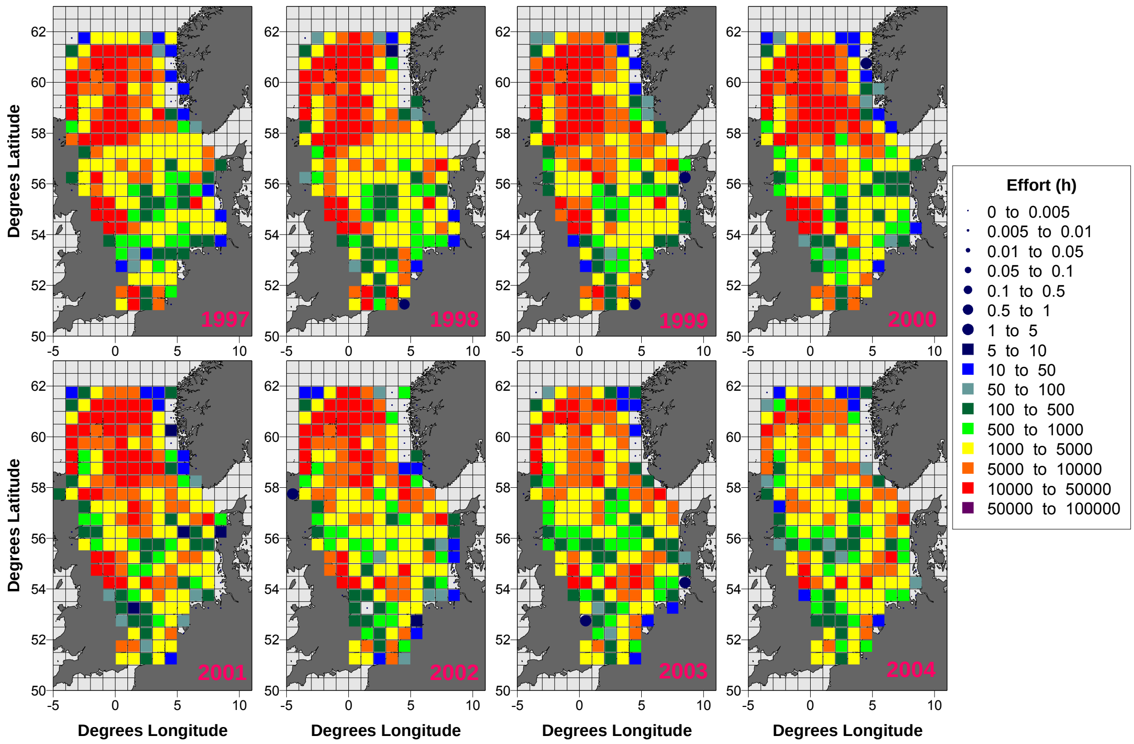


Figure 4.3.4.3 Spatial distributions of fishing effort (hours-fishing) using otter trawl directed at fish for human consumption by the nine major fishing nations operating in the North Sea in each of the years between 1997 and 2004.

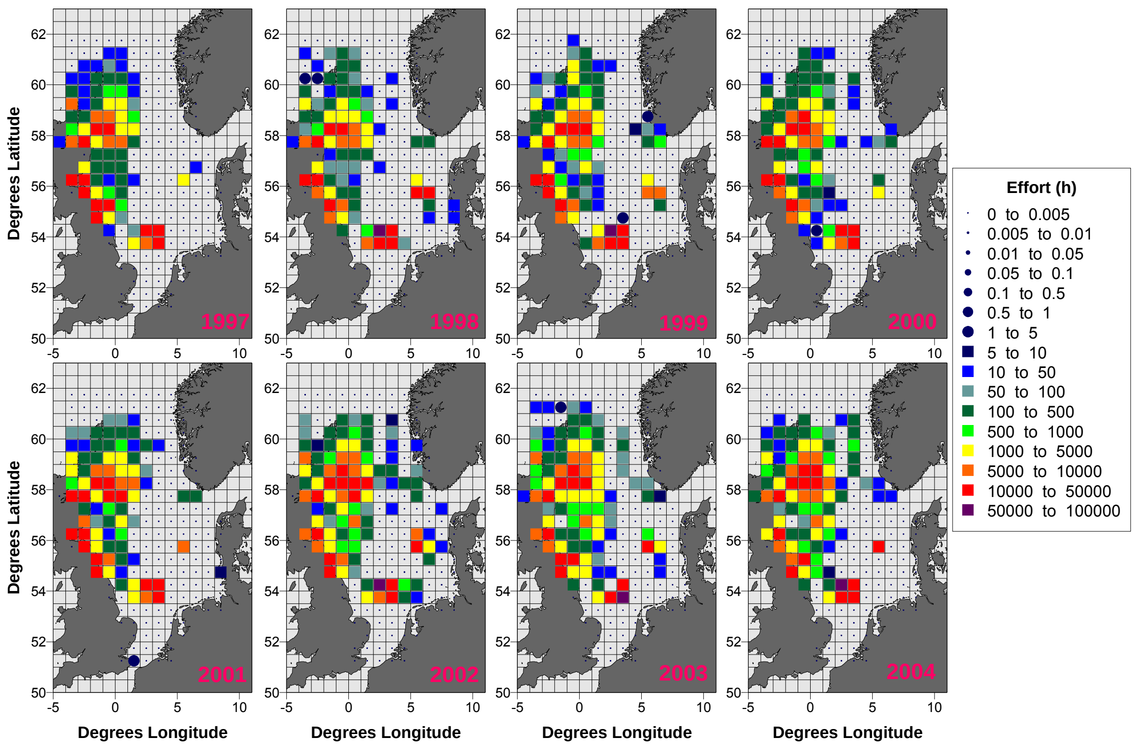


Figure 4.3.4.4 Spatial distributions of fishing effort (hours-fishing) using otter trawl directed at *Nephrops* by the nine major fishing nations operating in the North Sea in each of the years between 1997 and 2004.

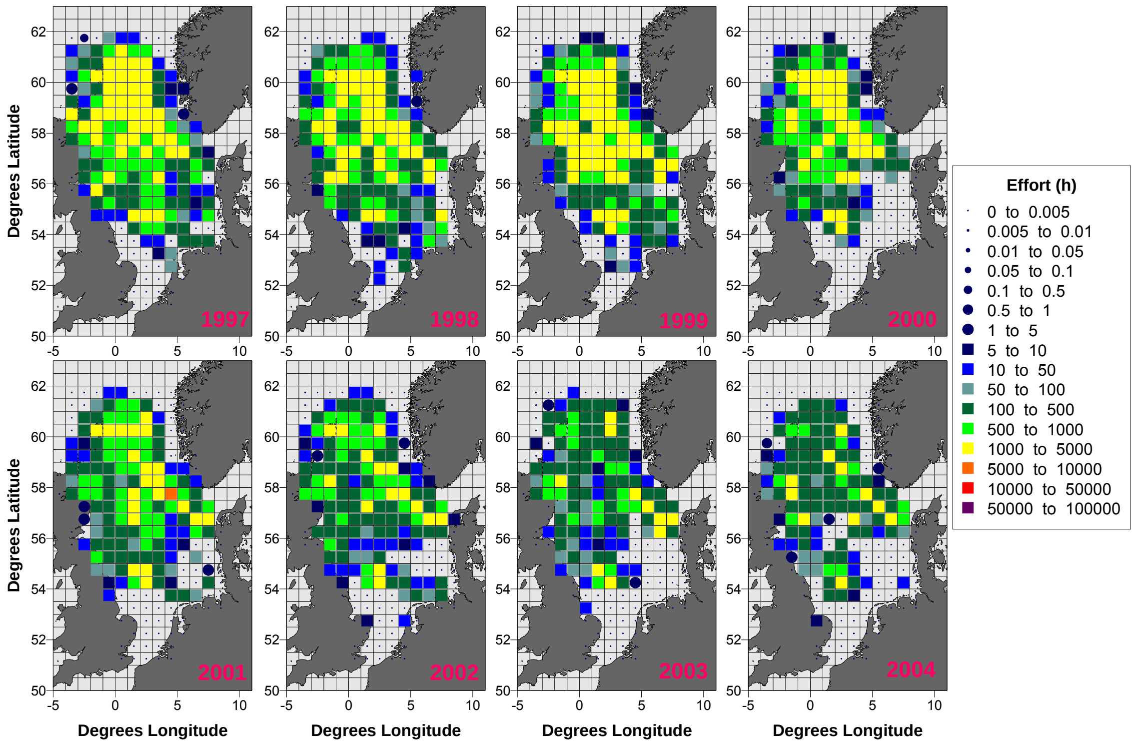


Figure 4.3.4.5 Spatial distributions of fishing effort (hours-fishing) using seine gear by the nine major fishing nations operating in the North Sea in each of the years between 1997 and 2004.

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 whole area impacted (Figure 4.3.3.2). 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 4.3.4.3). 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 4.3.4.4). The use of seine nets occurs primarily 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 4.3.4.5).

4.3.4.2 Bycatch of target and non-target species

Extensive discarding occurs in most fisheries on roundfish, flatfish, and *Nephrops* in the North Sea. These discards are largely small and juvenile fish. Any improvements to gear selectivity which would contribute to a reduction of catches of small cod must take into account the effect on the other species within the mixed fishery.

The *Nephrops norvegicus* fishery in the North Sea is currently managed by three regulatory mechanisms: output is restricted by TACs; input is controlled by limiting days-at-sea; and exploitation patterns are modified by technical conservation measures specifying gear restrictions and Minimum Landing Sizes. An important *Nephrops* trawl fishery in the North Sea lies adjacent to the Farne Deep, off the east coast of England. In the 2001/2002 season, up to 82 vessels worked on this fishery; the fleet consisted of vessels less than 30 m long. The vessels use single and twin *Nephrops* otter trawls. Nets with a small mesh size are legally allowed to catch *Nephrops* *norvegicus*, compared to other demersal whitefish species and consequently large quantities of other organisms can also be caught, and much of this is discarded. Since 2002 the vessel numbers have fluctuated but a significant fleet still prosecutes this fishery.

The amount of biological material caught and subsequently discarded in the English *Nephrops* fishery 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. It has been estimated that whiting discards from this fishery 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.

The high discard mortality on small commercial fish was destructive and contributed to the decline of the important North Sea 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 foodwebs with the potential to alter ecosystem dynamics. Therefore, the economic and ecological consequences of discarding are intrinsically linked and not confined to the direct mortality of commercial species.

4.3.4.3 Physical disturbance of the seabed

Beam and otter trawl effort has declined by 31% and 44% respectively; however, otter trawl effort directed at *Nephrops* increased by 65%. Given that *Nephrops* are restricted to a narrow range of seabeds and these are relative robust to the physical impact of *Nephrops* trawls (although not biological effects, particularly on sea pens) this implies that there is currently less overall physical disturbance than previously. However, the spatial distribution of effort data (see Section 4.3.3) shows that effort has increased in some area, thus previously lightly impacted areas may now be subjected to high intensities of physical disturbance.

4.3.4.4 Shifts in community structure

There is evidence of changes in benthic communities in areas heavily trawled for benthos so that it is likely that this widespread increase will have had some effect on the benthic communities however the spatial distribution of the macrofaunal communities was unchanged between 1986 and 2000. At a more local scale, 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.

4.3.4.5 Indirect effects on the food web

The removal of the target fish and the incidental catch of small fish has resulted in declining trends in the status of 13 fish populations. 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 since records began over 100 years ago. Spawning biomass of sandeel was at the lowest level observed in 2004 as a result of a targeted industrial fishery.

Harbour *Phoca vitulina* and grey *Halichoerus grypus* seals have gone through large population changes over the past century. Both species typically inhabit coastal habitats, because they need haul out sites for pupping and weaning. However, they make extensive foraging trips into the open sea (grey seals in particular). Because of extensive hunting, followed by reduced reproduction rates owing to effects of contamination, the populations of harbour seals along the continental coast reached an all-time low in the 1970s. Subsequently, these populations have increased steadily at an annual rate of 4%, with two major interruptions in 1988 and 2002, when the populations were hit by outbreaks of the phocine distemper virus. The numbers of harbour seals at Orkney, Shetland and the Scottish North Sea coast have continued to decline since the phocine distemper virus (PDV) outbreak in 2002. This is in contrast to the situation following the 1988 outbreak, and in contrast to the harbour seals in other UK areas and in the southeastern North Sea. Further stresses imposed on these species through interactions with fishing gears are likely to impede population recovery.

Overfishing of the large predatory fish species has had an indirect effect on community structure. 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.

The overall decline in fishing activity and in fish discards in particular may have indirectly 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; however there is only limited evidence to support this.

4.3.5 Conclusions and priorities for action

While fishing mortality on all stocks in Region II is generally high it is, following the changes in the management regime, beginning to decrease for several demersal stocks. The longterm result of such high fishing pressure has been to affect the reproductive capacity of key stocks, including cod, and resulting in unsustainable harvesting. Fishing not only has direct effects on the North Sea Region through removal of target species, but also causes mortality of non-target species such as fish and invertebrates, birds and marine mammals, through their incidental catch in fishing gear. There is, for example, extensive discarding in most fisheries on roundfish, flatfish, and *Nephrops* in the North Sea, and this increases mortality on small and juvenile fish of commercial importance such as plaice, as well as non-target species. Removal of large bodied predators by fishing has also had an indirect effect on community structure, with significant increases in abundance of small fish. Provision of discards to the environment by trawling fleets has 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 North Sea showed an increasing trend.

Despite recent evidence of declines in the levels of fishing mortality exerted by commercial fleets, there is still concern in Region II for a number of threatened and declining elasmobranch species. Catch data for various pelagic species, including porbeagle, basking shark, blue shark, and thresher shark are very limited, and this should be resolved in future by greater effort by North Sea states to report species-specific landings. In addition, the accurate delineation of stock structure, and further biological studies including tagging and genetic studies, are required to better delineate the stocks.

Habitat conservation in offshore waters will take increased prominence as the Habitats and Birds Directives is applied to offshore waters. Priorities for action as spatial management is applied include the need for clarification of conservation objectives and close links to management action, particularly measures to regulate the adverse effects of fishing activity.

The description of the state of the Greater North Sea will be an integral part of international progress towards the achievement of good environmental status under the Marine Strategy Framework Directive. For OSPAR this will require an active examination of the suite of Ecological Quality Objectives, which are currently applicable only in the North Sea, with a view to their wider development and adoption.

The effect of climate change on the population dynamics of key pelagic fish species that perform an import role in the marine food web may also be a concern. If sandeel populations decline, and are not replaced by an alternative pelagic forage fish species that can perform a similar ecosystem function, then the capacity for the marine food web to support current populations of many top predators, including charismatic species as well as commercial fish species, could be compromised.

4.3.6 Further reading

Greenstreet, S.P.R., Robinson, L.A., Piet, G.J., Craeymeersch, J., Callaway, R., Reiss, H., Ehrich, S., *et al*. 2007. The ecological disturbance caused by fishing in the North Sea. *FRS Collaborative Report*, 04/07. 169pp.

Horwood, J. O'Brien, C., and Darby, C. 2006. North Sea cod recovery? ICES Journal of Marine Science: Journal du Conseil, 63(6): 961–968.

STECF. 2006. Commission staff working paper. Report of the scientific, technical and economic committee for fisheries fishing effort management. STECF opinion expressed during plenary meeting held in Ispra from 6–10 November 2006.

4.4 Regional QSR III: Celtic Seas

4.4.1 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, in some locations for *Nephrops* and scallops. There were also large seasonal pelagic fisheries for mackerel and herring while the inshore grounds have supported crab and lobster fisheries.

The main fishing nations operating in Region III are Ireland and Scotland (UK) along with France and Spain.

4.4.2 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 volume. In this section we consider those measures with a purely regional basis.

In the Celtic Sea since 1998 there has been substantial change in 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 forced fishermen to adopt new gears. Over this period economics, and in particular a period of 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.

In the demersal trawl fisheries there is now widespread use of twin-rig trawls for species such as *Nephrops* and monkfish. The motivation for the adoption of this gear has been the greater ‘swept area’ that can be covered with this gear compared to standard single rigs. Increases in catch rates of 30–50% are commonly quoted, particularly in *Nephrops* fisheries, where this method is now ubiquitous in Scotland and Ireland. The move to twin rigging has been accompanied by an improvement in available gear monitoring equipment, which allows fishermen to control spread and the 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 commonly being used. The recent increases in fuel prices has halted this trend and begun a shift, as evidenced in Ireland, Scotland and France of fishermen, back to single rig trawls, using trawls constructed in low diameter, high tenacity materials. There is also switching to more fuel efficient methods such as Scottish seining or gillnetting. These shifts look likely to continue as fuel prices continue to rise.

In the pelagic trawl fisheries in the Celtic Sea prosecuted mainly by Irish, UK, and Dutch vessels there have been some quite dramatic changes in trawl design over the last 10 years. Fishermen have managed to master the art of “aimed trawling” assisted by the 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 m meshes) and constructed in 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 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 been 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 the increasingly complex regulatory framework that now exists in the region and also latterly market pressures for fishermen to act responsibly has driven the development of gear technology to deliver better environmental 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 available on the benefit to stocks of commercial fish species available.

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 2007 in the eastern Channel 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 and it is doubtful whether any meaningful reduction in cetacean bycatch has been achieved by these measures in the Celtic Sea area.

Detailed 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. However, as this stock is in a similar status of overexploitation as the other cod stocks in Community waters, it will now be included in the recovery plan. Fishing for hake is prohibited for some gears/meshes within a substantial area to the south and west of Ireland (Figure 4.4.2.1). 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 hand lines. The fishery for Celtic Sea Sole (ICES division VIIf, 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 Welsh coasts (ICES rectangles 30E4, 31E4 and 32E3) during February and March 2007 with some gear-specific derogations. Lobster v-notching is an important 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.

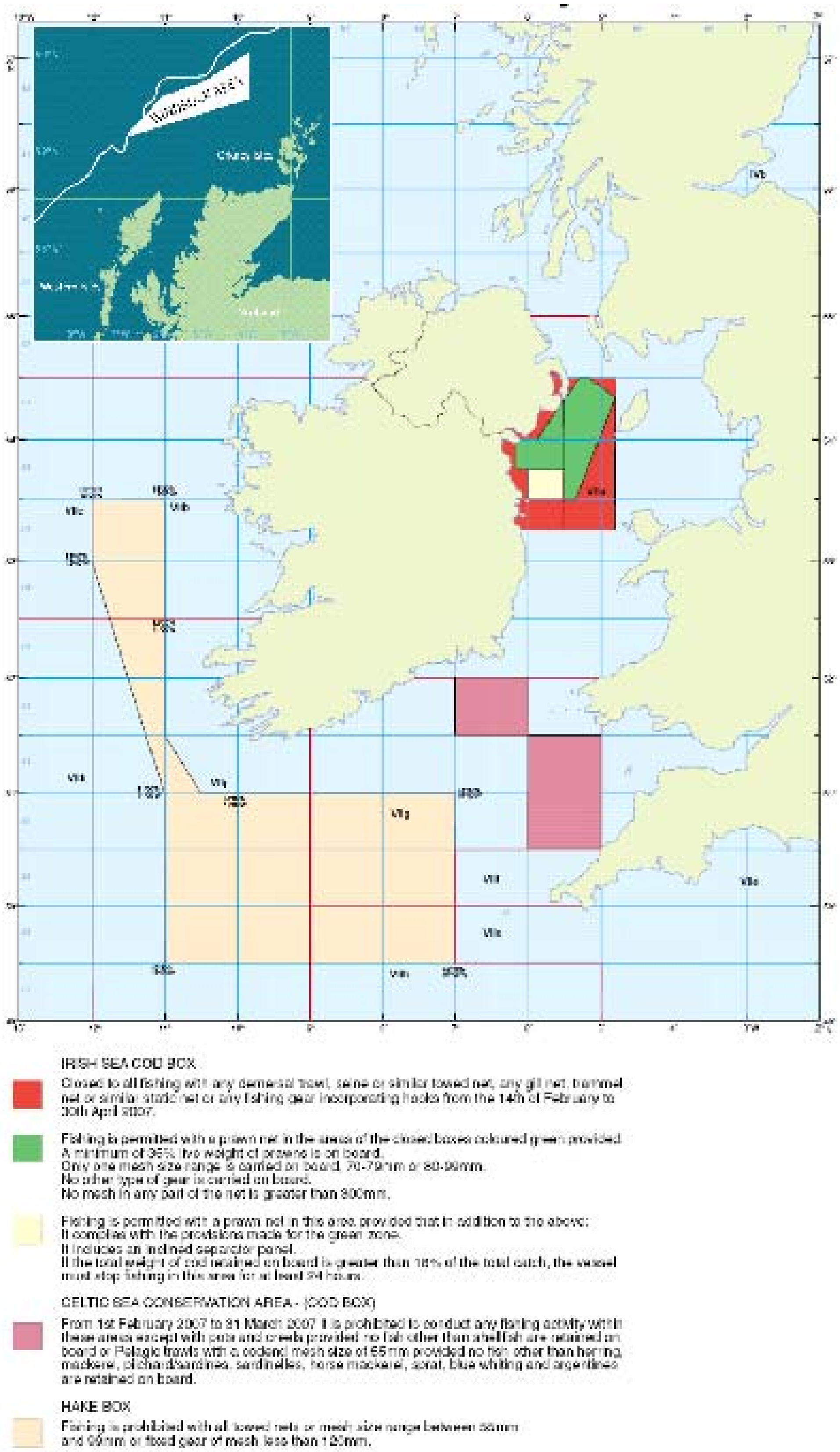


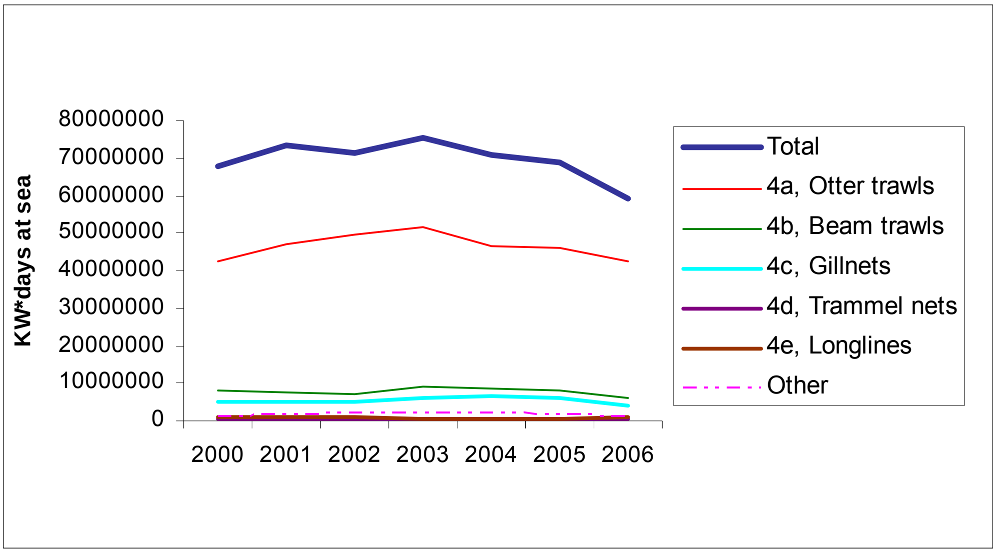
Figure 4.4.2.1 Areas closed to fishing for cod and hake in 2007 with insert showing the 'windsock area' north of Scotland which is included in the 'cod recovery plan'.

4.4.3 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 a large increase in landings in the late 1990s.

The fishing effort employed in the Celtic Seas, excluding the Irish Sea has tended to increase up to 2002 and subsequently declined (Figure 4.4.3.1a), 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 and as data capture has improved so the other category has 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 4.4.3.2).

a)



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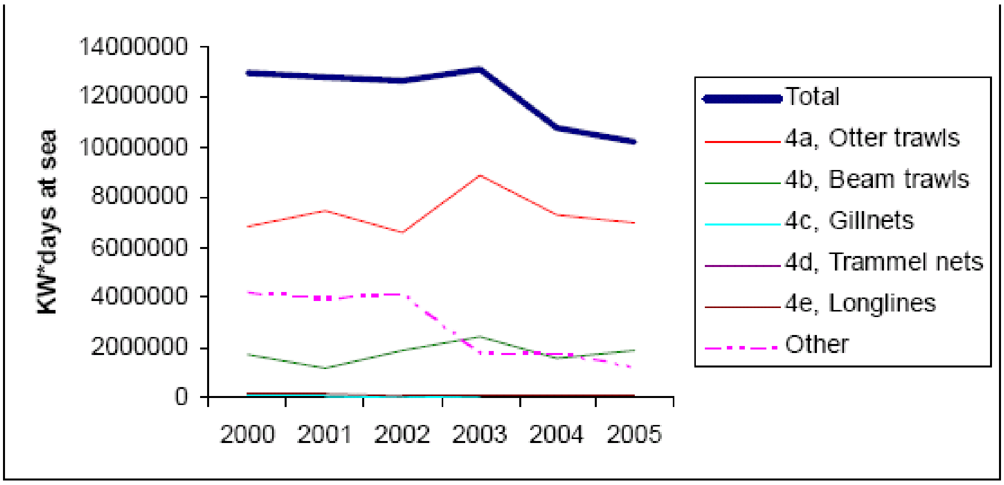


Figure 4.4.3.1 Trends in nominal fishing effort (kW*days at sea) in (a) the Celtic Seas excluding the Irish Sea and (b) the Irish Sea by major gear type (from STECF 2006).

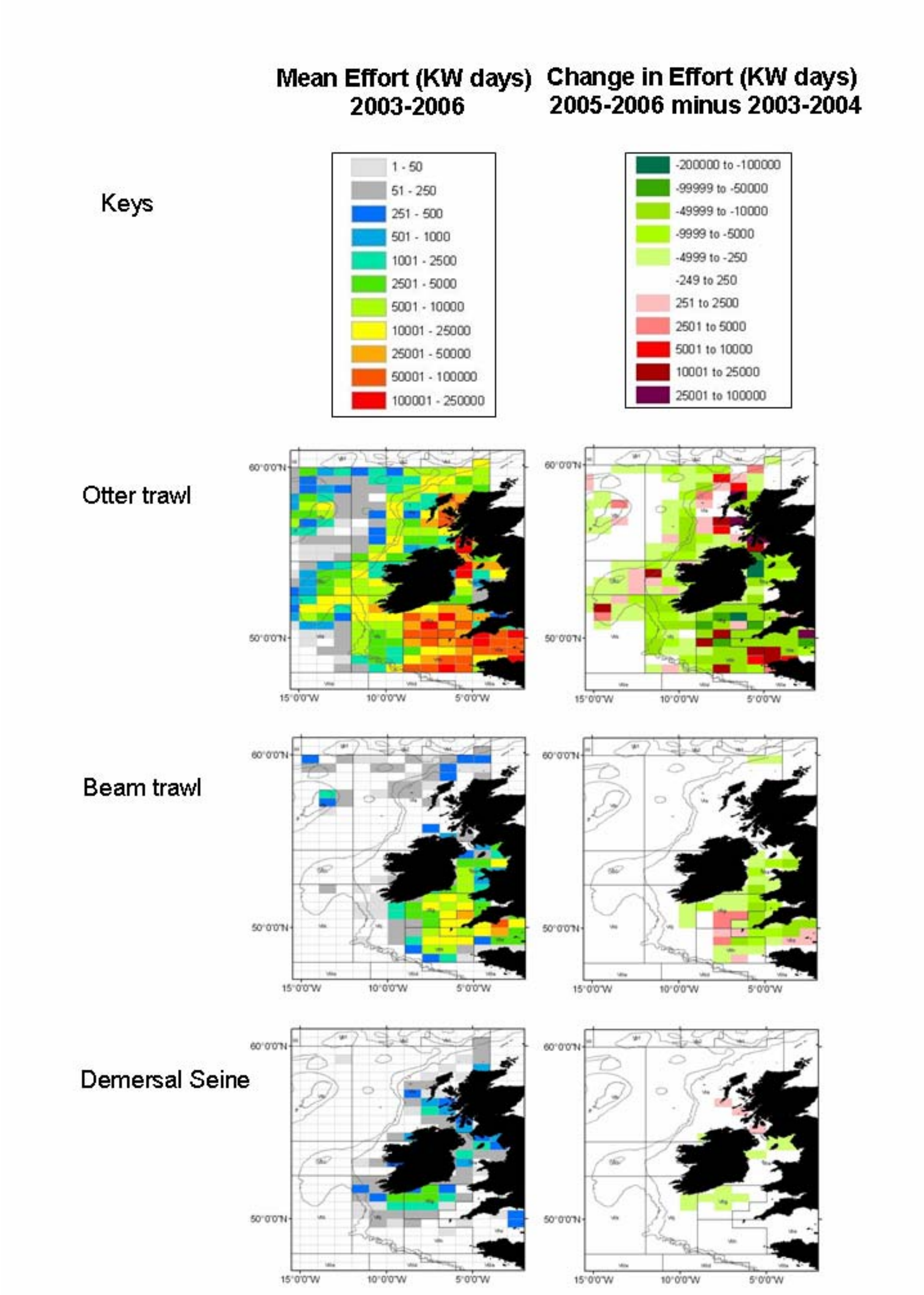


Figure 4.4.3.2 Demersal Effort (kW*days) by three main gear types (Otter trawl, Beam trawl and demersal seine) and by ICES statistical rectangle: left column mean effort 2003–2006 and right column recent change in effort (2005–2006 effort minus 2003–2004 effort) (data from Anonymous, 2007-note no Spanish effort data supplied).

Mackerel range from north of the Arctic Circle in the north 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, but 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 4.4.3.3).

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 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 4.4.3.3).

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 4.4.3.3), 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.

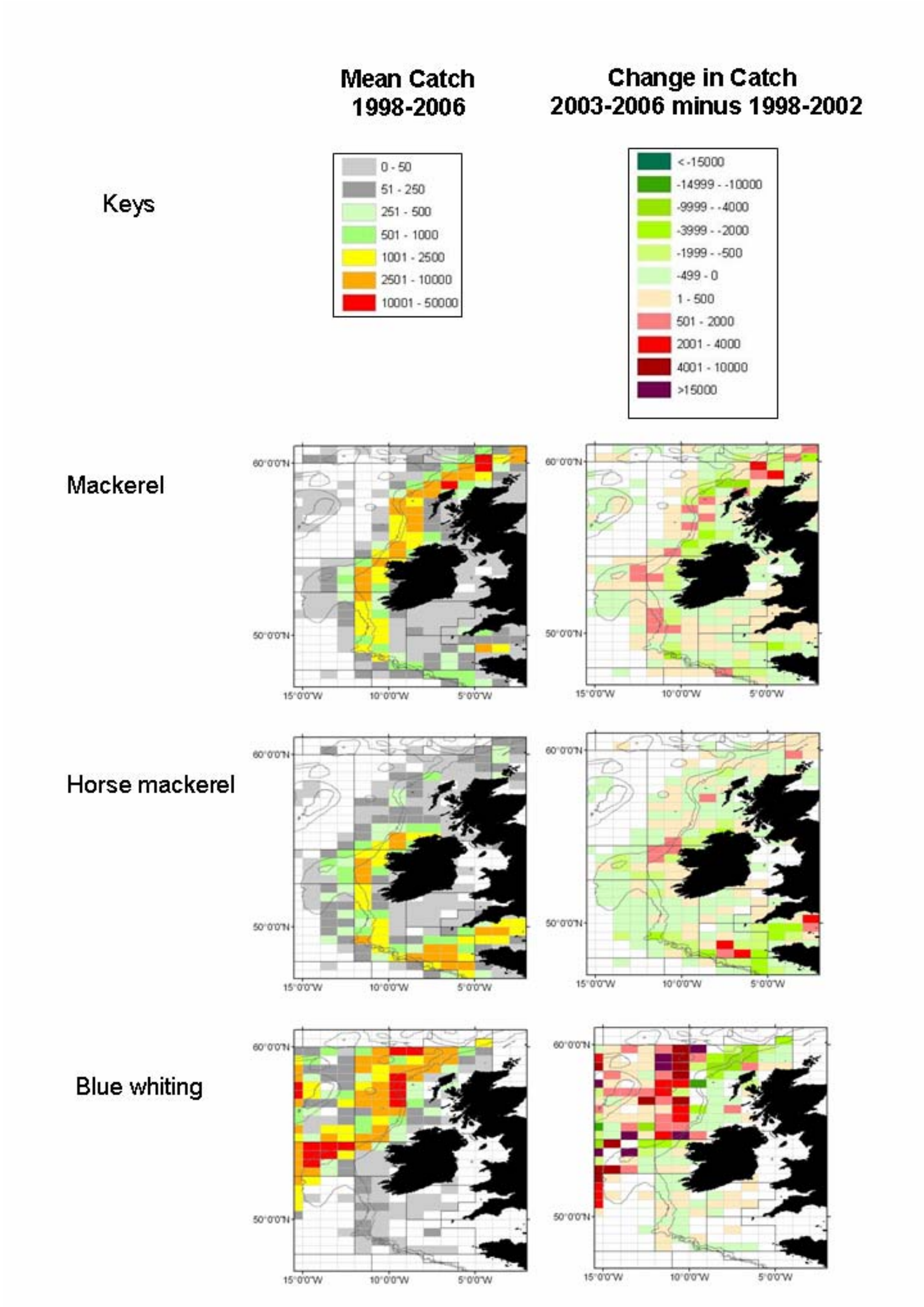


Figure 4.4.3.3 Commercial catch of three major pelagic species (mackerel, horse mackerel and blue whiting) by ICES statistical rectangle: left column mean catch 1998–2006 and right column recent change in catch (2003–2006 minus 1998–2002) (data from WGMHSA (Mackerel and Horse Mackerel), WGNPEL (Blue Whiting)).

Belgium, the Netherlands and the United Kingdom (UK) are the main nations with beam trawl fisheries. These fleets target species such as flatfish, mainly sole (*Solea solea*) and plaice (*Pleuronectes platessa*), and round fish species as cod (*Gadus morhua*). The fishing grounds are the greater North Sea, the Celtic Sea, Irish Sea and the Bay of Biscay (OSPAR-regions II, III and IV). The activities of these fleets have been well studied and the effort patterns, as well as the impacts are probably as well documented as any fleet in the EU.

This 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 a provision for 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 also being driven by the market place as well. Public perception of beam trawl caught fish has become increasingly negative putting pressure on fishermen to adopt more responsible fishing practices. This move has gained increasing momentum worldwide with the advent of certification schemes such as MSC 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 4.4.).

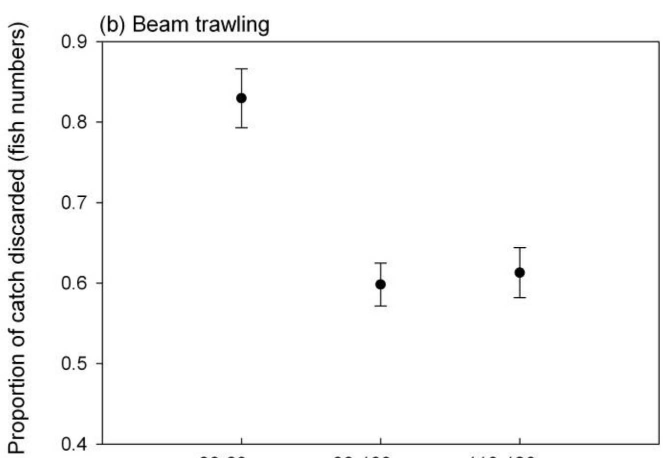


Figure 4.4.3.4 Proportion of catch discarded (all finfish numbers combined) by English and Welsh registered beam trawlers in the North Sea between 1999 and 2006 fitted for varying codend mesh size groups (Modified from Enever *et al.*, submitted).

The introduction of gear based technical measures into the beam trawl fleets to improve selectivity and reduce impact on benthic organisms largely mirrors the previous case study in the *Nephrops* fisheries (see Section 4.3.4.2). The gear measures developed are all technically feasible but have not necessarily been translated into legislation. In the case of the large mesh top sheet or square mesh panels tested the recommendations from testing have not necessarily been correctly interpreted into regulations. The voluntary uptake of the benthos release panel in particular seems to be growing. The motivation for this is largely market driven.

Assessment of the impacts of the measures has proven difficult and therefore largely is a work in progress. Scientific follow-up will be difficult without fishermen's cooperation; a high input from them will be needed for any assessment. Other technical measures are still under investigation, e.g. electrified beam trawling, rotated mesh and square mesh codends but indications are that a combination of modifications, focusing on the reduction of discards, has potential, especially for fish species and to a lesser extent for invertebrate species.

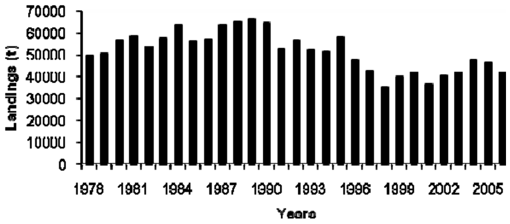
4.4.4 Impacts of fisheries on the ecosystem

Commercial fishing has direct and indirect effects on the marine ecosystem which can be summarized as:

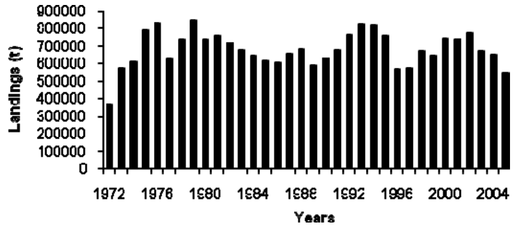
1. trends in commercial fish stocks;
2. bycatch of target and non-target species, including birds and marine mammals;
3. physical disturbance of the sea bottom and related impacts on benthic communities and habitats;
4. shifts in community structure; and
5. indirect effects on the food web.

4.4.4.1 Trends in commercial fish stocks

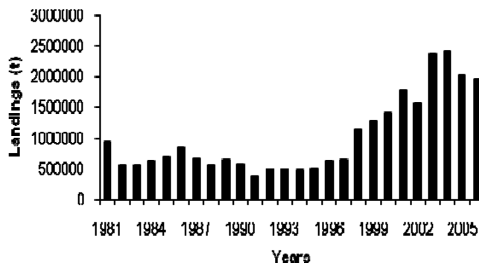
Fishery scientists express the level of mortality that the fishery causes as a fishing mortality rate F. This is the part of the instantaneous mortality rate, i.e. the continual, day by day, mortality of fish, due to fishing, the remainder being the natural mortality. F therefore scales to the proportion of the stock being removed by fishing but how it scales varies for different fish species depending on their natural mortality rates. For a species such as cod, an F value of 0.1 equates to 10% of the stock being removed by the fishery, at F=0.5 it is 40%, at F=1.0 it is 64% and at F=1.5 it is 78% of the stock removed. Thus F provides a direct measure of how much pressure the fishery is putting on the fish population and for all the species exploited in the Celtic Seas while F has varied the level of fishing mortality in recent years is comparable to or even higher that one or two decades ago (Figure 4.4.4.1.1). This suggest that fishing pressure on stocks has not decreased markedly and that increases in efficiency (technical creep) have more than compensated for any reduction in the number of vessels or restrictions on their time at sea. In cod, haddock and plaice where recovery plans are in operation there is evidence of lowered F in recent years.



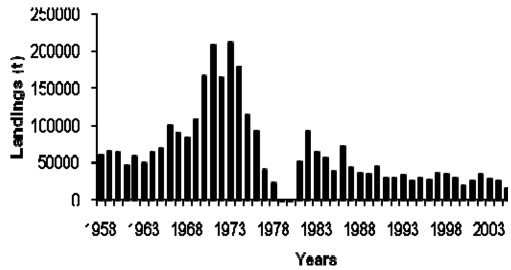
Hake-Northern stock.



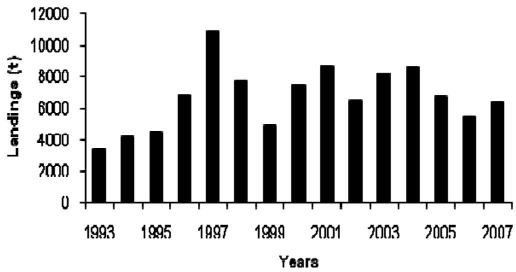
Mackerel.



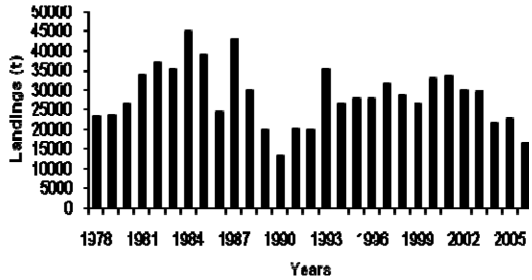
Blue whiting combined stock.



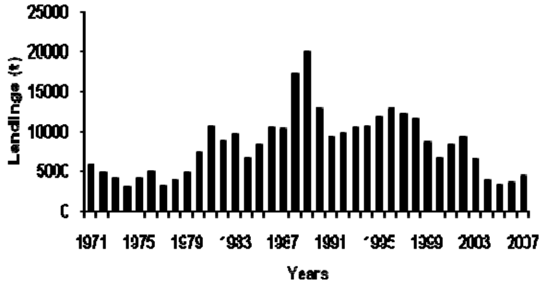
Herring.



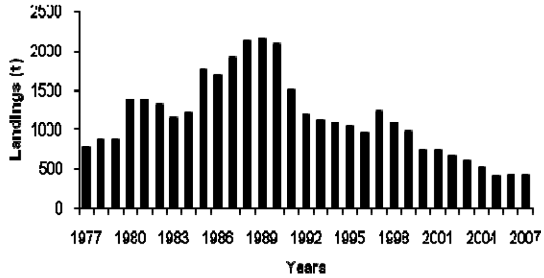
Haddock in Divisions VIIb–k.



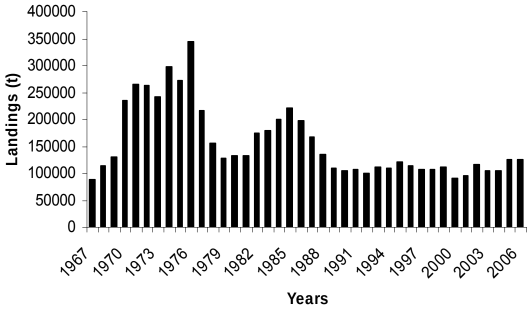
Haddock in Division VIa (West of Scotland).



Cod.

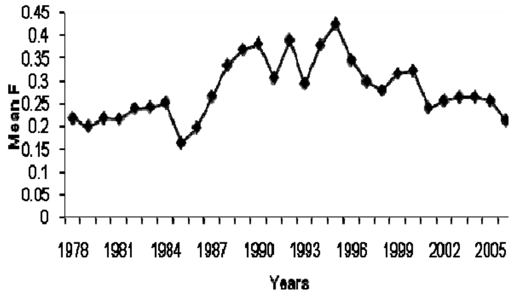


Plaice.



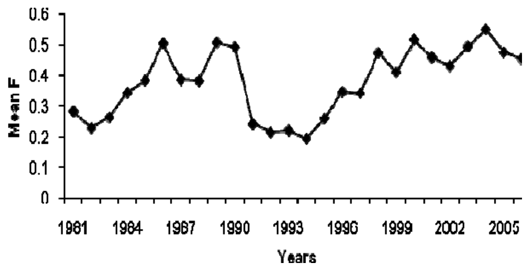
Saithe in Sub-area IV, Division IIIa and Sub-area VI.

Figure 4.4.4.1.1 Landings of the principle species from the Celtic Sea Region. Note different time scales over which reliable data are available and that saithe (in Sub-area IV, Division IIIa (Skager-rak) and Sub-area VI) are included here since the majority of the catch may occur in Sub-area VI.

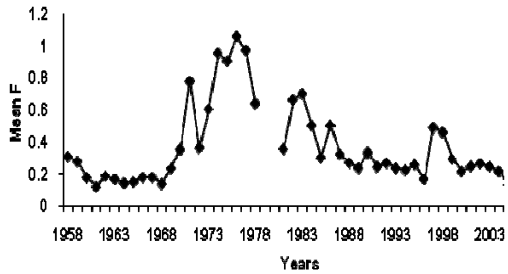


Hake.

Mackerel.

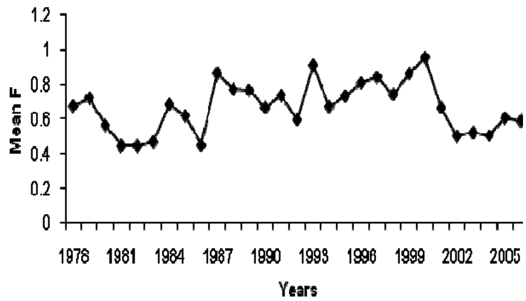


Blue whiting combined stock.

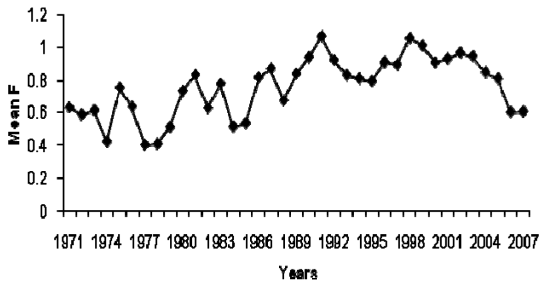


Herring.

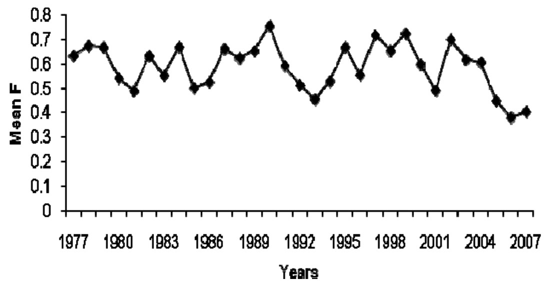
Haddock in Divisions VIIb–k.



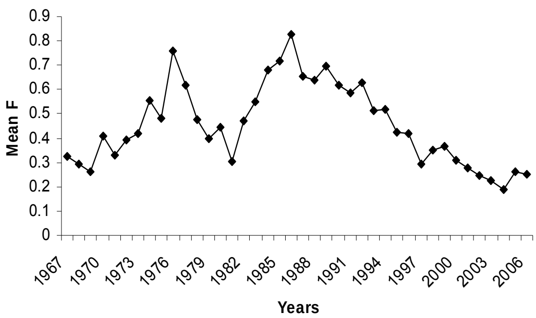
Haddock in Division VIa (West of Scotland).



Cod.



Plaice.



Saithe in Sub-area IV, Division IIIa and Sub-area VI.

Figure 4.4.4.1.2 The fishing mortality (F) imposed on the principle commercial species from the Celtic Sea Region. Note different time scales over which reliable data are available and that saithe (in Sub-area IV, Division IIIa (Skagerrak) and Sub-area VI) are included here since the majority of the catch may occur in Sub-area VI.

Landings of rays appear as a series off 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 4.4.4.1.3). 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.

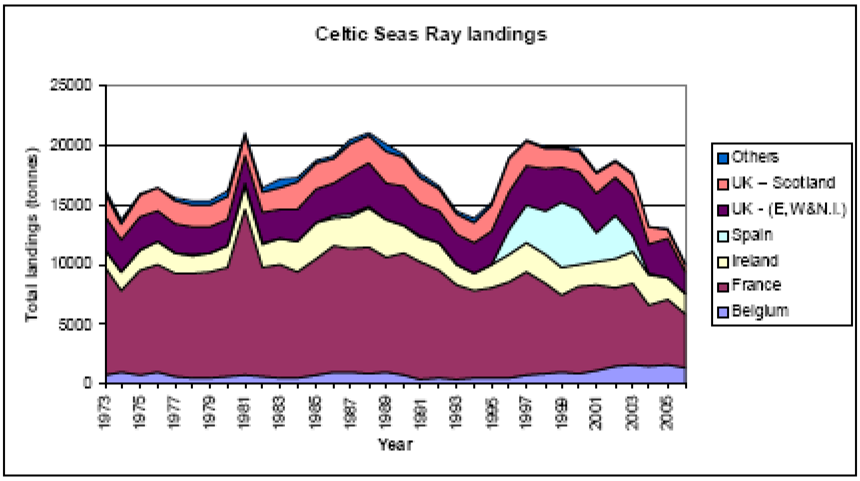


Figure 4.4.4.1.3 Total landings (tonnes) of Rajidae by nation in the Celtic Seas from 1973–2006 (Source: ICES).

4.4.4.2 Bycatch of target and non-target species

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. Recent 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. Unfortunately this practice appears to be increasing in recent years.

Some of the fisheries potentially cause considerable mortality of non-target organims. For example scallop dredging and beam trawling are both recognised to cause considerable mortality to benthic organisms and are widely practised in the Region. Direct estimates of this mortality are now normally made but good data exist from research studies in the 1990s in the Region.

Analysis of discarding levels of the demersal fleet around Ireland has shown that a significant proportion of the catch is discarded. 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 trawler, while the Scottish" seiners discard mostly whiting, haddock and grey gurnard and beam trawls mostly dab and plaice. The majority of these discard species consist of immature fish and discarding appears to be increasing in recent years.

4.4.4.3 Physical disturbance of the seabed

The most important direct ecosystem effects of beam trawl fisheries are on habitats, benthos, commercial fish species and wider fish communities. The extensive bottom fisheries using otter and beam trawls and scallop dredges will have an impact on the physical nature of the seafloor and habitats in the area. These were well described by research studies in the 1990s but the effect of fisheries on habitat structure is not routinely monitored.

4.4.4.4 Shifts in community structure

The benthos of the Celtic Seas have been surveyed intermittently over the last 100 years with the majority of the sampling being in the Irish Sea. This and the extensive studies of fisheries impacts carried out in the region in the 1990s mean that some 'baseline' data exist. However, while areas of the seafloor are monitored, for example for the impacts of oil/gas exploration or as part of pre-construction environmental surveys for wind farms, there is no systematic and routine collection of data on the state of benthic communities in the Celtic Sea area. Systematic assessment of the impact of fisheries on this component is, therefore, impossible.

Interactions of the fishery with other parts of the marine community are patchily described. Zooplankton abundance 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 given the fish community shift towards smaller pelagic species feeding at a lower trophic level. There is some evidence that suggests 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.

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 OSPAR Region III.

Changes in other ecosystem components (i.e., cephalopods, benthos, macrophytes, phytoplankton, seabirds, marine reptiles, water column and biochemical habitat and physical habitat) due to fishing practices may have occurred but we were unable to document them. Generally, an increase in discards has a positive effect on seabird populations, although this is not always the case. Given the increase of this practice in the Celtic Sea in recent years it is likely that this ecosystem component has been affected.

4.4.4.5 Indirect effects on the food web

The fisheries have also brought about a change in the food web in the Region. There is general agreement that the size structure of the fish community has changed significantly with a decrease in the relative abundance of large fish that naturally predate smaller fish, such as cod and hake, with a coincident increase in smaller pelagic species which feed at a lower trophic level (Blanchard *et al*., 2005, Trenkel *et al*., 2004).

4.4.5 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. 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 have not halted these declines.

OSPAR should work with the European Commission to develop a long term management plan for hake, address the depleted state of the herring (in ICES areas VIaS, VIIb, c, g, h, j, k) and spurdog stocks and to facilitate conservation measures for porbeagle. OSPAR should continue to work with the European Commission to promote measures to reduce discards.

4.4.6 Further reading

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4.5 Regional QSR IV: Bay of Biscay and Iberia

4.5.1 Introduction

The region extends from west of Brittany (48°N) to the Gibraltar Straight (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 characterised 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). 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. larges 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. By contrast, megrim, anglerfish, anchovy and *Nephrops* stocks belong to the southernmost area.

4.5.2 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 volume. In this section we consider those measures with a purely regional basis.

In Region IV as a consequence of the depleted status of stocks, several recovery plans have been adopted over the last ten years. All aim at restoring Spawning Stock Biomass at 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 4.5.2.1).

Although there is no recovery plan for *Nephrops* in the Northern Bay of Biscay, a diversity of measures have been adopted either by the French administration or by the Producers' organisations (POs) themselves. A 9 cm minimum landing size regulation is established since December 2005, together with a 70 mm codend mesh size since 2000. A licence 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 weekends, and individual quotas are imposed by the French POs since 2006.

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 or improvement were seen in 2006 and 2007, the fishery will not be reopened until the end of 2008. Only experimental fishing with scientific observers on board representing 20% of French and Spanish effort has been allowed in 2007.

Table 4.5.2.1 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.

STOCK	YEAR ADOPTED	TECHNICAL MEASURES
Northern hake	2004	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)
Southern hake	2006	Minimum landing size Protected areas Minimum mesh size
Bay of Biscay sole	2006	None?
Cantabrian Sea *Nephrops*	2006	None?
West of Portugal and Gulf of Cadiz *Nephrops*	2006	Closed season 45 days Daily fishing hours restriction 2 days closed each week

In 2004 the EU took a decision to better protect cetaceans in EU waters, following much of the advice received from ICES and STECF. The measures introduced in Regulation 812/2004 included a step by step reduction of the use of driftnets from 1 January 2005 until complete prohibition by 1 January 2008, the monitoring of bycatches through observer schemes and the compulsory use of acoustic deterrent devices on fishing nets.

The use of acoustic devices or 'pingers', was made mandatory for gillnet fisheries (from June 2005 for the North Sea and the Baltic Sea, from January 2006 in the Celtic Sea and the western Channel and 2007 in the eastern Channel) for all vessels over 12 m. The regulation provided technical specifications for the efficiency of the acoustic deterrent devices, while there was also a requirement for scientific studies or pilot projects to increase knowledge about the effects over time of the use of acoustic deterrent devices. Member States were encouraged to test newly developed and efficient types of acoustic deterrent devices not in conformity with the technical specifications laid down in this Regulation on a temporary basis.

The measures introduced were to be closely monitored in order to allow for their adaptation over time, while Member States were tasked with ensuring full monitoring of the state of cetacean populations as required under the Habitats Directive. Subsequently, though, the introduction of acoustic deterrent devices under Regulation 812/2004 has been compromised due to a combination of factors. In most EU countries anecdotal evidence suggests there is only limited enforcement of the regulations and only a limited number of vessels complying with the regulations; e.g. Denmark reports around 30 vessels, while Sweden report 9 vessels in the Baltic Area using pingers.

Regulation 812/2004 seeks assessment and monitoring of the impact of pingers on bycatch but in reality very few Member States have been able to carry out such monitoring. This is mainly due to the costs involved in maintaining observer programmes. In some cases a large amount of data from anecdotal sources has been used to supplement the quantitative data gathered from observer programmes. This lack of systematic monitoring has prevented the true extent and potential impacts of pingers on protected species bycatch from being fully understood or documented in EU waters. Scientific monitoring is essential to identify unexpected negative effects of mitigation devices.

It is also worth noting that fishermen in a number of European countries have raised concerns about the resilience of the current commercially available "pingers" and also the practicalities of using these devices for commercial fisheries. These concerns have been addressed in a series of trials carried out in Ireland, UK, Sweden, Denmark and France in 2005 and 2006. As a result of this work, all available models of pinger have now been extensively assessed in terms of ease of use, resistance to damage and long-term running costs. The trials have highlighted a number of serious issues and difficulties relating mainly to the reliability of the devices. Problems with deployment were found, although some of these problems have been resolved by changes to rigging or operating practice. It is clear that more consideration of the construction, practical handling and deployment of such devices is required before they can be considered a universal solution to certain bycatch problems in gillnet fisheries. Costs associated with the introduction of mitigation technologies remain an issue for fishermen and ways to help mitigate economic costs should be carefully considered. For instance the requirement for fishermen to use pingers under Regulation 812/2004 has very real cost implications for fishermen. In Europe current commercially available devices cost in the region of €50–100 per device and a vessel fishing with 10 km of gillnet gear using the recommended spacing between devices of 100 m–200 m would require 50–100 devices at a cost in the region of €2500–5000. Given there are still technical difficulties with these devices, which were flagged when 812/2004 was being formulated, these costs are significant and have undoubtedly been a hindrance to acceptance by fishermen in Europe.

Application of Regulation 812/2004 is perhaps flawed given the objective of the regulation was to mitigate incidental catches of cetacean species in general. Research and development, however, has mainly been focused on the use of pingers to reduce harbour porpoise bycatch in gillnet fisheries. The signal characteristics of the available pingers are well suited for Harbour porpoises; only limited success has been achieved with other cetacean species. For species such as bottlenose dolphins, tests have shown them to be wholly ineffective (Anon., 2006).

It is clear that the successful implementation of a framework for bycatch reduction can be encouraged by appropriate legislation, while conversely legislation can also unwittingly be an impediment to successful introduction of bycatch mitigation technologies. Regulation 812/2004 has largely failed in its objective, through being unrealistically prescriptive and not taking account of all of the technical, biological and economic issues fully. In this case there has perhaps been a failure by managers to consider all of the issues and impacts of adopting legislation to use bycatch reduction devices leading to:

- Poor compliance by fishermen with the regulations;
- Negative Ecological Impacts;
- Economic Impacts on stakeholders;
- Technical Problems with the devices;
- Biological Impacts;
- Poor monitoring; and
- Poor acceptance by stakeholders.

4.5.3 Fishing activities in the OSPAR maritime area

The main economic forces acting on the fishers are the price of fish and fuel prices which have increased.

The number of French vessels fishing in the Bay of Biscay decreased from 2000 to 2006 (Figure 4.5.3.1), except for liners and gillneters. However, fishing effort in power times days fished increased or remained stable for each sector except for the small pelagic fishery as the anchovy fishery was closed in 2005 (Figure 4.5.3.2). 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 between 2000 and 2005 (Figure 4.5.3.3).

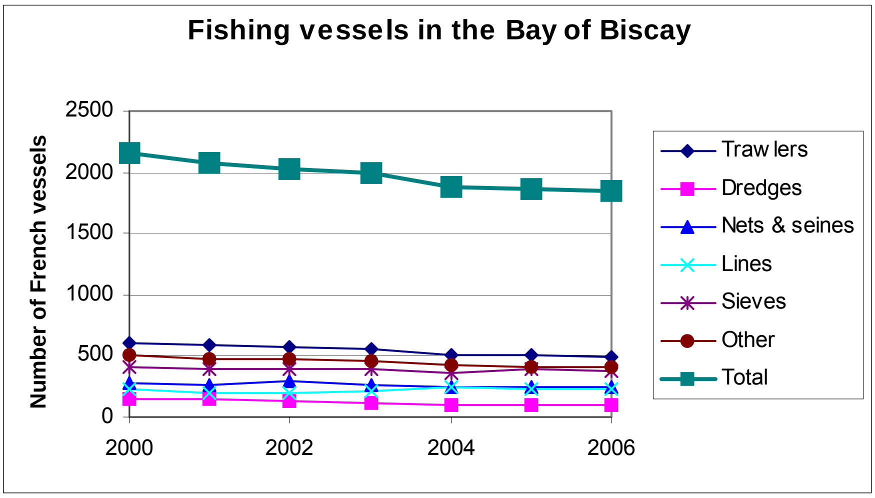


Figure 4.5.3.1 Number of French vessels fishing in the Bay of Biscay 2000–2006. Source: French administration.

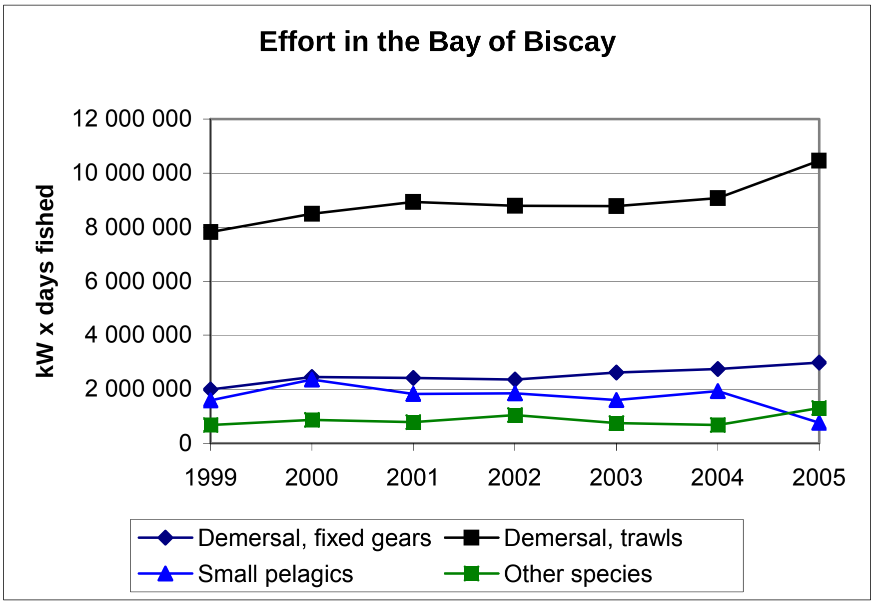
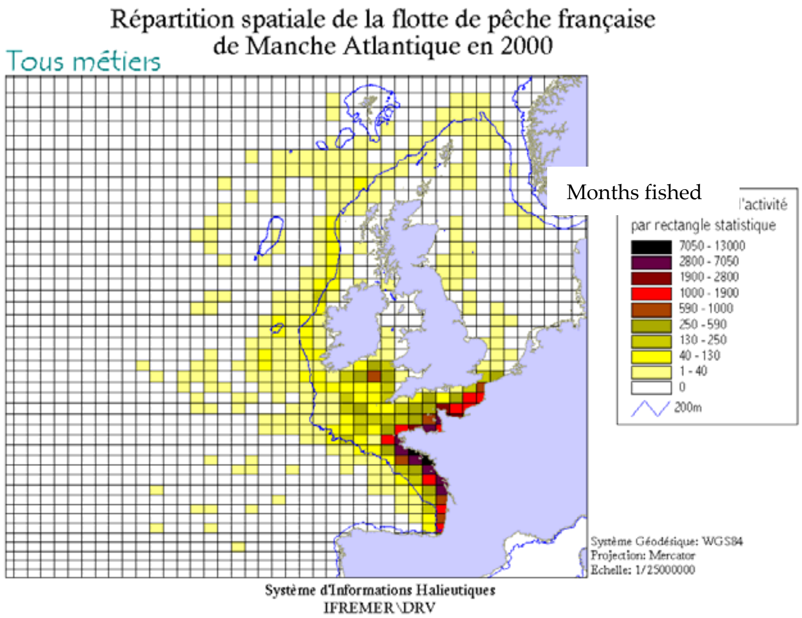


Figure 4.5.3.2 Effort in horse power times days fished by French vessels in the Bay of Biscay. Source: IFREMER aggregated VMS, market and logbook data.


Répartition spatiale de la flotte de pêche française
de Manche Atlantique en 2000
Tous métiers
Months fished
l'activité
par rectangle statistique
7050 - 13000
2800 - 7050
1900 - 2800
1000 - 1900
590 - 1000
250 - 590
130 - 250
40 - 130
1 - 40
0
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Système Géodésique: WGS84
Projection: Mercator
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Système d'Informations Halieutiques
IFREMER\DRV

2000

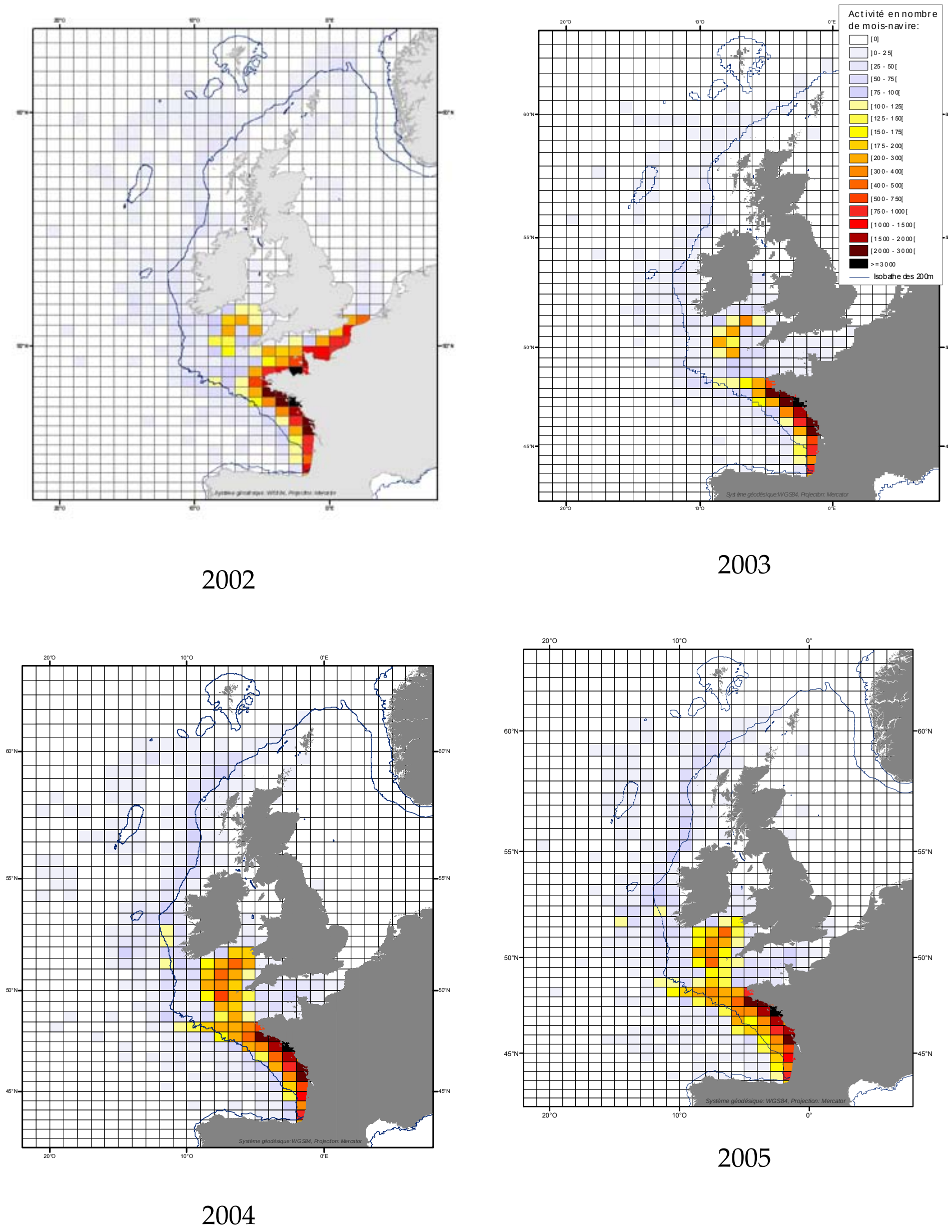


Figure 4.5.3.3 Number of months fished per statistical rectangle by French vessels. Source: Fishing activity survey (100% coverage). 2000 and 2002: the whole French fleet outside Mediterranean, 2003–2005 only Atlantic vessels.

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.

4.5.4 Impacts of fisheries on the ecosystem

Commercial fishing has direct and indirect effects on the marine ecosystem which can be summarized as:

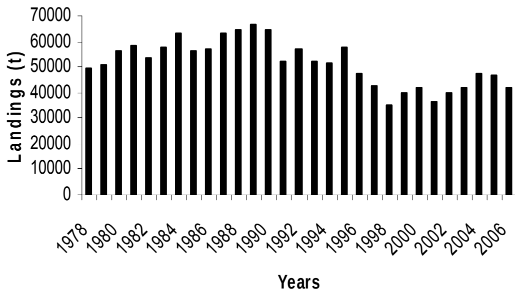
1. trends in commercial fish stocks;
2. bycatch of target and non-target species, including birds and marine mammals;
3. physical disturbance of the sea bottom and related impacts on benthic communities and habitats;
4. shifts in community structure; and
5. indirect effects on the food web.

In OSPAR Area IV the documented critical issues regarding the impact of fisheries relate to points 1, 2, 3 and 4.

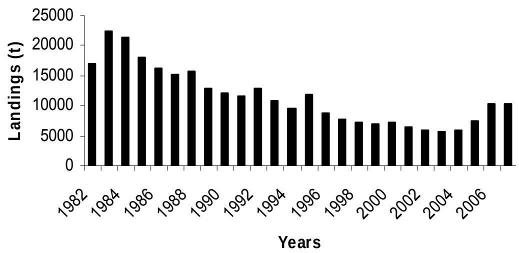
4.5.4.1 Trends in commercial fish stocks

Landings of most species in the Iberian region have declined in recent decades (Figure 4.5.4.1.1). In the Bay of Biscay landings from most stocks have been maintained, with various amplitudes of fluctuations; the exceptions to this being sole which landings decreased markedly since 1995, and anchovy which declined severely from 2001 until the fishery was closed in 2005. By contrast, the Northern stock of hake started to recover in 2002 after a long period of decline (Figure 4.5.4.1.1).

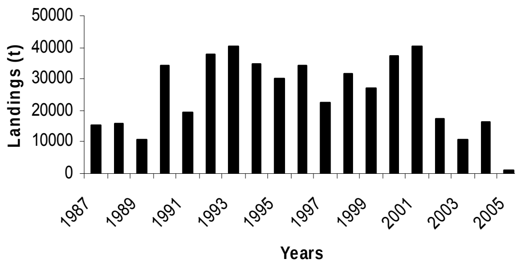
In most cases, declines in landings were accompanied by declines in fishing mortality; Southern hake and Biscay sole are the two stocks undergoing increasing fishing mortality (Figure 4.5.4.1.2).



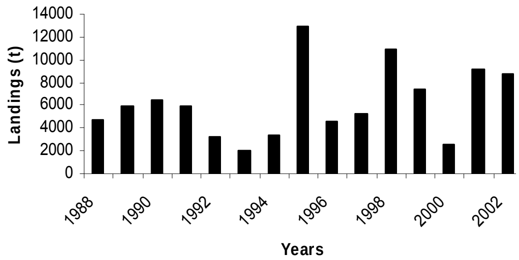
Hake-Northern stock (IIIa, IV, VI, VII, VIIIa, b).



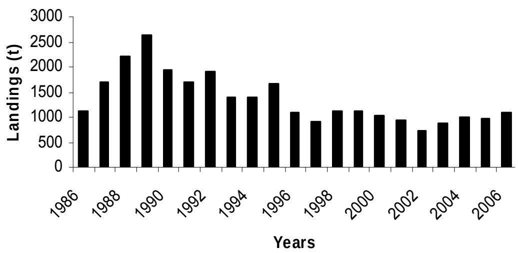
Hake-Southern stock (VIIIc and IXa).



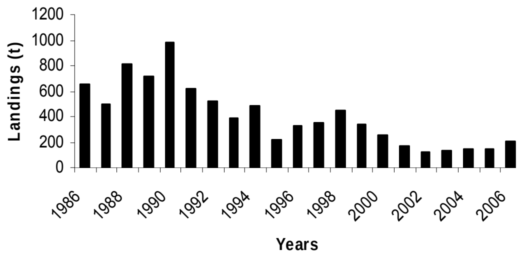
Anchovy in Sub-area VIII (Bay of Biscay).



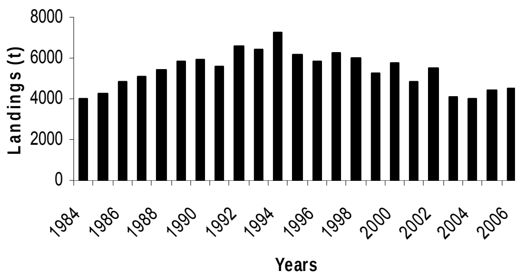
Anchovy in Division IXa.



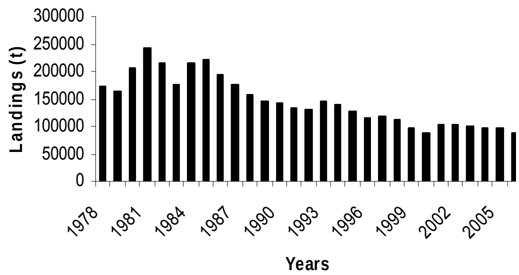
Megrim (*Boscii*) in Divisions VIIIc and IXa (2007).



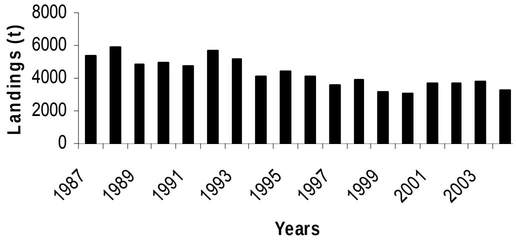
Megrim (*Whiffiagonis*) in Divisions VIIIc and IXa (2007).



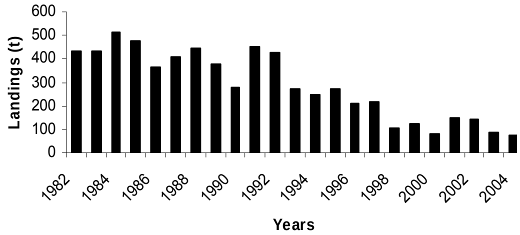
Sole in Divisions VIIIa, b (Bay of Biscay).



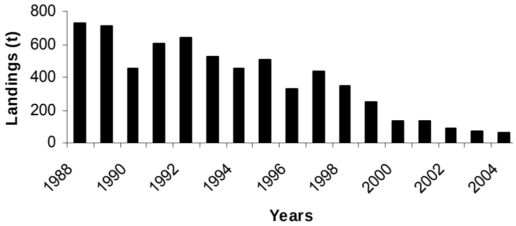
Sardine in Divisions VIIIc and IXa.



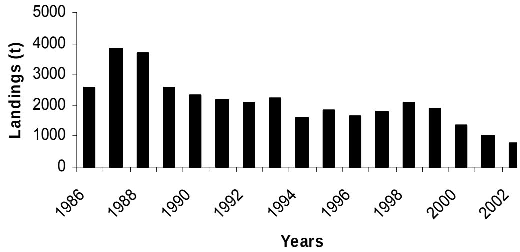
Nephrops in Divisions VIIIa, b (Management Area N).



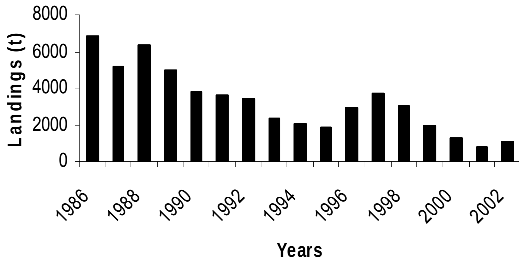
Nephrops in Division VIIIc (Management Area O)-FU25.



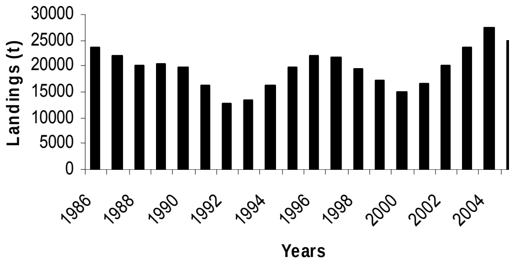
Nephrops in Division IXa (Management Area Q)-FU26–27.



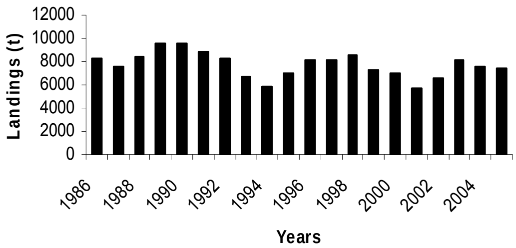
Anglerfish (*Budegassa*) in Divisions VIIIc and IXa.



Anglerfish (*Piscatorius*) in Divisions VIIIc and IXa.

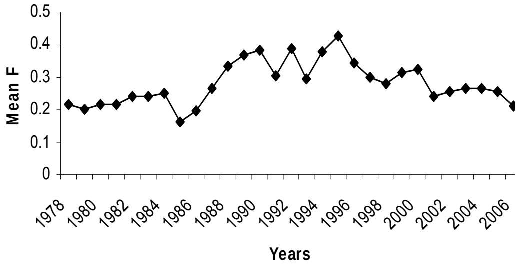


Anglerfish (*Piscatorius*) in Divisions VIIb–k and VIIIa, b.

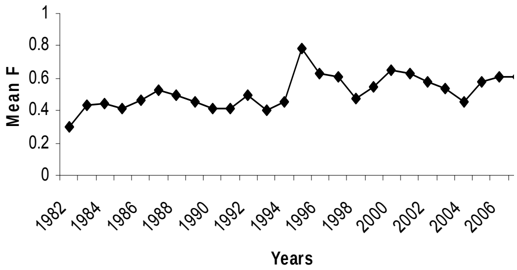


Anglerfish (*Budegassa*) in Divisions VIIb–k and VIIIa, b.

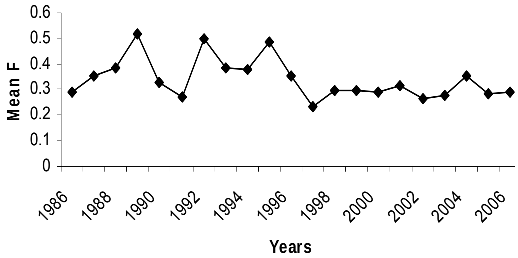
Figure 4.5.4.1.1 Landings of the principle species from the Biscay and Iberian Region. Note different time scales over which reliable data are available.



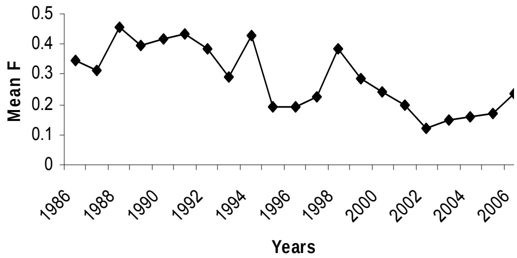
Hake-Northern stock (IIIa, IV, VI, VII, VIIIa, b).



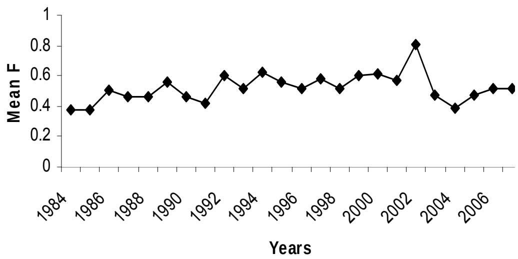
Hake- Southern stock (VIIIc and IXa).



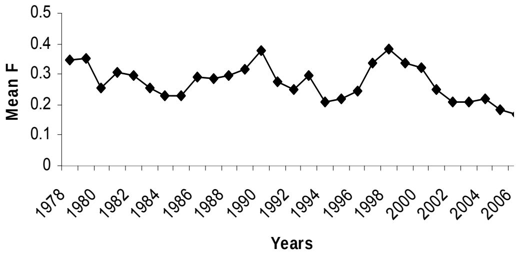
Megrim (*Boscii*) in Divisions VIIIc and IXa (2007).



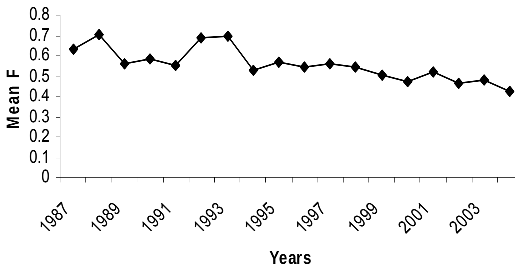
Megrim (*Whiffiagonis*) in Divisions VIIIc and IXa (2007).



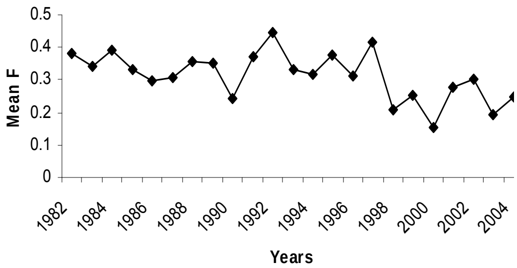
Sole in Divisions VIIIa, b (Bay of Biscay).



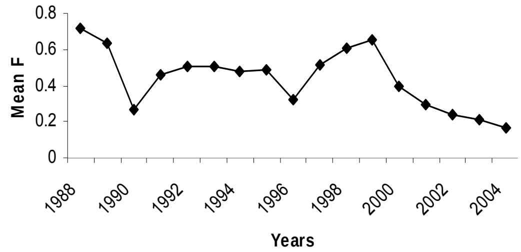
Sardine in Divisions VIIIc and IXa.



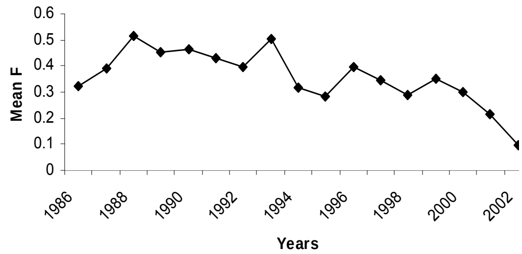
Nephrops in Divisions VIIIa, b (Management Area N).



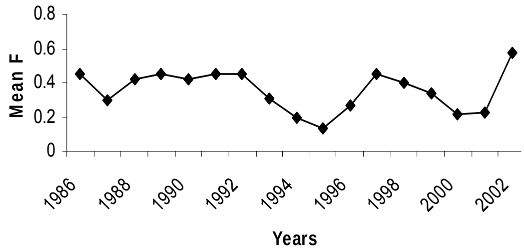
Nephrops in Division VIIIc (Management Area O)-FU25.



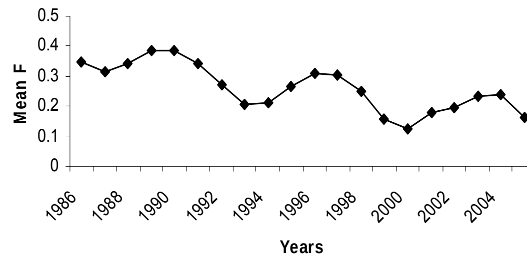
Nephrops in Division IXa (Management Area Q)-FU26–27.



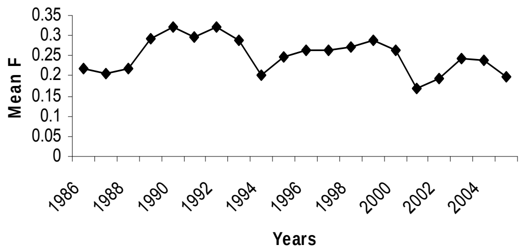
Anglerfish (*Budegassa*) in Divisions VIIIc and IXa.



Anglerfish (*Piscatorius*) in Divisions VIIIc and IXa.



Anglerfish (*Piscatorius*) in Divisions VIIb-k and VIIIa, b.



Anglerfish (*Budegassa*) in Divisions VIIb–k and VIIIa, b.

Figure 4.5.4.1.2 The fishing mortality (F) imposed on the principle commercial species from the Biscay and Iberia Region. Note different time scales over which reliable data are available.

Up to 90 % of French landings from the Bay of Biscay are composed by 34 stocks (Forest, 2001; Forest, 2005). Reliable stock assessments are only available for a limited number. However, evidence for 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 North East Atlantic (NEA) mackerel, NEA blue whiting, Southern hake and sole on the Bay of Biscay continental shelf (ICES divisions VIIIab). The status of these stocks did not improve since 1998, and the status of Bay of Biscay anchovy deteriorated, the fishery is closed since July 2005. Some other stocks are in a better shape owing to decreasing fishing mortality and/or good recent recruitments, namely Northern hake, anglerfish in Celtic Sea and Bay of Biscay, megrim in Celtic Sea and Bay of Biscay and *Nephrops* in the Bay of Biscay. Northern hake has experienced a long period of overexploitation, and a recovery plan is currently implemented. The main concerns about the success of the recovery plan are high discarding rates of juveniles hake, in particular in the *Nephrops* fishery, and TAC overshooting (ICES, 2007). The *Nephrops* stock in Divisions VIIIab seems to be stable. However, the gear selectivity implies a high mortality of small *Nephrops* and consequently large amounts of discards. Various regulation systems are expected to reduce fishing pressure on *Nephrops*.

4.5.4.2 Bycatch of target and non-target species

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; e.g. red seabream used to be one of the dominant large fish species, and its collapse in mid 80s generated a major change in the community structure. In addition, 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 onboard 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. The main fish species discarded are the small sized snipe-fish (*Macrorramphosus scolopax*) and silver pout (*Gadiculus argenteus*) and the medium sized blue whiting (*Micromesistius poutassou*). None of these species survive.

4.5.4.3 Physical disturbance of the seabed

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 and there are no fragile invertebrates.

4.5.4.4 Shifts in community structure

Information on trends in seabird populations was not available however 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 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.

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.

Using survey-based indicators for the whole community and 51 target and non-target fish populations, large changes were detected between 1987 and 2002, but they could not be ascribed to a reduced impact of fishing, thus the fish community in the Bay of Biscay remains strongly impacted by fishing, and dominated by small-sized species (Figure 4.5.4.4.1). Over the last ten years few changes have occurred at the community level (Figure 4.5.4.4.1).

In the Cantabrian Sea, the mean trophic levels of the demersal and benthic fisheries have declined. Most of this change occurred from 1983 through to 1993 and has since varied without a clear trend. The fish communities are now largely dominated by lower trophic level planktivorous fish (blue whiting, horse mackerel). There have been some positive effects of management practices to reduce fishing mortality and trawling effort in this area. Most notably, there appears to be a recovery of elasmobranchs in recent years.

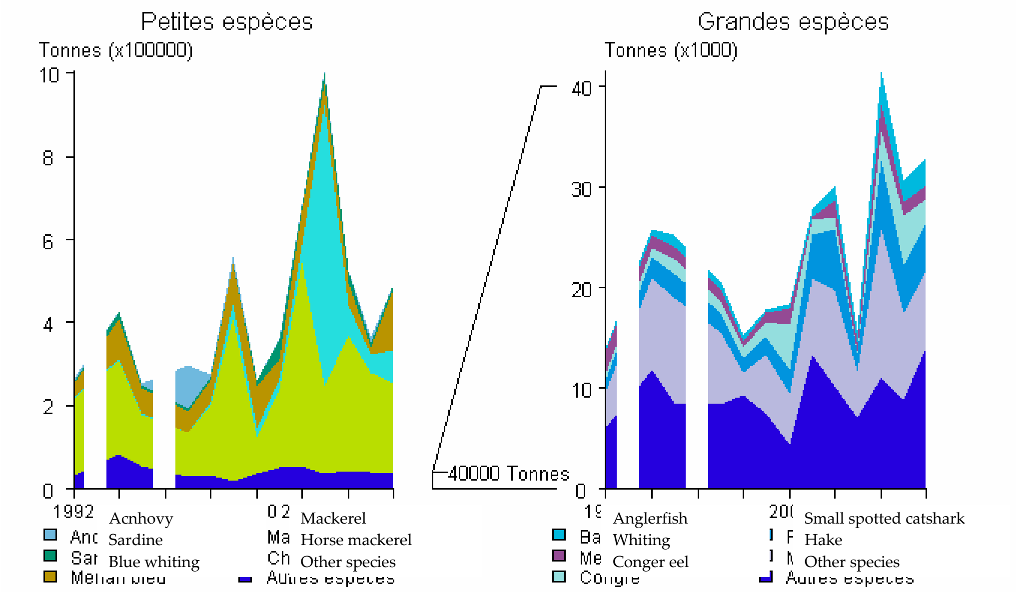


Figure 4.5.4.4.1 Biomass of the main large (right panel) and small (left panel) species in the Bay of Biscay.

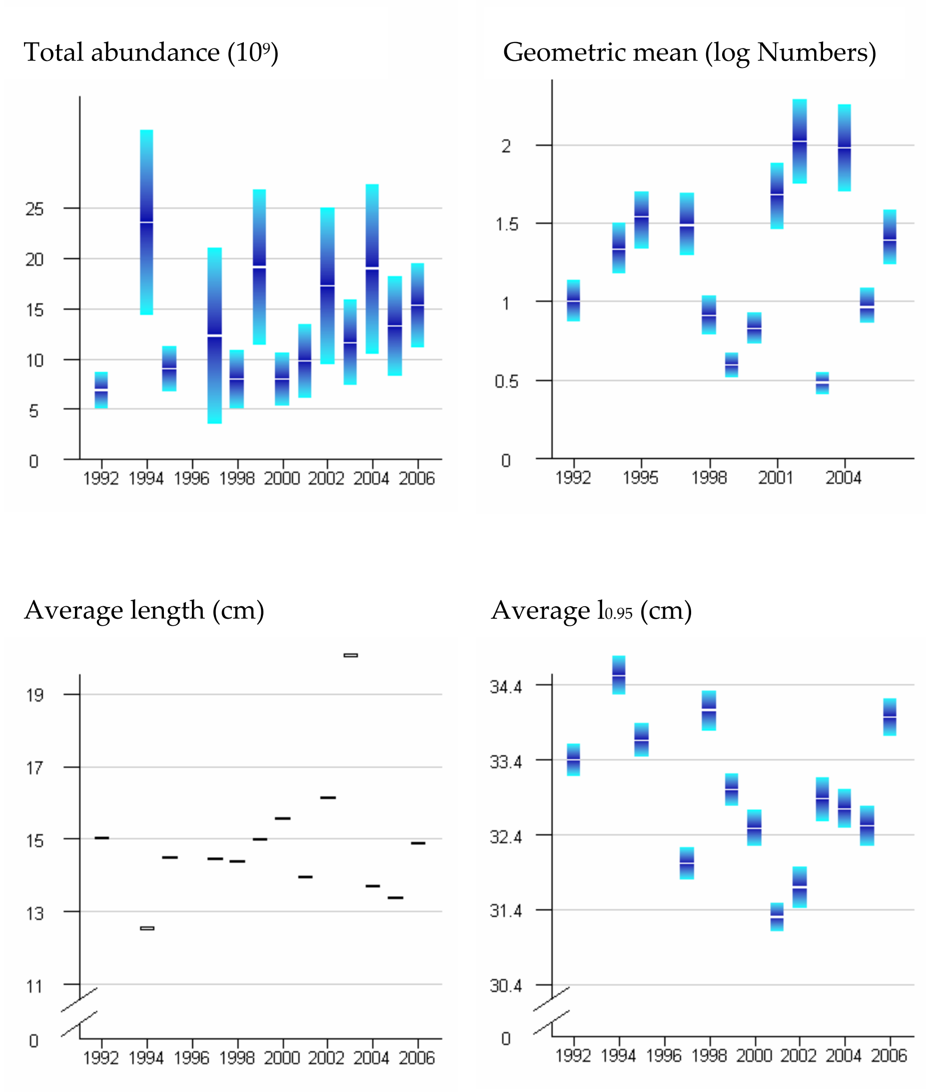


Figure 4.5.4.4.2 Bay of Biscay community attributes, 1992–2006. Total abundance: estimated total number of animals. Geometric mean: mean of log-transformed population abundances. Average length: individual average length in the community. Average l0.95: average of population 95th percentile of the length distribution. Bars show 95% confidence intervals.

4.5.4.5 Indirect effects on the food web

The plankton community has changed over the last 50 years), although in a less pronounced way that in more Northern areas like the North Sea. These changes have not been attributed to fishing impacts.

Some species of marine mammals have dramatically increased both their abundance and range throughout the region (Harbour seal, *Phoca vitulina*) while others have declined (Habour porpoise, *Phocoena phocoena*). Both trends may be linked to changes in fishing practice although direct evidence was not available to support this conclusion.

4.5.5 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.

Work to improve fishers' stewardship and involve them in more ecosystem-friendly practices, *e.g.*, the development and implementation of more selective gears needs to be a priority.

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4.6 Regional QSR V: Wider Atlantic

4.6.1 Introduction

The majority of Region V is deep water greater than 3000 m in depth. The exceptions are some banks to the west of Scotland and south-west 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 banks are similar to those in the more offshore parts of Region III, targeting for instance haddock. On the continental slopes there are bottom trawl and set-net fisheries for species such as monkfish *Lophius* spp., hake *Merluccius merluccius* and deepwater sharks. Bottom-fisheries for deep-water species such as redfish *Sebastes* spp., orange roughy *Hoplostethus atlanticus*, and roundnose grenadier *Coryphaenoides rupestris* 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, IV and V, 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. 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 (EU, Faroes, Iceland).

4.6.2 The development of fisheries management and policy since 1998, and an assessment of their effectiveness

Major changes in the management of fisheries in the north-east Atlantic are described in the QSR NE Atlantic Overview volume. In this section we consider those measures with a purely regional basis.

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. Under the EU Common Fisheries Policy, TAC's where introduced for some species, e.g. red (=blackspot) seabream *Pagellus bogaraveo*, black scabbardfish *Aphanopus carbo*, and deep water sharks, in 2003 (EC Reg. 2340/2002) and maintained in 2004 (EC Reg. 2270/2004) and 2006 (EC Reg. 2015/2006). A specific access requirements and conditions applicable to fishing for deep water stocks was established (EC Reg 2347/2002). 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 since 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, fishermen are encouraged by local authorities to exploit the deeper strata (>700 m), but the poor response of the market has been limiting the expansion of the fishery.

Regulations were introduced in 2006 and 2007 to reduce gear lengths and limit soak times in the bottom-set gillnet fishery on the continental slope west of Europe. Since then fishing effort appears to have reduced.

NEAFC regulates effort in the fisheries for deepwater species 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, entanglingnets and trammelnets have been banned from use in the NEAFC Regulatory Area since early 2006 in waters deeper than 200 m due to excessive soak times leading to much wasted fish and the long term adverse effects of lost or abandoned nets.

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 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 was discarded).

In 2007, ICCAT introduced measures to reduce seabird bycatch in tuna fisheries. The measures apply to vessels fishing S to 20°S. All vessels are required carry and use bird-scaring lines (tori poles) to specified design. Vessels are encouraged to use a second tori pole and bird-scaring 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 deepwater 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 Khlivnoy, 2008 indicated that at least part of the closed area contained few juvenile haddock.

4.6.2.1 Mitigation of impacts in the pelagic trawl fishery for blue whiting around the Faroe Islands

Blue whiting is one of the major pelagic fish resources in the Northeast Atlantic. In 2004 the total recorded catch of blue whiting in the North Atlantic reached 2 377 569 t mainly taken by Norway, EU countries, Iceland, Faroe Islands and Russia. The total blue whiting catch in the Faroese EEZ in 2004 was 435 000 t (ICES, 2005). It is a highly valuable fishery and management has essentially been in the form of quotas and mesh size.

In the last decade there have huge technical developments in pelagic fishing, both in vessels size and design, as well as in development of trawl design. Today pelagic trawls used for blue whiting have horizontal openings of 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 cod-end. These trawls have the ability to catch several 100 tonnes in a few minutes towing time using 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 Inspection estimated an average bycatch in Faroese waters to be approximately 1% with similar estimates being made for the fishery in Icelandic waters. Given the catch sizes in this fishery, these bycatches leaves have the potential to impact on saithe and cod stocks.

For the Faroese pelagic fishermen this bycatch was valueless as it could not be sorted from the blue whiting catch so given the main problems were in Faroese waters there was a strong motivation for them to look at ways of reducing saithe and cod catches to the benefit of the Faroese demersal fleets. On the 1st of January 2007 it became mandatory for the Faroese blue whiting fishery to use a sorting grid in Faroese waters where bycatch is an issue. The type of sorting grid is not specified, but the bar spacing has to be 55 mm. Acceptance of this gear measure is reportedly high for the Faroese fishing industry and this has largely been helped with a strong education campaign by the Faroese fisheries laboratory in assisting fishermen with the installation and use of the grid. Grants for purchase and installation costs have also 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 from inception to regulation took only a year or so. The Faroese experience shows the importance of industry collaboration but also the need for back up technical support and education of fishermen to encourage acceptance. The adoption of this grid is perhaps paralleled to the introduction of Turtle Excluder Devices in the US, South-east Asia and Australia where education programmes that have accompanied their introduction to advise fishermen on correct installation and handling, as well as provision of back up technical assistance to solve rigging and handling problems that may have arisen.

4.6.3 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 and use rockhopper trawls with small mesh codends and have 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 Rockall area, Hatton Bank, mid-Atlantic Ridge and to the west of the Azores. They target species such as redfish, orange roughy, roundnose grenadier, deepwater 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 thee 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 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.

There is a directed gillnet fishery for deepwater sharks and deepwater red crab *Geryon affinins* that takes place on Hatton and Rockall Banks. This fishery is very poorly documented, but there is a bycatch of mora *Mora moro* and greater forkbeard *Phycis blennoides*. The fleet that operates in this area also targets monkfish with tangle nets. The nets used in this fishery are low standing typically 8–10 meshes high with a mesh size of 250 mm. In recent years as with the fisheries in the Celtic Sea for monkfish and deepwater shark the international fisheries have been restricted. Since 2005, vessels operating in the NEAFC Regulatory Area are not permitted to deploy gillnets, entanglingnets or trammelnets at any position where the charted depth is greater than 200 metres. In recent years a directed fishery for deepwater red crab, using pots, in this area also. Effort levels in this fishery are not known but vessels reportedly are 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 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 fishermen 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 fishermen have tended to drop the headline so these trawls 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 deepwater 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 deepwater 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 alfonsino. The gear used is 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 connected to a steel wire that runs to the surface. The fishery is predominantly targeting red seabream. Since mid-1990s, the landings of other deep water species have decreased (Figure 4.6.3.1.1.). Since 2000, the use of bottom longline in the coastal areas has significantly been reduced, as a result of a ban on the use of longlines within 3 miles of the islands. As a consequence, the smaller boats that operate 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.

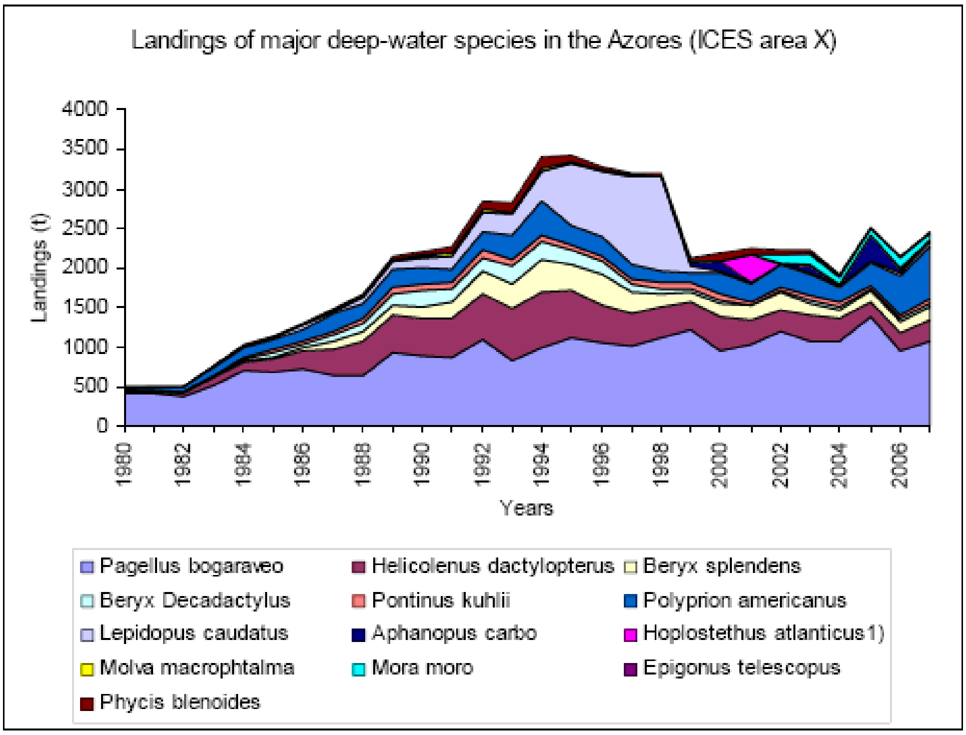


Figure 4.6.3.1 Annual landings of major deep water species in Azores from the hook and line fishery (1980–2007).

There are a number of surface longline fisheries in this area targeting 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.

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. There is an artisanal fleet fishing 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 of a month or more duration working and average of 2500 hooks per set. These vessels are much more sophisticated tended to work with line hauling and line setting equipment and also using chemical lightsticks to attract swordfish.

In the Atlantic west of Ireland, deepwater gillnet fisheries targeting monkfish, hake and deepwater sharks have developed since the mid-1990s. A fleet of up to 50 vessels have been involved in this fishery working on the continental slopes to the West of the British Isles, North of Shetland, at Rockall and the Hatton Bank. These fisheries were not well documented or understood, until publication of the DEEPNET report in 2004 (Hariede *et al*., 2004) which focused attention on to the practices within these fisheries.

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 fishermen 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 in around 2000–2001. The vessels worked around a limited number of seamounts in depths out to 1200 m. In 2002 following concerns about the state of deepwater 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.

4.6.4 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.

In OSPAR Region V the most critical issues regarding the impact of fisheries relate to points 1 and 3. There is some evidence for point 2, and few studies have been carried out on points 4 and 5.

4.6.4.1 Trends in commercial fish stocks

There is good evidence that some deep-water fish (500–1800m) have been severely depleted in the eastern part of Region V by the deep water fisheries. Unlike the commercial shelf-water 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, black scabbard fish, blue ling, and orange roughy as well as deep sea squalids (sharks) and Macrouridae.

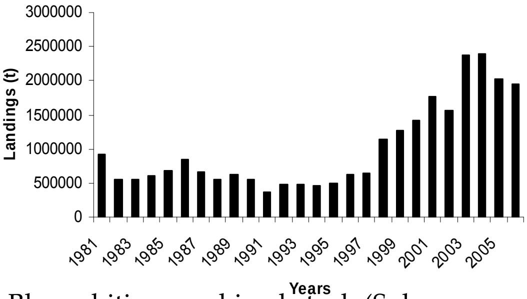
Populations of large fish that aggregate on oceanic bathymetric features such as seamounts are particularly sensitive to overfishing, due to low productivity and high catchability. On the southern part of the mid-Atlantic Ridge and adjacent seamounts, populations of alphonsinos were depleted also in the 1970s. More recently, longline fisheries appear to have depleted seamounts 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). Along the mid-Atlantic Ridge, roundnose grenadiers were depleted by fisheries in the 1970s (Merrett and Haedrich, 1997).

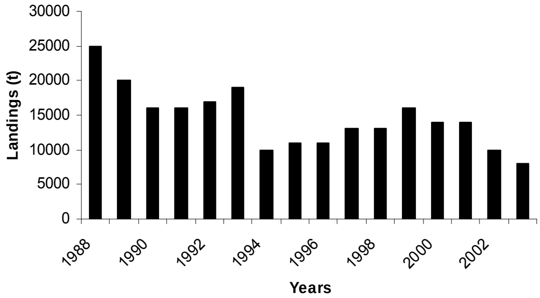
These depletions of dominant species lead to major changes in demersal deep sea fish communities due to the loss of their larger predators and corresponding ecological functions. In addition to catching target species, deep water fisheries bycatch unwanted species that are either too small or unpalatable. Discarding rates are often high (in the order of 50%) and the bulk of the discarded catch is made of smoothheads (Alepocephalidae) because of their high abundance (Allain *et al*., 2003).

Landings of blue ling, tusk and haddock have declined over the past decade, all continuing long-term declines (Figure 4.6.3.1.1). It is assumed that this reflects a decline in spawning stock biomass. Fishing mortality on haddock at Rockall has declined (Figure 4.6.3.1.2). The blue whiting fishery has grown greatly in the past decade and has then declined; fishing mortality paralleled this increase, but has remained high (Figure 4.6.3.1.2). Much of this growth of the fishery has occurred in OSPAR Region 1.

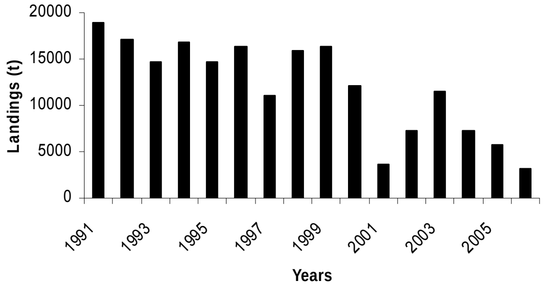
Tuna and billfish are also important fisheries in this area but there was insufficient time to document their population trends in this report.



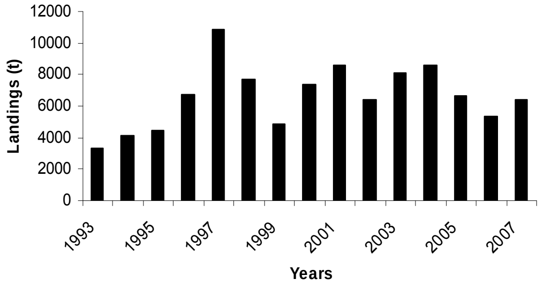
a) Blue whiting combined stock (Sub-areas I-IX, XII and XIV).



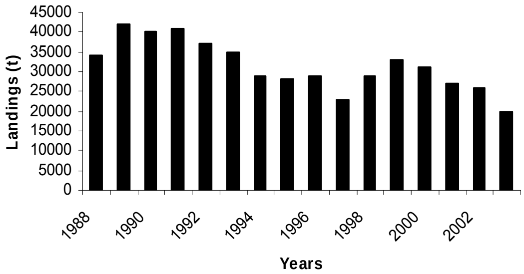
b) Blue ling *Molva dypterygia* (All relevant ICES sub-areas including some outside Region V).



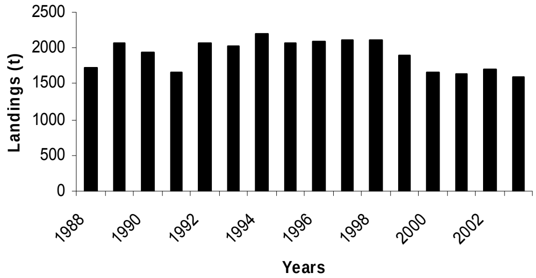
c) Haddock in Division VIb (Rockall).



d) Haddock in Divisions VIIb–k.

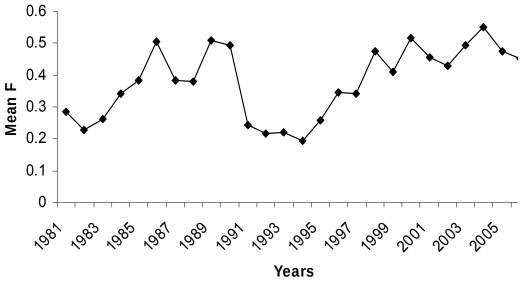


e) Tusk *Brosme brosme* (All relevant ICES sub-areas including some outside Region V).

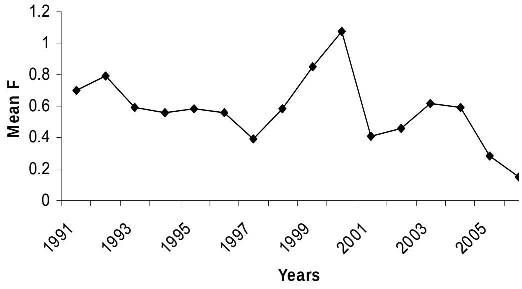


f) Red (=blackspot) seabream (All relevant ICES sub-areas including some outside Region V).

Figure 4.6.3.1.1 Landings of selected species of commercial importance from parts of OSPAR Region V. Data from ICES.

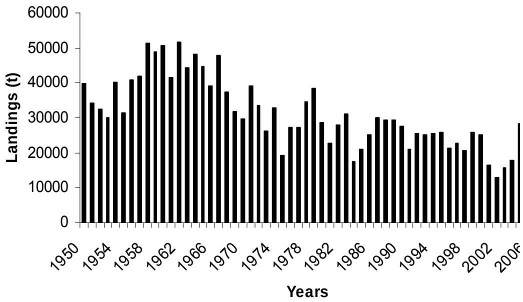


Blue whiting combined stock (Sub-areas I-IX, XII and XIV).

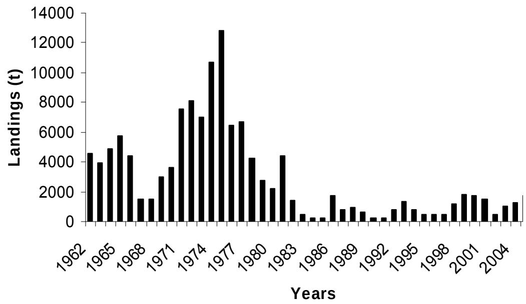


Haddock in Division VIb (Rockall).

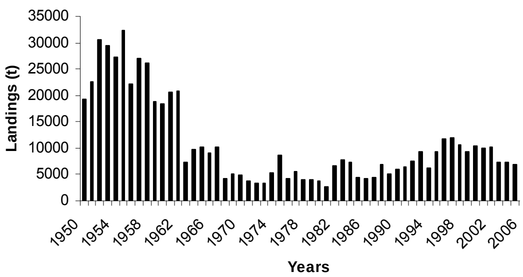
Figure 4.6.3.1.2 Fishing mortality on selected stocks of importance in Region V.



a) Albacore tuna.



b) Bigeye tuna.



c) Northern bluefin tuna.

Figure 4.6.3.1.3 Landings of three species of tuna, 1950–2007 in north-east Atlantic (Data from ICCAT).

4.6.4.2 Bycatch of target and non-target species

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 drift net 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 basanus*, 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 that was replaced by the trawl fishery, 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 (that 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 monitoring demersal longline fisheries around the Azores placed three observers on board vessels from between 6 and 9 months between 2005 and 2007, during which time no seabirds were recorded as bycatch.

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.

4.6.4.3 Physical disturbance of the seabed

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 of 150 to 200 m height and about 1 km wide.

Seamounts often have coral reefs, and support 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.

4.6.4.4 Shifts in community structure

There is no information available directly describing changes in 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.

4.6.4.5 Indirect effects on the food web

There is no information available directly describing indirect effects on the food web within Region V. Based on research elsewhere and given the depletion of some fish stocks, it is likely that such changes have occurred.

4.6.5 Conclusions and priorities for action

The effects of fishing in OSPAR Region V are relatively poorly studied. The life-history characteristics of many of the deep-water species fished in the Region are such that it is comparatively easy to overfish and deplete stocks of these fish. The high value of the large pelagic fish in the region has also led to depletion of their stocks. There are a number of biogenic habitats in deep water in Region V that are very susceptible to damage from seabed fisheries, particularly trawling, but also 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 longlining (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.

4.6.6 Further reading

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5 Fish community EcoQO

Previous work by WGECO and WGFE has established the EcoQO for the demersal fish community of the North Sea as "The proportion (by weight) for fish greater than 40 cm in length should be greater than 0.3". This EcoQO was recommended to OSPAR by ICES in 2007. Current work now focuses on provision of the scientific advice regarding the management action necessary to achieve this target within a specified period of time. To this end, WGECO were asked to address the following term of reference:

> Review the progress made by WGSAM and WGFE in modelling management action (range of demersal community average fishing mortality), and associated timescales involved, to achieve the Fish Community EcoQO target of "The proportion (by weight) for fish greater than 40cm in length should be greater than 0.3" (with a ±10% range in target values). Consider the results of the analyses undertaken by these two WGs and carry out any additional analysis or modelling required so as to complete the matrix below, which could then be used as the basis for the provision of advice to meet the EcoQO target.

Fishing mortality averaged across the seven main demersal species (cod, haddock, whiting, saithe, sole, plaice, Norway pout)	EcoQO Indicator Proportion (by weight) of fish > 40 cm in length	Time to reach Indicator target
$0.85F_{PA}$	0.27	?
	0.30	?
	0.33	?
$1.00F_{PA}$	0.27	?
	0.30	?
	0.33	?
$1.15F_{PA}$	0.27	?
	0.30	?
	0.33	?

5.1 Context to the ToRs set for WGSAM (2007), WGFE (2008) and WGECO (2008)

The main objective underlying the ToRs set to WGSAM, WGFE, and here to WGECO, was to illustrate the time-scales required to achieve the North Sea demersal fish community EcoQO under various fishing mortality (*F*) scenarios. The key question is whether any additional management intervention, over and above the actions taken to attain management objectives for the individual commercial stocks, will be necessary to achieve the EcoQO for the North Sea demersal fish community within an acceptable time frame, and if so, what further reduction in *F* would be required. Theoretical multi-species size-based fish community models need to be used to examine the performance of the proportion of large fish index under a range of fishing mortality scenarios so that managers can determine which level of mortality achieves the Fish Community EcoQO in an acceptable time-frame.

It is not the intention that the Fish Community EcoQO should allow management objectives for individual commercial stocks to be violated; if the Fish Community EcoQO were adopted, achieving the EcoQO proportion of large fish index target of 0.3 does not justify exceeding *F* and biomass (*B*) reference points for the management of individual commercial stocks. However, even if individual commercial stock management objectives are met, managers would still be expected to strive to achieve the Fish Community EcoQO. Both the individual stock objectives and the Fish Community EcoQO are required to be met. The relationship between the single-species management reference points and the community-based reference point has not been established. It is not known whether or not fishing the commercial stocks consistently at F_{PA} would result in size distributions of the species that would ensure achievement of the Fish Community EcoQO. This work is intended to first clarify if compliance with the single species reference points is sufficient to ensure achievement of the EcoQO for the community.

If the Fish Community EcoQO is not achieved when all demersal stocks are fished consistently at F_{PA}, it is necessary to investigate the further reduction in F that would be required to achieve the community EcoQO. Because the different species in the demersal fish community have different L_{inf} and growth characteristics, there would not be a unique solution to this question. To bound the range of options available to management one can explore a family of scenarios:

- Set F=0 for one demersal species and F=F_{PA} for all other species. Repeat for each demersal species individually. This establishes if the Community EcoQO could be achieved were managers to allocate all the additional constraints on fishing to a single target species, while applying conventional management to all other species.
- Reduce F from F_{PA} stepwise in incremental percentages, until the equilibrium biomasses and age compositions for the suite of demersal stocks was consistent with the Community EcoQO. This would establish the magnitude of action necessary, were additional constraints allocated proportionately to all stocks.

Together, these scenarios would delineate a "solution space" within which policy and management could seek specific combinations of measures that would comply with both the single-species and the community reference points, and reflect the best compromise among the social and economic objectives for the various fisheries.

Currently the status of most stocks is in a transitional phase. After a period of widespread and sometimes severe overfishing, in recent years management has reduced F, in some cases to well below F_{PA}. The biomasses and age compositions of these stocks has not yet stabilised at current F, but it also informative to know if the community would achieve the Community EcoQO, were F to be kept at current, or status quo, fishing mortality levels (F_{SQ}) for all stocks where F is currently below F_{PA}, and reduced to F_{PA} for those stocks where F is currently >F_{PA}. If the Community EcoQO is achieved in that scenario, then additional management measures would not be needed. If the EcoQO were not met in this scenario, then again it would be necessary to run additional scenarios with either proportionate reductions to F for all stocks, or F reductions scaled as a function of F_{SQ} and F_{PA}. The former set of scenarios allocates the necessary additional constraints equally to all stocks, whereas the latter set would require less incremental action by managers of stocks that have already reduced F by the greatest amount.

In practice, these scenarios were not the ones that were run, but results are expected in due course. Moreover, the definition of the Community EcoQO and selection of its reference value has always been based on only the demersal fish community of the North Sea (defined in Greenstreet *et al.*, 1999; ICES, 2007). For the scenarios that were run in 2007, WGSAM incorrectly calculated the proportion of large fish index across all species in the MSVPA. This included herring, sprat and sandeel that have high biomass but never grow to lengths in excess of 40 cm. Consequently, the size structure of the end-point fish community of WGSAM's various MSFOR runs always failed to reach a proportion of large fish index target of 0.3, regardless of how low fishing mortality was set.

5.2 Considerations for carrying on this work

Mortality levels set in the ToRs given to all three working groups (see ToR table above) were influenced by consideration of OSPAR's Ecological Quality Issue for Commercial Species. This considers the proportion of species exploited sustainably and so focuses attention on F_{PA}. However, in ICES advice F_{PA} is not a **target** for management, rather it is a benchmark set to guide management decisions to keep the risk of violating the biologically-based **limit** reference point. ICES advice is based on F_{PA} because, given the level of uncertainty in actually estimating both F and the true value of F_{PA}. Given these uncertainties fishing mortality rates higher than F_{PA} may in fact exceed the F likely to lead to reductions in B to levels where productivity is impaired (below B_{LIM}). In situations where F is in fact greater than F_{PA}, F_{PA} may be used as an immediate "short-term initial target", simply to get exploitation of the stock concerned back onto a more sustainable footing. However, exploitation at $F=F_{PA}$ is not commensurate with optimal management of fish stocks, and there is still a need for managers to specify the management objectives such that the corresponding biomass and fishing mortality target reference points (B_{TAR} and F_{TAR} respectively) can be established (with, of course $B_{TAR}>B_{PA}$ and $F_{TAR}<F_{PA}$.).

The fishing mortality scenarios listed in the ToR table given to the three working groups therefore need to be reconsidered. First the mortality scenarios to be explored should be changed, so the results are maximally informative in evaluating the demands this EcoQO would place on management, over and above those already associated with single-species management. For these scenarios, there are two questions whose answers are useful. Will the EcoQO be achieved at all in each scenario? If it will be reached, how long would it take from the present state of the North Sea? In addition, WGSAM considered the intervals between the mortality levels that it was asked to explore to be too narrow, such that there was little scope to distinguish between them in respect of the performance of the proportion of large fish index.

We therefore present a revised mortality scenario table for future ToRs (Table 5.2.1). Examination of the F=0 scenario would provide insight as to what value the proportion of large fish index might attain under circumstances of zero impact from fishing activity on the demersal fish community. It would be of interest to determine the extent to which this differs from the value of 0.3 set as the EcoQO.

Table 5.2.1 Scenarios for theoretical multi-species size-based fish community models to explore the effects of different levels of fishing mortality on the performance (recovery time) of the North Sea demersal fish community proportion of large fish index. Shaded cells indicate "feasibility" scenarios (can the EcoQO be achieved?). Non-shaded cells indicate scenarios with regard to achievement of the EcoQO from status quo conditions, with regard to providing time scale indications.

Fishing mortality averaged across the seven main demersal species (cod, haddock, whiting, saithe, sole, plaice, Norway pout)	Value of EcoQO at equilibrium	Time to reach Indicator target from Present stock status
F=F_{PA} for all stocks		?
ONLY if F=F_{PA} scenario FAILS to achieve EcoQO target, then: *F=0 for one stock and F=F_{PA} for all other stocks. Repeat with F=0 for each stock*		?
F=F_{SQ} for all stocks		?
0.75 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0.50 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0.25 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0		?

5.3 Other main out-comes from the review of work by WGSAM and WGFE

WGFE carried out a review of other theoretical modelling approaches that might be used to complete the table above. They identified six attributes that a model should posses in order to address the questions posed:

- Size-based: Since the EcoQO is size-based, involving length and weight measures, a model is required that is size-based for, at the very least, those fish species involved in the calculation of the indicator.
- Dynamic: The question posed involves time-scales of changes in the indicator with fishing pressure, so a dynamics model is required.
- Multi-species: The model must take account of (but not necessarily resolve individually) multiple species since the EcoQO is a community indicator. Since we are looking at community-level responses to changes in fishing, the model should capture the main processes driving ecosystem structure.
- Representation of fishing: We require a representation of fishing mortality and one which is alterable in the model for the purposes of investigating the impact of changes in fishing on the community structure.
- North Sea specific: Since the EcoQO has been specifically formulated for the North Sea demersal fish community, if the model is to be used as an advice tool then it must be capable of representing this specific community.
- Predictive: The model is required to make community-level predictions with appropriate uncertainty bounds.

WGFE identified four recently published models, and two further models, which are at relatively advanced stages of development, that contained all (or most) of these attributes and reviewed their suitability in addressing the EcoQO advice issue. WGFE's review of these models is detailed, but their essential findings are summarised in a table repeated here (Table 5.3.1). One of the models (Maury *et al*., 2007) reviewed by WGFE was excluded from their table, but for completeness, it is included in Table 5.3.1. Only one of the six models was actually North Sea specific, but WGFE considered that each of the models could be re-parameterised to simulate the North Sea situation. Unfortunately, development of the only North Sea specific model was incomplete and so not available to run the simulations required to complete the ToR table. While there were many similarities between some of these models, each differed from the other in key respects. Each model, if parameterised to represent the North Sea, could provide useful insight on which to base management advice. Critically though, none of the models was yet capable of being used to address the questions set in the ToR, leaving WGFE in the position of being unable to complete the ToR table.

Table 5.3.1 Summary of the features of the models (after ICES, 2008) with respect to the list of key attributes identified is being necessary prerequisites of any model used to address North Sea demersal fish community EcoQO management advice. (*) Parameterisation of the Pope *et al.* (2006) model was bounded by fits to seven aggregate properties of the North Sea fish community, but the model was not designed specifically for the North Sea.

Attribute	Hall *et al.*, 2006	Pope *et al.*, 2006	Benoit & Rochet, 2004	Maury *et al.*, 2007	Andersen, unpublished (ICES, 2008)	Speirs *et al.*, unpublished (ICES, 2008)
Size-based	yes	yes	yes	yes	yes	yes
Dynamic	yes	no	yes	yes	yes	yes
Community-based	yes	yes	yes	yes	yes	yes
Multi-species	yes	yes	no	no	yes	yes
Representation of fishing	yes	yes	yes	yes	yes	yes
North Sea specific	no	partly(*)	no	no	no	yes

5.4 Recommendations

WGSAM remains the obvious group to use MSFOR to examine the scenarios set in Table 5.2.1 and a ToR to this effect should be set for this working group.

Only one of the multi-species size-based models reviewed by WGFE was currently parameterised to simulate the North Sea situation, but this model was not yet fully developed. The remaining five models reviewed could potentially all provide useful insight into the behaviour of the proportion of large fish index under different fishing mortality scenarios, but work would be required to re-parameterise these to mimic the North Sea. A study group consisting of scientists involved in as many of these models as possible would be required to carry out this work. A two year time-span with three meetings should be sufficient. The goal for this study group should be to use as many of the theoretical multi-species size-based models as possible to address the scenarios listed in Table 5.2.1.

5.4.1 ToR for WGSAM 2008

Use the MSVPA model in forecast mode (MSFOR) to address the scenarios in the table below. These scenarios address the provision of advice regarding the management action necessary to achieve the North Sea demersal Fish Community EcoQO. The proportion of large fish index on which the EcoQO is based concerns the demersal fish assemblage only. Pelagic species, such as herring, sprats, and sandeels, should be included in the MSFOR runs, but MSFOR output abundances at age for these species should be excluded in calculations of the proportion of large fish index. The EcoQO for the index is "The proportion (by weight) for fish greater than 40 cm in length should be greater than 0.3".

Table Legend: Scenarios for theoretical multi-species size-based fish community models to explore the effects of different levels of fishing mortality on the performance (recovery time) of the North Sea demersal fish community proportion of large fish index. Shaded cells indicate "feasibility" scenarios (can the EcoQO be achieved?). Non-shaded cells indicate scenarios with regard to achievement of the EcoQO from status quo conditions, with regard to providing time scale indications.

FISHING MORTALITY AVERAGED ACROSS THE SEVEN MAIN DEMERSAL SPECIES (COD, HADDOCK, WHITING, SAITHE, SOLE, PLAICE, NORWAY POUT)	VALUE OF ECOQO AT EQUILIBRIUM	TIME TO REACH INDICATOR TARGET FROM PRESENT STOCK STATUS
$F=F_{PA}$ for all stocks		?
ONLY if $F=F_{PA}$ scenario FAILS to achieve EcoQO target, then: *F=0 for one stock and $F=F_{PA}$ for all other stocks. Repeat with F=0 for each stock*		?
$F=F_{SQ}$ for all stocks		?
0.75 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0.50 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0.25 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0		?

5.4.2 ToR for proposed Study Group

OSPAR's Ecological Quality Objectcive (EcoQO) for the Fish Community of the North Sea is "The proportion (by weight) for fish greater than 40 cm in length should be greater than 0.3". The proportion of large fish index on which the EcoQO is based concerns only the demersal fish assemblage (species defined in Greenstreet *et al.*, 1999) sampled using the ICES first quarter International Bottom Trawl Survey. The study group is asked to parameterise the theoretical multi-species size-based fish community models reviewed by ICES Working Group on Fish Ecology (ICES, 2008) for the present day North Sea situation. These models should then be applied to address the scenarios listed in the table below. The results of these simulations will provide the basis for scientific advice to fisheries managers to inform them of the action required to achieve the EcoQO.

Table Legend: Scenarios for theoretical multi-species size-based fish community models to explore the effects of different levels of fishing mortality on the performance (recovery time) of the North Sea demersal fish community proportion of large fish index. Shaded cells indicate "feasibility" scenarios (can the EcoQO be achieved?). Non-shaded cells indicate scenarios with regard to achievement of the EcoQO from status quo conditions, with regard to providing time scale indications.

FISHING MORTALITY AVERAGED ACROSS THE SEVEN MAIN DEMERSAL SPECIES (COD, HADDOCK, WHITING, SAITHE, SOLE, PLAICE, NORWAY POUT)	VALUE OF ECOQO AT EQUILIBRIUM	TIME TO REACH INDICATOR TARGET FROM PRESENT STOCK STATUS
$F=F_{PA}$ for all stocks		?
ONLY if $F=F_{PA}$ scenario FAILS to achieve EcoQO target, then: *F=0 for one stock and $F=F_{PA}$ for all other stocks. Repeat with F=0 for each stock*		?
$F=F_{SQ}$ for all stocks		?
0.75 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0.50 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0.25 [*F_{PA} or F_{SQ}, whichever is lower, for each stock*]		?
0		?

The study group should be chaired by a scientist familiar with the development of the North Sea Fish Community EcoQO to its current form. Members of the study group should include, as far as is possible, scientists intimately involved in each of the theoretical models.

5.4.3 Justification for both ToRs

The EcoQO for demersal Fish Communities in the North Sea "The proportion (by weight) for fish greater than 40 cm in length should be greater than 0.3" was recommended to OSPAR by ICES in 2007. Scientific advice will be required to achieve this EcoQO.

5.5 Summary

As a response to a OSPAR 2005 request for further development of the EcoQO on changes in the proportions of large fish in the North Sea, ICES in 2007 advised that the proportion (by weight) of fish greater than 40 cm in length should be greater than 0.3, based on the ICES Q1 IBTS survey series.

WGECO considers that, essentially, both the individual stock objectives (keeping $F<F_{PA}$ and $B>B_{PA}$) and the Fish Community EcoQO should be met. Currently it is not known whether fishing each of the commercial stocks at F_{PA} is sufficient to ensure that the Fish Community EcoQO will be met, or whether additional management intervention will be required. WGECO therefore recommends that an ICES study group be set up to do further modeling to address this issue.

5.6 References

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Hall, S. J., Collie, J. S., Duplisea, D. E., Jennings, S., Bravington, M., and Link, J. 2006. A length-based multispecies model for evaluating community responses to fishing. Canadian Journal of Fisheries and Aquatic Science, 63: 1344–1359.

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Pope, J. G., Rice, J. C., Daan, N., Jennings, S., and Gislason, H. 2006. Modelling an exploited marine fish community with 15 parameters – results from a simple size-based model. ICES Journal of Marine Science, 63: 1029–1044.

6 Assessment framework to assess the efficacy of gear-based technical measures

ToR d) "*begin the process of developing a framework to identify methodologies to assess and quantify the efficacy of gear-based technical measures introduced to reduce the environmental impact of fishing*".

6.1 Introduction

WGECO and WGFTFB have discussed the subject of fishing impacts at length in the past, but usually in isolation (e.g. ICES, 2004a; ICES, 2006). The ecosystem-based approach to fisheries management requires the integration of different disciplines (sometimes organised within different Working Groups at ICES) to comprehensively address major concerns about impacts of fishing and ways to mitigate these. Initiatives to share the expertise of WGECO and WGFTFB and integrate advice began in 2007, focussing on the impacts and mitigation measures of *C. crangon* beam trawl fisheries in the North Sea, with participants from both Working Groups contributing. Exchange of expertise has continued and been further developed in 2008 through mutual WGECO/WGFTFB ToRs that address broader issues (i.e., ToRs b) and d) in this report).

In ToR d), collaboration will help to develop a framework that ultimately could be used to assess the efficacy of gear-based technical measures (GBTMs) introduced to reduce the environmental impact of fishing. Evaluations of the efficacy of GBTMs have been undertaken by fishing gear technologists for many years but these have tended to focus on specific issues such as the reduction in discards of non-target species, or a reduction in cetacean bycatch (Kraus *et al*., 1997; Larsen, 1999; Revill *et al*., 1999; Goodson *et al*., 2001; Barlow and Cameron, 2003; Polet, 2003; Valdermarsen and Suuronen, 2003; He *et al*., 2004; Revill and Jennings, 2005; Catchpole *et al*., 2008; Depestele *et al*., 2008). There have rarely been holistic assessments of how the technical measure has contributed to the overall reduction in environmental impacts of the fishing gear. To complete such an assessment, the expertise required will sometimes be beyond that represented in the field of fishing gear technology. Thus the process of beginning to develop a framework to identify methodologies for the assessment of the efficacy of GBTMs in reducing environmental impacts of fisheries is undertaken here with participants from both WGECO and WGFTFB. Ultimately it is anticipated that this framework will result in a more focused approach in gear technology research and development work, taking account of all relevant ecosystem impacts and how to assess the effect of a GBTM on them.

6.2 Developing a framework

For the assessment of the efficacy of GBTMs to reduce the environmental impact of specific fishing gears, it is recommended that any framework should include consideration of the following steps:

1) What are the current environmental impacts of a particular fishing gear, and which of these are significant adverse impacts? Where impacts are insignificant gear technologists should not consider mitigation measures further.
2) Of those significant adverse impacts, which can GBTMs practically address?

3) How can the effects of a proposed GBTM on those impacts identified in Step 2 be assessed in gear trials? If methodologies do not currently exist for some impacts, could any be developed?

4) Given appropriate gear trials based on methodologies developed in Step 3, to what extent do proposed GBTMs actually reduce those significant adverse impacts?

5) Are there any new impacts, or existing impacts that have actually become more severe or likely as a result of the gear modification (i.e. moving into the significant adverse impact category)? How does any change in impact (as identified in Steps 3, 4 and 5) actually contribute to reducing the overall environmental impacts of the fishing gear?

At this meeting, we have addressed Step 1 by developing a methodology that can be used to describe the current significant adverse impacts of any fishing gear (Section 6.3). This draws on previous reports compiled by WGECO and WGFTFB, refers to risk assessment methodologies, and the guidelines currently being drawn up by the FAO on the management of deep-sea fisheries in the high seas. The outcome of Step 1 can act as a firm basis to prioritise the need for mitigation measures for a particular fishing gear, but the methodology will require further exploration by WGECO in 2009 to make it fully operational (see Sections 6.4 and 6.5).

We have not developed Steps 2–6 further as these will require additional collaboration with WGFTFB, and it is envisaged that the work completed this year is the start of an incremental process to make the overall framework operational. In Section 6.4 we describe the process required to advance this work.

6.3 Documenting the environmental impacts of fishing gears

6.3.1 Interactions between fishing gears and ecosystem components

There is a large amount of peer-reviewed scientific papers on the environmental impacts of fishing (e.g., see reviews in Jennings and Kaiser, 1998; Hall, 1999; Kaiser and de Groot, 2000). For the purpose of assessing how GBTMs can contribute to reducing these, it is important to focus and group impacts in terms of broad fishing gear types, ecosystem components they affect and how adverse the current levels of impacts are. Overview work (ICES, 2006 Section 3, and previous reports back to 1990) and more focused fishery specific work (e.g. ICES, 2007 Section 6) have been undertaken by WGECO over a number of years, where impacts to ecosystem components have been described by fishing gear. Generally the impacts are organised by ecosystem component, where ecosystem components are categorised at a coarse ecological level such as 'benthos', 'seabirds' and 'physical habitat'. Here we use the ecosystem components listed in ICES (2007 Section 7), but we exclude all plankton because it is widely accepted that fisheries have negligible *direct* effects on the plankton (ICES, 2006). All impacts documented here are a result of direct fishing effects because it is these direct effects that gear modifications are applied to (see ICES, 2004b Section 12.2 for a definition of direct and indirect fishing effects). In Table 6.3.1.1 all known interactions between the major fishing gear types and ecosystem components are documented. This table should be consulted as a first step to identifying which components should be considered in designing gear trials.

Table 6.3.1.1 Known interactions between fishing gear types and ecosystem components as these gears are used in normal fishing practice (shaded in grey). No known interaction is indicated by a blank white cell. Severity and likelihood of the interactions are not indicated here (see further development in Section 6.3.2).

	Physical habitat	Water column & bio-chemical habitat	Benthos	Macrophytes	Non-target fish	Commercial fish & shellfish	Marine mammals	Cephalopods	Marine reptiles	Seabirds
Otter trawling	■	■	■	■	■	■		■	■	■
Beam trawling	■	■	■	■	■	■		■	■	■
Dredging	■	■	■	■	■	■			■	
Demersal seines	■	■	■	■	■	■		■	■	■
Bottom longlines	■	■	■	■	■	■	■	■	■	■
Bottom set nets	■	■	■	■	■	■	■	■	■	■
Pots and creels	■	■	■	■	■	■	■			
Pelagic set nets					■	■	■	■	■	■
Pelagic trawling[1]	■	■	■	■	■	■	■	■	■	■
Pelagic longlines					■	■	■	■	■	■
Purse seines					■	■	■	■	■	■

[1] It has been reported that it is now normal fishing practice for some of the pelagic trawl fleets operating in the ICES area to make contact with the benthic environment in pursuing their target stocks. This reflects the behaviour of some of the target species to swim downwards in trying to escape the gear.

6.3.2 Qualitative scoring of the current level of adverse impacts of fishing gears on ecosystem components

Having identified potential interactions between the fishing gear being considered and ecosystem components (Section 6.3.1), it is necessary to assess the level of adverse effects of those interactions in order to prioritise any requirement for mitigation of impact. For some interactions, impacts may be negligible and/or very unlikely to occur. Methodologies for scoring the level of impact between a particular human pressure (such as selective extraction of individuals in a fishery) and ecosystem components have been developed by a number of *fora,* including WGECO (ICES, 2007 and see discussion in Section 7 of this report), OSPAR (OSPAR, 2007) and further afield (Fletcher, 2005; Halpern *et al.*, 2007; Hobday *et al.*, 2006; Tyler-Walters *et al.*, 2007; Robinson *et al.*, 2008). Although useful, these methodologies usually result in a number of output categories of risk or impact, and this overcomplicates what is required here, which is primarily to allow gear technologists to better plan research and development work.

For the purpose of providing a framework for advice on the impacts gear technologists need to consider in assessing the efficiency of gear modifications, only two categories of impact are required: one for interactions where the impact level suggests a need for consideration of mitigation of the impact, and the other for interactions where there are insignificant impacts. Following this logic, gear technologists would be encouraged to assess any effect of their gear modification on reducing impacts to the first category of interactions only. The terminology defined by the FAO in their paper currently being consulted on for international guidelines for management of deep-sea fisheries in the high seas (FAO, 2008), lends itself well to this purpose. In the FAO approach, criteria for significant adverse impacts are defined and we have adapted these criteria here for target species, non-target species and assemblages, charismatic species, and habitats (Tables 6.3.2.1–6.3.2.4).

In compiling these tables we emphasize that some of the international definitions used have not yet been made operational. For example, recovery times are included as criteria for significant adverse impacts to habitats, but the definition of "fully recovered" has not been agreed and the means of measuring it for ecosystem properties such as function and productivity, for non-target species and habitats, requires review. The criteria used in these tables should therefore be treated as "work-in-progress". We propose to begin the process of operationalising the tables through the case studies examined in 2009 (see Sections 6.4 and 6.5), but we also support an additional ToR to WGECO, where the broader issue of defining some of these key terms is addressed.

Target species

Here we define target species as those species that the fishing gear is directed at in the geographic area of interest. For example, in the North Sea this would be Plaice and Sole for beam trawls. All other species, regardless of their status as commercial species, should be treated as non-target species in assessing a particular fishing gear. All mortality to the target species is considered under impacts to target species (landings, discards and mortality in the path of the gear).

For target species, the terminology adopted is analogous to the current definition of F_{LIM} as used in fisheries management, for those stocks where an F_{LIM} is defined. We have adapted and used the broader terminology used in the FAO guidelines, as this is inclusive of all target species, some of which do not have defined limit reference points (Table 6.3.2.1). We have also applied a precautionary approach (and this is applied for all impact groups) for situations where a lack of information on population size and/or resilience is recorded.

Table 6.3.2.1 Criteria for identification of significant adverse impacts for target species (shellfish, fish, cephalopods, macrophytes).

CATEGORY	CRITERIA
No significant adverse impact	Long-term projections imply that population size and recruitment potential are not compromised.
Significant adverse impact	Affecting recruitment levels of stocks/or their capacity to increase such that the ability of affected populations to replace themselves is compromised. No information is available on resilience of the populations.

Non-target species and assemblages

For non-target species significant adverse impacts are identified where any species in the assemblage is deemed to be vulnerable to fishing such that mortality from the fishery is considered unsustainable given current practice (Table 6.3.2.2). Here, mortality should be interpreted as any mortality resulting from the fishery, including both mortality sustained in the catch and in the path of the gear (e.g. in the towpath of the gear on the seafloor, or after passing through the gear).

Vulnerability of species to particular fisheries is dependent partly on the likelihood of them suffering any mortality due to the fishery, and also on their sensitivity to the fishery. Sensitivity is itself a function of the resistance of the species to the fishery (its' gear and behaviour), and the resilience of the species to raised levels of mortality (ability to recover) (Bax and Williams, 2001; Zacharias and Gregr, 2005). There is much literature describing life history and ecological characteristics that are associated with high vulnerability to fisheries and these sources will be consulted by WGECO when applying this methodology in future meetings. We also recognise that there are two other sets of criteria that apply for significant adverse impacts to non-target species and assemblages; one that applies to protected species and those currently assessed to be at risk of extirpation, and another that follows the precautionary approach where limited information or understanding is encountered (Table 6.3.2.2).

Table 6.3.2.2 Criteria for identification of significant adverse impacts for non-target species and assemblages (benthos, fish, and cephalopods).

CATEGORY	CRITERIA
No significant adverse impact	For species previously identified as being vulnerable to fishing, mortality[1] is assessed as being sustainable for the population.
Significant adverse impact	For any species previously identified as being vulnerable to fishing, mortality is assessed as being unsustainable for the population. No information is available on resilience of species, or on mortality rates of the populations in this fishery. Where any population or species currently assessed to be at risk of extirpation, or otherwise specifically protected by legislation or regulation, suffers any mortality.

[1]Mortality here includes any mortality in the catch or in the path of the gear (includes on the seafloor and unaccounted mortality of animals passing through the gear).

Charismatic species (marine mammals, marine reptiles and seabirds)

For significant adverse impacts to charismatic species, we refer to the unacceptable levels that were defined in international agreements drawn up by ASCOBANS for marine mammals (Anonymous, 2000). These levels have been set for the amount of fishing mortality to a population from a defined geographic area from any one fishery (Anonymous, 2000; ICES, 2008). Although these levels exist for some marine mammals, WGECO are not aware of any existing corresponding levels for seabirds and marine reptiles. Equivalent measures will need to be discussed in future meetings where necessary for particular fishing gears. Again, a precautionary approach has been followed in dealing with situations where limited information or understanding is encountered (Table 6.3.2.3).

Table 6.3.2.3 Criteria for identification of significant adverse impacts for charismatic species (seabirds, marine mammals and marine reptiles).

CATEGORY	CRITERIA
No significant adverse impact	No/negligible impact to any population or species (for example, mortality below the unacceptable level[1]).
Significant adverse impact	Affecting the capacity of populations such that their ability to replace themselves is compromised. This point should be defined by the unacceptable level[1], where any mortality above the unacceptable level is deemed to cause a significant adverse impact. No information is available on resilience of species, or on mortality rates of the populations in this fishery. Where any population or species currently assessed to be at risk of extirpation, or otherwise specifically protected by legislation or regulation, suffers any mortality.

[1] The unacceptable level will depend on which component you are considering. For example, unacceptable levels have been defined for some species of marine mammals, such that in the OSPAR area the mortality rate can not be >1.7% of the population in any fishery (Anonymous, 2000).

Habitats

For habitats, criteria for significant adverse impacts were adapted from the FAO terminology about deterioration of productivity, and risk of permanent local loss. We added terminology on structure and function, as we recognised that these are equally important characteristics of a habitat and that long-term degradation of any of these aspects (productivity, structure or function) should be considered a significant adverse impact (Table 6.3.2.4). The FAO Guidelines (2008) identify serious adverse impacts to habitats as impacts where recovery takes longer than 5–20 years. Here assessing priorities for gear technologists to address should be based on impacts that are expected to persist several years or longer, with consideration of natural conditions that affect physical and biological processes. Again presence of features of habitats that are protected and/or currently assessed to be at risk of extirpation were also considered as criteria for significant adverse impacts, and the precautionary approach would be applied where limited information or understanding was encountered (Table 6.3.2.4).

Table 6.3.2.4 Criteria for identification of significant adverse impacts for habitats, incl. macrophytes and biogenic habitats (horse mussel beds, coral reefs etc.).

CATEGORY	CRITERIA
No significant adverse impact	Productivity, structure and function of natural habitats exposed to the gear (e.g. in the towpath or snagged damaged hauling or shooting the gear) have fully recovered[1] in 5-20 years, dependent on natural background conditions.
Significant adverse impact	Degrades the long-term productivity, structure and function of natural habitats, where long-term is interpreted as being greater than 5-20 years, dependent on natural background conditions. No information is available on habitat types in the area that the fishery operates in. Where any habitat currently assessed to be at risk of permanent local loss, or has features that are otherwise protected by legislation or regulation, suffers any damage or degradation of conservation status.

[1]Here we have adapted the terminology used in the FAO guidelines (FAO, 2008). Some of the terms used (e.g. fully recovered) are not clearly defined yet and it will be essential to complete those definitions before these tables can be made fully operational (see recommendations and ToRs for 2009).

6.4 The way forward

We have begun the process of developing a framework to identify methodologies to assess and quantify the efficacy of GBTMs introduced to reduce the environmental impact of fishing. We have provided an indicative methodology that identifies any significant adverse impacts of particular fishing gears that should then be considered in terms of planning experiments to develop suitable mitigation measures (Section 6.3). We recognise that this methodology will require trialling for existing fishing gears before it can be considered fully operational. In particular, the terminology used for the criteria that define significant adverse impacts may prove difficult to apply for some aspects of the ecosystem where it is currently poorly defined in the wider international literature. A separate ToR to WGECO for 2009 will be suggested to specifically consider some of these more theoretical concepts and their definitions. In parallel, we recommend a ToR where the current levels of impact of two fishing gears with very different environmental footprints are considered (see Section 6.5).

The fishing gears to be considered should be discussed with members of WGFTFB in preparing for the 2009 meeting, but it is recommended that one be a towed demersal gear and one a pelagic gear.

In Section 6.2 we outlined all the steps required in a framework to be used to assess the efficacy of GBTMs to reduce the environmental impact of fishing. Here we have detailed the methodology for the first Step, but following identification of the significant adverse impacts of any fishing gear being considered, it will then be necessary to consider whether mitigation of any of those impacts can be practically addressed by GBTMs (Step 2). In order to begin the process of documenting this, it is recommended that in 2009, WGFTFB list any existing and developing GBTMs for reduction of any impact for the interactions shown in Table 6.3.1.1. This should not be undertaken at the detailed level of listing every specific example for particular fisheries, but at a broad gear level such as 'escape panel' for marine reptile bycatch, or 'mesh size alteration' for decreasing discards of undersized target species.

Knowing which impacts can be addressed using GBTMs, the third step in the process should identify how gear technologists assess the reduction of direct effects in gear trials. As the second part of a ToR for WGFTFB in 2009, it is suggested that examples of assessment methods for different ecosystem component/fishing gear interactions are described. WGFTFB should also highlight where there are currently no examples of assessments of the change in impact following gear modification for particular ecosystem component/fishery interactions. For example, are differences in habitat impact currently assessed, and if so, how? The outcomes of this ToR from WGFTFB can then be discussed in collaboration with WGECO in the following year in terms of designing new methodologies where there are currently no existing methods or the methods are not deemed to be adequate.

Completing development of Steps 3–6 will require further collaboration between the WGs in the years to follow and the means to address this will be discussed in the 2009 meetings following completion of work on Steps 1–3.

6.5 Recommendations

In order to take this work forward through continuing collaboration between WGECO and WGFTFB, it is suggested that, as the next step, WGECO will develop further the methodology described in Section 6.3. A number of fishing gears will be used as examples in a specific area. It is envisaged that from 2010 onwards WGECO will complete descriptions of the significant adverse impacts of all the major gear categories operating in the ICES area over a number of successive meetings. These will need to be updated periodically.

6.5.1 ToR for WGECO in 2009

Using two existing fishing gear types, describe the significant adverse impacts of those gears for the ICES area, using the methodology developed by WGECO in 2008. Highlight issues that are specific to geographic areas and those that are generic to the gear. Based on this process recommend any modifications to the methodology required to make it operational.

6.5.2 ToR for WGFTFB in 2009

It is recommended that WGFTFB focus on further development of Steps 2 and 3 (as described in Section 6.4) in 2009. Specifically, it is recommended that the following ToR be set for WGFTFB in 2009:

Review the framework, developed by WGECO in 2008 to identify methodologies to assess and quantify the efficacy of gear-based technical measures introduced to reduce the environmental impact of fishing. List existing and developing gear-based technical measures (GBTMs) by category, for the known interactions between fishing gears and ecosystem components tabulated in Table 6.3.1.1 of the WGECO report 2008. For each ecosystem component listed in Table 6.3.1.1, describe examples of existing methodologies used to assess any effect of gear modifications and highlight where none exist.

6.5.3 Justification for both ToRs

On a request of WGFTFB, WGECO has initiated the process of developing a framework to assess the efficacy of gear-based technical measures (GBTMs) in 2008. The proposed ToRs for 2009 originate from the ongoing, mutual process of collaboration between both WGs. The exchange of expertise maximises the capability of ICES in assessing possible measures designed to reduce the ecosystem effects of fisheries. Development of the methodology needs an assessment of the current significant adverse impacts of a particular gear category for each ecosystem component in an ICES area, and a list of existing and developing GBTM's, which can practically address these impacts. WGECO has the expertise to address the first ToR, whereas WGFTFB has the experience for the latter. We recommend that at least one member of each WG attend the other WG to work on these collaborative ToRs.

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7 Assessment matrix of pressure of human activities and ecosystem components

ToR e) Building on previous work on ecosystem assessments during WGECO 2007 and OSPAR paper BDC 07/3/10-E, complete the process of scoring interactions between the pressure of human activities and ecosystem components, and plan the populating of cells in the assessment matrix with state or pressure indicators currently available or under development.

7.1 Preface

Previous attempts by WGECO and OSPAR to score the interactions between human activities and ecosystem components have struggled to consistently compare different pressures across very different components at different geographic scales. Determining how decisions on the level of interaction have been made has also been difficult due to their reliance on expert judgement without supporting justification. A risk-based approach has recently been developed by the University of Liverpool and Cefas for the JNCC (Robinson *et al.*, 2008). This approach specifically addresses the issues mentioned above by incorporating information on a component's resistance to a pressure (how much of the pressure it can withstand) and its resilience (its recovery rate) to specific pressures. The confidence of the assessment is also scored and is supported by a fully audited information trail. This methodology significantly advances the approaches used by OSPAR and WGECO in 2007, but requires substantially more information on the pressures acting in specific geographic areas and an agreement on suitable thresholds for the individual components (i.e. how much impact is acceptable) before it can be advanced further.

WGECO attempted to further populate the matrix using this risk-based approach but considered that the information requirements of the method were too great and the range of experts too restricted to attempt the assessment during this meeting. WGECO concluded that it was essential that threshold values for the components were identified before the assessment was conducted and that this would require a broad consultation with a wide body of experts and stakeholders. Information on the spatial and temporal distributions of pressures and components was also necessary to complete the assessment.

Analysis and discussion of this risk based ecosystem assessment is also underway within the OSPAR Biodiversity committee (OSPAR, 2008). Recommendations during their most recent meeting suggest that further elaboration of the table, and scoring of the cells, would be undertaken at a workshop during summer 2008. WGECO support the use of a workshop to assess a small number of ecosystem components in one OSPAR region to further develop the methodology and confirm whether it can be used to consistently assess the degree of impact. WGECO would like to contribute to future work in this area to avoid a separate, parallel work agenda with OSPAR.

7.2 Introduction

A tool which can be used to prioritise resources for effective monitoring and management of the marine environment is required urgently given the multiple national and international policy demands and the significant gaps in our current biodiversity monitoring efforts. Identifying the key pressures on marine ecosystem components will allow management action to focus on the most damaging activities and the ecosystem components that are most vulnerable to them.

7.2.1 Comparison of approaches

WGECO has been developing frameworks for the provision of integrated ecosystem management advice since 2005. Several other approaches have been developed in parallel since this time and a summary of these is shown in Table 7.2.1.

WGECO identified three different categories of assessment tool; those addressing the a) likelihood of impacts, b) level of impact, and c) rating both likelihood and impact and thus can be classified as risk based approaches (Table 7.2.1).

The OSPAR (BDC 07/3/10–E) was the only framework examined which used a likelihood model. This framework is used to address monitoring issues.

The approaches developed by WGECO (2007) and Halpern *et al.*, 2007 were considered impact models. WGECO developed a two-stage model to link human activities/threats to related pressures, and subsequently identified the ecosystem components impacted from the pressures in previous years (ICES 2005a, 2006). Halpern *et al.*, 2007 used 5 different response matrices to analyse the impact of a pressure on an ecosystem component. The advantages of this higher resolution are easy scaling to local and regional settings and easy updating of specific matrix entries according to new available information. The WGECO, 2007 risk based model incorporated only 2 out of 5 possible response matrices (Table 7.2.1).

The third type of model identified were risk based models which consider both the impact and likelihood of the impacts. Risk based approaches combine two terms, i.e. consequence or potential loss, and the likelihood of occurrence of the consequence or loss function. By definition an impact is the consequence (Burdge *et al.*, 2003), or response of a system to a threat (Halpern *et al.*, 2007). These authors define vulnerability as impact weighted by a measure of certainty. For reasons of simplicity, differences between impact and vulnerability are not distinguished any further.

The risk equation is simple:

Risk = consequence x probability of consequence

Fletcher, 2005 developed a structured approach to obtain quantitative risk categories for ecosystem components ('The Australian Approach'). Firstly, impact scores for ecosystem components were derived in terms of consequence levels during expert and stakeholder workshops. These consequence levels were diversified for 5 different types of ecosystem components. While diversifying, they took account of aspects of pressure intensity, frequency and extent on the ecosystem component (Fletcher, 2005), which implicitly links their approach to derive impact scores with the more formalized approach of Halpern *et al.*, 2007. To further evaluate the risk, the likelihood of pressure was estimated and multiplied by the consequence level. The resulting risk score was assigned to one of 5 risk categories, ranging from negligible to extreme.

Last year WGECO used a risk assessment model based on previous WGECO and OSPAR studies to investigate the interaction between 47 pressures and 15 ecosystem components (ICES, 2007a). It can be described as a model with 4 matrices, i.e. one each for human activities x pressure, pressure x ecosystem component by intensity, pressure x ecosystem component by spatial extent and pressure x ecosystem component by likelihood (Table 7.2.1).

Likelihood was coded in three ordinal levels:

- no impact likely

- impact possible
- impact likely

The consequence of having an impact was described in terms of intensity of impact on the ecosystem component and the spatial extent of this interaction, i.e.:

- acute vs. chronic
- local vs. widespread.

WGECO considered that the Robinson *et al.*, 2008 approach to prioritising the interactions between components and pressures was the most advanced of the techniques currently available and should be used to further populate the matrix.

Table 7.2.1 Impact assessment modelling within WGECO. Model components are either assigned to describing the impact or the likelihood. For risk assessment models, both descriptors of impact and of likelihood are required. P = pressure indicator, EC = ecosystem components'P matrix' indicates pressure matrix of human activities, 'response matrices' indicate impact components considered.

	Prior evaluation	ECs addressed	Derivation of scores through	Description of assessment model	
Likelihood model					
OSPAR 07 [1]		Species / species groups & Habitats	Expert judgement and literature review	LIKELIHOOD Likelihood matrix	P x EC by likelihood (not / possible / likely)
Impact models					
Halpern *et al.* (2007)		Habitats	Extended expert survey (> 100 participants)	IMPACT P matrix Response matrices (+confidence)	human activities x P P x EC by spatial overlap P x EC by frequency P x EC by intensity P x EC by functional impact P x EC by recovery potential
ICES 2005a/2006		Species / species groups & Habitats	Expert judgement and literature review	IMPACT P matrix Response matrix	human activities x P P x EC

	Prior evaluation	ECs addressed	Derivation of scores through	Description of assessment model	
Risk based assessment models					
The Australian Approach *inter alia* Fletcher (2005)		Species / species groups	Workshops with experts and stakeholders	IMPACT Response matrix LIKELIHOOD Likelihood matrix	P x EC_i by total impact (modifications for *i* categories of EC) Total impact implicitly takes account of intensity, frequency, overlap issues etc. P x EC_i by likelihood
ICES 2007 [2]		Species / species groups & Habitats	Expert judgement and literature review	IMPACT P matrix Response matrices LIKELIHOOD Likelihood matrix	human activities x P P x EC by spatial overlap P x EC by intensity P x EC by likelihood (no / possible / likely)
Robinson *et al.*– JNCC 2008 [3]	Thresholds matrix	Species / species groups & Habitats	Expert judgement and literature review	IMPACT P matrix Response matrices (+confidence) LIKELIHOOD Likelihood matrix	human activities x P P x EC by spatial overlap P x EC by intensity P x EC by frequency P x EC by recovery potential P x EC by exposure (yes / no)

[1] OSPAR BDC 07/3/10-E, [2] ICES CM 2007 / ACE:4, [3] Robinson *et al.*, (2008)

7.3 The Robinson *et al.*, 2008-JNCC approach

Robinson *et al.*, 2008 developed a risk based approach to prioritise the interactions between ecosystem components and pressures on behalf of the JNCC and based on previous WGECO and OSPAR work. The approach requires clear objectives and thresholds to mark the point at which an impact becomes unacceptable (e.g., sustainable use).

Ultimately, this assessment provides a priority code for management based on information on (a) the likelihood of a pressure causing a component to move beyond its threshold (dependent on the current level of resistance of the component and the degree of exposure to the pressure), and (b) the recovery time for the component to return to a level above the threshold (dependent on the component's current level of resilience). This method is based on the widely accepted concepts of sensitivity and vulnerability, and the principles of risk assessment. Confidence in each step of the assessment is rated and an overall confidence score given to each component/pressure interaction in the matrix.

7.3.1 Rationale of the method

The approach is based on the sensitivity of components to pressure and their exposure to those pressures.

Sensitivity is the degree to which a component responds to a pressure, and is a function of its resistance to a pressure (i.e., how much of the pressure it can withstand) and its inherent resilience (i.e., its recovery potential).

Vulnerability is the probability or likelihood that a component will be exposed to a pressure to which it is sensitive. When undertaking the assessment, the extent of spatial overlap between pressure and component would be assessed so that where there was no spatial overlap, there was no need to take the assessment any further.

Prioritising the interactions between different pressures and components is based on the likelihood of a pressure causing the component to move beyond its threshold, and the recovery time for the component to return to a level above the threshold (incorporating the sensitivity and vulnerability of a component to a specific pressure). Recovery time is a *relative* score and assumes that the pressure will be removed at the point at which the assessment is made. Priority is assessed as a category based on the resilience and resistance of a component to a pressure.

Thresholds are used to identify when the sustainability of the components becomes threatened. These thresholds provide a common standard against which the degree of impact can be assessed and ensure that the assessment is consistent across very different components. The thresholds are specific and measurable and based on internationally recognised acceptable limits for components, such as the precautionary biomass reference point (B_{pa}) for fish.

7.3.2 Methodology

The steps in the methodology are:

Starting point: Information requirements

It is essential that thresholds are agreed for each component, preferably with state and pressure indicators to support them. Information is required on the spatial and temporal distribution of the pressures, and their frequency and intensity, and the spatial and temporal distribution of the components. This information can be at a relatively coarse level of detail.

Step 1: Spatial overlap

Describe the degree of spatial overlap between the component and the pressure. If there is no overlap, there is no risk from the pressure (go to step 5); if there is a spatial overlap proceed to Step 2.

Confidence in the assessment undertaken in this step should be recorded; either as low or high. Note, if confidence in describing the spatial distribution of either the pressure or component is low, the confidence in this whole step is described as low.

Step 2: Selecting a resistance category (low or high)

The allocation of a resistance category (low or high) depends on the extent to which the component is resistant to a particular pressure. This should be assessed using existing data, evidence or judgement to determine resistance relative to the threshold values. This will require information on the spatial extent of the pressure and component (Step 1), the intensity and frequency of the pressure and the response of the component to the pressure.

Confidence in the assessment should be recorded as either low or high.

Step 3: Selecting a resilience category (none to high)

The current resilience of components should be assessed using existing data, evidence or judgement, based on their recovery time. Resilience is the time taken to move from the current status of the component to a point above the threshold level for that component.

Confidence in the assessment undertaken in completing this step should be recorded; either as low or high.

Step 4: Applying the resistance/resilience matrix

Having selected a resistance and resilience category for a particular component, it is then possible to select the appropriate combination of these for the described component and the specific pressure (Table 7.3.2.1).

Step 5: Selecting the priority score

Finally the priority score is completed using the outcome of Step 4, and the information on component/pressure combinations where there is no spatial overlap (Step 1), ('No need for review'), using Table 7.3.2.2.

Step 6: Confidence assessment

The number of low confidence scores are summed on completion of the assessment for a particular pressure/component combination. Where no lows are recorded the confidence assessment is very high (VH); one/three lows is high (H); two/three lows is moderate (M); and three/three lows equates to low confidence (L). An additional copy of the assessment matrix should then be completed to reflect the distribution of confidence scores amongst cells.

Table 7.3.2.1 Combined resistance and resilience categories for ecological components to define priority codes.

		RESISTANCE (TO SPECIFIC PRESSURE)	
		LOW	**HIGH**
RESILIENCE (recovery time)	**NONE**	LN	HN
	LOW	LL	HL
	MEDIUM	LM	HM
	HIGH	LH	HH

Table 7.3.2.2 Management priority codes given to each combination of resistance and resilience outputs, and the link to risk to sustainability of the components. Priority is in reference to the need for managers to review management of pressures and status of components.

VULNERABILITY	PRIORITY CODE	RISK TO SUSTAINABILITY OF COMPONENTS
no spatial overlap	no need for review (N)	limited or no risk
high resistance, high resilience (HH)	low priority, update when necessary (LU)	limited or no risk
high resistance, medium resilience (HM)	medium priority, update when necessary (MU)	risk of compromise to sustainability
low resistance, high resilience (LH)	medium priority, action to be taken (MA)	risk of compromise to sustainability
high resistance, low resilience (HL)	high priority, update when necessary (HU)	risk of compromise to sustainability
low resistance, medium resilience (LM)	high priority, action to be taken (HA)	risk of compromise to sustainability
high resistance, no resilience (HN)	urgent priority, update when necessary (UU)	risk of serious or irreversible harm
low resistance, low resilience (LL)	urgent priority, action to be taken (UA)	risk of serious or irreversible harm
low resistance, no resilience (LN)	urgent priority, action to be taken (UA)	risk of serious or irreversible harm

7.3.3 WGECO review of the risk based methodology

WGECO attempted to assess the effect of 53 pressures against the demersal fish component for the Greater North Sea using the method developed by Robinson *et al.*, 2008. After a lively discussion, the group decided that it was premature to conduct the assessment without further input from a wider body of expertise and stakeholders. It was considered essential to have:

- basic information and knowledge on all components and all pressures assessed (e.g. temporal and spatial distributions),
- agreement amongst scientists and customers on the thresholds for all components,

before the assessment was undertaken.

The Robinson *et al.*, 2008 approach was commended by WGECO for providing a consistent and transparent method to assessing pressures on ecosystem components which was a significant advance on existing techniques. The main advancements of this approach compared to the risk assessment model WGECO applied in 2007 (ICES, 2007a) were:

- An *a priori* evaluation of objectives for ecosystem components by means of a threshold matrix. This allows for the evaluation multiple impacts since each impact is assessed against the same threshold value. This is consistent with the corresponding step of work conducted in the "Australian Approach" during the performance report development of defining acceptable ranges of ecosystem performance.
- A description of the impact in terms of 4 explicit response matrices. Recovery potential for ecosystem components in relation to the pressure go into priority setting of the ecosystem component. Halpern *et al.*, 2007 have resolved impacts into 5 different response matrices, which is at present the most transparent approach. In the "Australian Approach", the responses are summarized into one matrix after accounting for issues of intensity, strength etc. Although it may be appealing to work with only one response work, the derivation of scores for this matrix is not likely as transparent as in the Halpern *et al.*, 2007 or Robinson *et al.*, 2008 approach.
- Confidence values are indicated for each assessment parameter. Halpern *et al.*, 2007 used confidence scores multiplied with the impact scores to obtain a weighted score for vulnerability. Robinson *et al.*, 2008 use the confidence value as a descriptive parameter for the risk score not involved in further calculations.

Stakeholder and expert participation is considered essential to score the pressure impacts, threshold values and confidence intervals (ICES, 2007b; Fletcher, 2005; Hobday *et al*., 2006; Halpern *et al*., 2007). SGRAMA (ICES, 2007b) identifies broad participation of all relevant groups as step 1 in an "ICES framework for risk assessment". WGECO concluded that it was premature to assess the interactions between pressures and components using the Robinson *et al*., 2008 methodology without further input from a wider body of expertise and stakeholders.

The assessment can be conducted for either an 'aggregate' component (i.e. an assessment applied to the whole component), or for a 'worst case' scenario (i.e. focusing on the most susceptible species/species group of that ecosystem component). The worst case scenario can be used as a substitute for individual taxa or habitats and removes the need to further expand the list of components assessed.

Although the approach has not yet been fully tested, it is conceivable that the results would not be replicated consistently due to the different opinions and knowledge levels of the experts undertaking the assessment (Rice and Rochet, 2005; Piet *et al*., in press). However, the use of an audit trail provides transparency in the decision making process which will explain any differences in expert opinion.

The approach does not prioritise components which are highly resistant and highly resilient to a pressure. Nor does it deal with the indirect effects of pressures.

7.3.4 The way forward

A number of issues have been identified which need to be addressed before the methodology can be made operational. WGECO identified the following steps:

1) Finalise the list of components and pressures

The matrix used by Robinson *et al.*, 2008 had 1648 combinations of components and pressures. This is a considerable number of combinations to assess and for which to identify indicators. The latest version of the matrix used by OSPAR has expanded considerably from last year and now includes a total of 2700 combinations as they increased their list of pressure/activity combinations to 94 (from 46) (OSPAR, 2008). The considerable effort required to assess even a fraction of these combinations means that it is essential that the list of components and pressures is finalised before the assessment process proceeds. WGECO recommend that the number of rows and columns are finalised and agreed.

WGECO considers that an active attempt should be made to rationalise (i.e. reduce) the rows and columns to make the task more tractable. Attempts to increase the number of combinations should be actively resisted.

2) Develop thresholds

It is essential that the thresholds for each component are agreed and finalised before any assessment is attempted. Some of the thresholds used by Robinson *et al.*, 2008 are preliminary and designed only for testing the method rather than direct application. Published studies show that the involvement of stakeholders and a large body of experts is required to develop and agree acceptable thresholds for components (Fletcher, 2005; Halpern *et al.*, 2007). This has also been suggested by Robinson *et al.*, 2008. The knowledge and value judgements required to parameterize the thresholds for each ecosystem component cannot be fully provided by WGECO as it must include a much wider body of opinion, including stakeholder groups.

3) Definitive methodology

WGECO find the Robinson *et al.*, 2008 approach logical but considered that further testing and assessment is required to finalise the methodology. This will need to occur on a regional basis and at different spatial scales to account for specific regional differences in exposure to pressures and ecosystem component abundance.

OSPAR have proposed a workshop in summer 2008 to trial the Robinson *et al.*, 2008 approach on a limited number of components in one OSPAR region (OSPAR, 2008) to further develop and test the methodology. The thresholds for each component assessed will need to be determined before the method is formally applied.

The components can be assessed an 'aggregated response' of a component to a pressure or the 'worst case scenario' which would consider those individual taxa within a component who would be particularly sensitive to a pressure.

7.4 Indicators

Many criteria and frameworks to select indicators have been proposed (e.g., Rice and Rochet, 2005; ICES, 2002; FAO, 1999; UNCSD, 2001). A key point in most of these works is that indicators have to be agreed upon because users have to understand and accept them. For example, Rice and Rochet, 2005 structured their framework as a sequence of eight steps: (1) determining user needs; (2) listing candidate indicators; (3) determining screening criteria; (4) scoring indicators against criteria; (5) summarizing scoring results; (6) deciding how many indicators are needed; (7) final selection; and (8) reporting.

The framework will be changed as soon as it is to be applied to a structured suite of indicators rather than an unstructured list (Rochet and Trenkel, in press). Some criteria might apply to individual indicators, while some others like cost and theoretical basis are better applied to the whole suite of indicators (Rochet and Trenkel, in press). Especially, the theoretical basis should include a consistency among indicators and the appropriate representation of causal relationships between pressures and impacts. Modified steps to select indicators presented in a matrix would now include: (1) determining user needs; (2) listing candidate indicators for each cell; (3) checking that proposed indicators address pressure-impact relationships; (4) determining and weighting screening criteria; (5) scoring proposed indicators against criteria, either individually or collectively depending on criteria; (6) final selection; and (7) reporting. Steps 1 to 5 are further examined below.

1) User needs are considered to be expressed by the priority matrix dealt with in the previous section. Here, indicators are identified for combinations of pressure and state (reflected in the different components) considered to be urgent or of a high priority by Robinson *et al*., 2008: as there were a total of 1648 combinations in the matrix it would not be reasonable to aim at identifying a single unique indicator for each cell. Moreover, as the priority matrix is not fully assessed yet, WGECO did not try to address the indicator selection for all high priority cells, but rather proposed the analysis of two single components: the demersal fish community and habitats as an exercise to demonstrate what will be necessary in the full analysis.

2) Much work has been performed on indicators of fishing impact and pressure (e.g., Rice, 2000; ICES, 2005b; Daan *et al*., 2005; Piet *et al*., 2007). Proposed lists based on these works are shown in Table 7.4.1.1 for demersal fish. There is a large body of information on indices of water quality which can be used for the water column habitats. ICES has contributed extensively to the development of these indicators. Fewer studies have been conducted on developing indicators for benthic habitats. BEWG has tested several indicators of benthic communities (e.g., AMBI) (ICES, 2007c) and whilst these may be considered a proxy for benthic habitats, there are very few indicators which consider the benthic habitat directly. A list of proposed indicators for benthic habitats and their proxies is shown in Table 7.4.1.2.

3) The first models which aim to analyse the relationship between pressure and state indicators have been developed which allows for an assessment of the sensitivity of fish community indicators to fishing pressures (Fulton *et al*., 2005; Pope *et al*., 2006; Hall *et al*., 2006). However, these results need to be refined, parameterized for specific case-studies, and validated empirically. The results of much theoretical and empirical ongoing work in various countries and EU-funded programmes (FLR project, ICES, 2008, IMAGE project) should be made available in the forthcoming months or years.

4) Determining and weighting screening criteria is highly a matter of preferences and is to be determined by the users. Attempts to have criteria weighted by experts showed that weights varied among individuals and stakeholder groups and proved difficult to explain with predictive criteria like area of expertise or geographic origin (Rochet and Rice, 2005; Piet *et al*., 2008). WGECO suggests that the 9 main criteria identified by Rice and Rochet, 2005, namely concreteness, theoretical basis, public awareness, cost, measurement, availability of historical data, sensitivity, responsiveness and specificity, be evaluated and weighted.

5) Results of indicator scoring exercises by expert surveys have shown that i) as for criteria weights, indicators scores vary among experts in relatively unpredictable ways ii) some criteria can be evaluated generally (e.g., theoretical basis, sensitivity), whereas some other will have site-specific scores (e.g., availability of historical data) (Rochet and Rice, 2005; Piet *et al*., 2008). These publications report average scores for some of the proposed indicators against the 9 criteria. The shift to a combined evaluation of an indicator matrix might change the scoring results. As the emphasis is on ensuring that the indicator suite addresses pressure-state relationships, the scoring exercise could probably be restricted to checking that the proposed indicators do not fail against any other major criterion (e.g., that cost is not too expensive or that users do not misinterpret the indicator).

Table 7.4.1.1 Demersal fish indicators for those combinations of pressure considered of urgent or high priority by Robinson *et al.*, 2008.

PRESSURE(S) AGAINST WHICH INDICATOR IS USED	MAIN ACTIVITIES CONTRIBUTING TO PRESSURE	INDICATOR	STATUS (IN USE, STATE NO. OF YEARS, UNDER DEVELOPMENT, UNDER CONSIDERATION, USED OUTSIDE UK	GEOGRAPHIC COVERAGE (LOCAL, COUNTRY, UK, EUROPE)	PARAMETER(S) MEASURED (INCLUDING UNITS OF MEASURE)	DESCRIPTION (PURPOSE AND APPLICATION)	EFFECTIVENESS OF INDICATOR TO ADDRESS IMPACT (E.G. DIRECTLY EFFECTIVE, INDIRECTLY EFFECTIVE, INEFFECTIVE). GIVE REASONS.	SOURCE (POLICY DRIVERY, REFERENCE)
Habitat loss (to land)	Coastal infrastructure - defence & land claim	% key habitat loss (spawning grounds / nurseries)	To be developed. Requires fine habitat mapping with delineation of nurseries and spawning grounds	Local	Habitat surface area; lost surface area	To monitor the loss of key habitat due to coastal infrastructure		
Habitat structure changes	Sand & gravel extraction	% key habitat loss (spawning grounds / nurseries)	To be developed. Requires fine habitat mapping with delineation of nurseries and spawning grounds	Local	Habitat surface area; lost surface area	To monitor the loss of key habitat due to gravel extraction		
Siltation (turbidity) changes	Sand & gravel extraction	Local change in growth or mortality rates	To be developed	Local		To monitor changes in biological parameters due to gravel extraction		
Electromagnetic changes	Cables	Local change in growth or mortality rates	To be developed	Local		To monitor changes in biological parameters due to underwater cables		

PRESSURE(S) AGAINST WHICH INDICATOR IS USED	MAIN ACTIVITIES CONTRIBUTING TO PRESSURE	INDICATOR	STATUS (IN USE, STATE NO. OF YEARS, UNDER DEVELOPMENT, UNDER CONSIDERATION, USED OUTSIDE UK	GEOGRAPHIC COVERAGE (LOCAL, COUNTRY, UK, EUROPE)	PARAMETER(S) MEASURED (INCLUDING UNITS OF MEASURE)	DESCRIPTION (PURPOSE AND APPLICATION)	EFFECTIVENESS OF INDICATOR TO ADDRESS IMPACT (E.G. DIRECTLY EFFECTIVE, INDIRECTLY EFFECTIVE, INEFFECTIVE). GIVE REASONS.	SOURCE (POLICY DRIVERY, REFERENCE)
Emergence regime changes (inc. desiccation) - local	Coastal infrastructure - barrages	Local change in growth or mortality rates	To be developed	Local		To monitor changes in biological parameters due to coastal infrastructures		
Salinity changes - local	Coastal infrastructure - barrages, causeways, weirs, sluices	Local change in growth or mortality rates	To be developed	Local		To monitor changes in biological parameters due to coastal infrastructures		
Temperature changes - local	Power stations	Local change in growth or mortality rates	To be developed	Local		To monitor changes in biological parameters due to power stations		
Water flow (tidal currents) rate changes - local	Water abstraction (freshwater catchment)	Local change in growth or mortality rates	To be developed	Local		To monitor changes in biological parameters due to water abstraction		
Radionuclide contamination	Power stations - nuclear	Rate of radionuclide contamination in seafood	To be developed	Local		To monitor radionuclide contamination in seafood		EC Shellfish Hygiene Directive EC Food Hygiene Regulations

PRESSURE(S) AGAINST WHICH INDICATOR IS USED	MAIN ACTIVITIES CONTRIBUTING TO PRESSURE	INDICATOR	STATUS (IN USE, STATE NO. OF YEARS, UNDER DEVELOPMENT, UNDER CONSIDERATION, USED OUTSIDE UK	GEOGRAPHIC COVERAGE (LOCAL, COUNTRY, UK, EUROPE)	PARAMETER(S) MEASURED (INCLUDING UNITS OF MEASURE)	DESCRIPTION (PURPOSE AND APPLICATION)	EFFECTIVENESS OF INDICATOR TO ADDRESS IMPACT (E.G. DIRECTLY EFFECTIVE, INDIRECTLY EFFECTIVE, INEFFECTIVE). GIVE REASONS.	SOURCE (POLICY DRIVERY, REFERENCE)
Barrier to species movement	Coastal infrastructure - barrages, causeways, weirs, sluices	Proportion of escapement	To be developed. Needs an estimate of movement prior to barrier settlement	Local	Number of fish migrating prior/after barrier settlement	To monitor movement impediment caused by coastal infrastructure		
Removal of non-target species	Fishing - benthic trawling	% catch discarded; Survey-based population indicators for non-target species (length, abundance); Survey-based community indicators (length, abundance, proportion of target species)	Developed	Shelf or coastal ecosystem	Number & length of fish caught/discarded onboard commercial vessels; number & length of catch in trawl surveys	To monitor the pressure and impact of benthic trawling on non-target species	Survey-based indicators have a good potential to measure the effects of fishing on fish populations and communities (Rochet & Trenkel, 2003, Link et al, 2002); specific applications have already been developed for populations (Trenkel et al, 2007) and communities (Rochet et al, 2005).	CFP

PRESSURE(S) AGAINST WHICH INDICATOR IS USED	MAIN ACTIVITIES CONTRIBUTING TO PRESSURE	INDICATOR	STATUS (IN USE, STATE NO. OF YEARS, UNDER DEVELOPMENT, UNDER CONSIDERATION, USED OUTSIDE UK	GEOGRAPHIC COVERAGE (LOCAL, COUNTRY, UK, EUROPE)	PARAMETER(S) MEASURED (INCLUDING UNITS OF MEASURE)	DESCRIPTION (PURPOSE AND APPLICATION)	EFFECTIVENESS OF INDICATOR TO ADDRESS IMPACT (E.G. DIRECTLY EFFECTIVE, INDIRECTLY EFFECTIVE, INEFFECTIVE). GIVE REASONS.	SOURCE (POLICY DRIVERY, REFERENCE)
Removal of target species	Fishing - set netting	Fishing mortalityStock status (e.g. proportion of stocks harvested sustainably or at MSY)	In use	Stock area	Same + catch & effort statistics	To monitor the pressure and impact of set netting on target species	In use for years in the CFP and elsewhere	CFP

Table 7.4.1.2 Benthic habitat indicators for those combinations of pressure considered of urgent or high priority by Robinson *et al.*, 2008.

PRESSURE(S) AGAINST WHICH INDICATOR IS USED	MAIN ACTIVITIES CONTRIBUTING TO PRESSURE	INDICATOR	STATUS (IN USE, STATE NO. OF YEARS, UNDER DEVELOPMENT, UNDER CONSIDERATION, USED OUTSIDE UK	GEOGRAPHIC COVERAGE (LOCAL, COUNTRY, UK, EUROPE)	PARAMETER(S) MEASURED (INCLUDING UNITS OF MEASURE)	DESCRIPTION (PURPOSE AND APPLICATION)	SOURCE (POLICY DRIVERY, REFERENCE)	IMPACT(S) FOR WHICH INDICATOR IS USED
Removal of non-target species; physical damage	Fishing, benthic trawling	Abundance of sensitive benthos species	under consideration	local	Abundance	To monitor changes in abundance	STECF SEC(2004)29; OSPAR 06/6/2	Benthos
Removal of non-target species; physical damage	Fishing, benthic trawling	%Area coverage of highly sensitive habitats (e.g. reefs, mussel beds)	To be developed ; requires high resolution habitat mapping	local	Area	To monitor the loss of habitat	STECF SEC(2004)29	Benthic habitat

PRESSURE(S) AGAINST WHICH INDICATOR IS USED	MAIN ACTIVITIES CONTRIBUTING TO PRESSURE	INDICATOR	STATUS (IN USE, STATE NO. OF YEARS, UNDER DEVELOPMENT, UNDER CONSIDERATION, USED OUTSIDE UK	GEOGRAPHIC COVERAGE (LOCAL, COUNTRY, UK, EUROPE)	PARAMETER(S) MEASURED (INCLUDING UNITS OF MEASURE)	DESCRIPTION (PURPOSE AND APPLICATION)	SOURCE (POLICY DRIVERY, REFERENCE)	IMPACT(S) FOR WHICH INDICATOR IS USED
De-oxygenation	Nutrient enrichment	%Area coverage of depopulated areas	under consideration	local	Area	To monitor changes in abundance	OSPAR 06/6/2	Benthos
De-oxygenation	Nutrient enrichment	Changes in zoobenthos community structure in relation to eutrophication	under consideration; requires time series to identify trends	local	Abundance, AMBI*	To monitor changes in abundance	ICES CM 2007/MHC:10, OSPAR 06/6/2	Benthos
Hydrocarbon contamination	Oil and gas industry	Changes in zoobenthos community structure	tested, widely in use; requires time series to identify trends	local	AMBI*	To monitor changes in abundance	ICES CM 2007/MHC:10	Benthos
Heavy metal pollution	Land-based pollution	Changes in zoobenthos community structure	tested, widely in usetested, widely in use; requires time series to identify trends	local	AMBI*	To monitor changes in abundance	ICES CM 2007/MHC:10	Benthos
De-oxygenation	Aquaculture	Changes in zoobenthos community structure in relation to eutrophication	tested, widely in use; requires time series to identify trends	local	Abundance, AMBI*	To monitor changes in abundance	ICES CM 2007/MHC:10, OSPAR 06/6/2	Benthos

PRESSURE(S) AGAINST WHICH INDICATOR IS USED	MAIN ACTIVITIES CONTRIBUTING TO PRESSURE	INDICATOR	STATUS (IN USE, STATE NO. OF YEARS, UNDER DEVELOPMENT, UNDER CONSIDERATION, USED OUTSIDE UK	GEOGRAPHIC COVERAGE (LOCAL, COUNTRY, UK, EUROPE)	PARAMETER(S) MEASURED (INCLUDING UNITS OF MEASURE)	DESCRIPTION (PURPOSE AND APPLICATION)	SOURCE (POLICY DRIVERY, REFERENCE)	IMPACT(S) FOR WHICH INDICATOR IS USED
temperature	Climate Change	Shifts in distribution ranges of Megalurops agilis and Amphiura brachiata	under consideration	regional	Distribution range	extension of distribution ranges	ICES CM 2007/MHC:10	Benthic species
Introduction of non-indigeneous species	Aquaculture, Shipping	Shifts in distribution ranges	under consideration	regional	Distribution ranges of non-indigeneous species	extension of distribution ranges	ICES CM 2007/ACME:5	Benthic species
De-oxygenation	Nutrient enrichment	Redox potential discontinuity	tested; requires time series to identify trends	regional	RPD profile	Measurement of RPD layer	Nilsson and Rosenberg (1997) J. Mar Systems 11, 249-264	Benthic habitats
Hydrocarbon								
contamination	Oil and gas industry	Polycyclic aromatic hydrocarbons in sediments	tested, background concentrations available	local, regional	standardised concentration	Measurement of concentration	ICES CM 2007/ MHC:05	Benthic habitats

7.5 Recommendations

WGECO support OSPAR's proposal for a workshop in summer 2008 (OSPAR, 2008) to assess a small number of ecosystem components in one OSPAR region to further develop the methodology and confirm whether the methodology can be used to consistently assess the degree of impact. WGECO would like to be involved in the workshop and future OSPAR research in this area to avoid developing separate, parallel work agendas.

7.6 Acknowledgements

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8 Recommendations for developing capacity within ICES

Overall, the ICES process worked very poorly in coordinating the scientific expertise and resources of ICES in addressing the request from OSPAR for a summary of the evidence regarding the impacts of climate change on marine ecosystems in the OSPAR area. Over the past two years a number of Expert Groups were given and responded to Terms of Reference related to this request. Both WGECO and ACE reviewed progress in spring of 2007, evaluated strengths and weaknesses in the interim products available, and tried to implement course corrections to address the weaknesses. Nonetheless, by the time WGECO met to consolidate input from the various expert groups, all it had to work with were widely diverse and almost completely narrative input, which proved very difficult to weave into the type of convincing meta-analysis that characterised the outstanding 2007 IPCC report on the evidence for climate change and its impacts on global and to some extent regional scales. A substantial request such as the OSPAR climate change work depends almost entirely on the provision of standardised material from diverse ICES groups. In the short time available to WGECO, with other important priorities to address, the opportunity to undertake new collation and interpretation was limited. This was a major failing by ICES.

It was impossible to address some components of this Term of Reference at all. In particular it was not possible to provide feedback to WGOH on what oceanographic products were of most value in answering the OSPAR request. Although some individuals at WGECO made use of some of the oceanographic products of WGOH, there is little evidence that any of the other Expert Groups looked seriously at the recent WGOH reports, wherein they describe the operational oceanographic products that could be produced for use in exactly this kind of large scale and integrated study. Rather, to the extent that many of the Expert Groups used hydrographic data at all, it seems that they used whatever data a given participant in the Expert Group was aware of, and might have had a history of working with. This is far from making best use of the intellectual resources and diverse expertise of ICES.

The problem was much larger than just ineffective use of products among different Expert Groups. Recognising that individual Expert Groups worked hard on their ToRs, nevertheless, the majority of Expert Groups feeding into this process did not produce the products that were needed to synthesise an integrated product to address the request from OSPAR. There is opportunity to spread the blame for this failure widely between those coordinating the process, and those participating in it. It is clear that when one Expert Group is expected to produce a product that will be used by another Expert Group, the associated Term of Reference(s) must be written in far more prescriptive and directive language. It is possible that dummy examples of *exactly* what is required would have to be provided to each contributing Expert Group, to ensure that there is no misunderstanding about what is wanted. This is an unfortunate necessity, because it greatly limits the group in ICES with the most expertise in a particular area to use that expertise creatively and fully in addressing these major requests. However, the evidence is overwhelming; both in this case in other cases such as the REGNS initiative and other undertakings by groups like WGECO and WGRED which have integrated mandates, that individual Expert Groups quickly develop not only their own subject-matter expertise but their own culture as well. As a result, Expert Groups then interpret even common Term of References into their own cultures, answer them within the cultural context which each group has developed rather than in the context in which the product will be used, and produce products that reflect each groups' own culture. These group-specific products at best can be stacked in a pile and stapled together. This makes the final ICES product simply independent chapters with a staple through the pile, rather than a product that is integrated, synthesised, and has a high value added from the breadth of ICES expertise.

Several options are available for addressing this problem within the ICES process, but there is little reason for optimism that any of them will succeed.

1. Much more effort can be put into drafting highly directive and restrictive Terms of Reference. The Expert Group would receive the equivalent of a table into which it simply enters the correct values, and even the specific algorithms to derive the individual estimates. This would result in the desired consistency of products. However this type of strategy has not even worked across fisheries assessment Expert Groups, where data and analytic methods are much more standardized than in most ecological applications. In addition it would make the members of the Expert Group into little more than technicians, allowing little scope for the Expert Group members to apply their knowledge or creativity to the larger problem, and there is a risk the members would simply not consider such a restricted role to be worth their best effort (and possibly any effort at all).
2. Develop new Steering Committees for these multi-group integrated products, with membership from all the key Expert Groups that must contribute. This would ensure that a participant in each Expert Group would have a working knowledge of exactly how the product(s) was going to be used. Conceptually, this should increase the likelihood that the individual Expert Groups would produce their products in the forms needed by the other parts of ICES, but that was not the experience with the REGNS integrated assessment initiative. They had adopted exactly this model and found the Expert Groups were simply unwilling to devote time to producing "service products", if these preparation of such products took more than a small amount of time.
3. Develop a special Expert Group that is empowered to actually do each major integrative task from start to finish. The make-up of that Expert Group would have to be similar to option 2, but the membership would be larger and they would probably meet more often and for longer periods each time. They would use the various disciplinary Expert Groups for review of their work, guidance on data quality and access, but would not rely on the other Groups to product the necessary products for them. This might have a higher likelihood of producing a comprehensive and well-integrated product, but would take a major commitment of time from high-end experts working under the ICES banner. There would also be financial implications of experts required to attend both their 'home' expert group, and such special coordinated groups. This bring us to the underlying problem with ICES capability to undertaken these types of comprehensive and integrated advisory or information-providing tasks.

In discussions within WGECO regarding this problem, many participants from European laboratories made essentially the same observation. Given the dependency of research centres on bringing in external funding, they would never be given the time to be part of such an ICES coordinated Expert Group, if such participation required more than attendance at occasional Expert Group meetings. The message was "Make it a project, make us the researchers on the project, get it funded, and *then* I could work on it. Otherwise, don't make plans for initiatives that involve original work." Perhaps the role of ICES with regard to original work in support of advisory needs has become solely as peer review of work done by EU and other major projects, and not a group that people go to when something new and original needs to be done. That would be a major loss for ICES, but may reflect the reality of research funding in the member States and their national laboratories and universities.

ICES is not completely incapable of having a role in progressing the knowledge basis for advisory products. It has succeeded in making headway on management strategy evaluations and revisions of the precautionary framework in support of fisheries advice. This may mean that the fisheries science community is just more dedicated than the ecological science community, they are supported by greater political interest in their field, or that they simply have a narrower set of problems to address. However, efforts do not seem to be made with equal enthusiasm when the issues are ecosystem issues rather than fisheries issues. If this reflects the priorities of ICES and the member States that is their choice. However, the impression given that the Ecosystem Approach is important to the Member States, the ICES advisory clients, and ICES itself should be replaced by a more honest view-especially if it cannot be supported to a level that allows much meaningful new work to be undertaken within the ICES advisory framework.

Annex 1: List of participants

Name	Address	Phone/Fax	Email
Brander, Keith	The National Institute of Aquatic Resources Department of Sea Fisheries Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 61437545	keith@ices.dk kbr@aqua.dtu.dk
Depestele Jochen	Institute for Agricultural and Fisheries Research Ankerstraat 1 B-8400 Ostende Belgium	Phone +32 595 69 838	jochen.depestele@ilvo.vlaanderen.be
Dommasnes, Are	Institute of Marine Research P.O. Box 1870 N-5817 Bergen Norway	Phone 55238402	are.dommasnes@imr.no
Fock, Heino	Federal Research Centre for Fisheries Institute for Sea Fisheries Palmaille 9 D-22767 Hamburg Germany	Phone +49 40 38905 266 Fax +49 40 389 05 263	heino.fock@vti.bund.de
Frid, Chris	School of Biological Sciences University of Liverpool Crown Street L69 7ZB Liverpool United Kingdom	Phone +44 151 7954382 Fax +44 1517954404	c.l.j.frid@liv.ac.uk
Greenstreet, Simon P.R.	Fisheries Research Services FRS Marine Laboratory P.O. Box 101 AB11 9DB Aberdeen United Kingdom	Phone +44 1224 295417 Fax +44 1224 295511	S.Greenstreet@MARLAB.AC.UK
Johannesen, Ellen Observer	Roskilde University. Roskilde, Denmark	+45 6014 5310	eljo@ruc.dk

Name	Address	Phone/Fax	Email
Kenchington, Ellen L. Chair	Fisheries and Oceans Canada Bedford Institute of Oceanography P.O. Box 1006 Dartmouth NS B2Y 4A2 Canada		kenchingtone@mar.dfo-mpo.gc.ca
Link, Jason Correspondence	USA		
Lynam, Chris	The Marine Institute Rinville, Oranmore Co. Galway Ireland	Phone +353 Fax +353	chris.lynam@marine.ie
Paramor, Odette A.L.	University of Liverpool Crown Street L69 7ZB Liverpool United Kingdom		o.a.l.paramor@liv.ac.uk
Piet, Gerjan	IMARES, Wageningen UR P.O. Box 68 NL-1970 AB IJmuiden Netherlands	Phone +31 (0)255 564646 Fax +31 (0)255 564644	Gerjan.Piet@wur.nl
Rice, Jake C.	Fisheries and Oceans Canada 200 Kent Street Ottawa ON K1A OE6 Canada	Phone +1 613 990 0288 Fax +1 613 954 08 07	ricej@dfo-mpo.gc.ca
Rihan, Dominic	Irish sea Fisheries Board P.O. Box 1 Dun Laoghaire Co. Dublin Ireland	Phone +353 1 2841544 Fax +353 1 2300564	Rihan@bim.ie
Robinson, Leonie	School of Biological Sciences University of Liverpool Crown Street L69 7ZB Liverpool United Kingdom	Phone +44 151 795 4387 Fax +44 151 795 4404	Leonie.Robinson@liverpool.ac.uk
Rochet, Marie-Joelle	IFREMER Nantes Centre Dept. EMH P.O. Box 21105 F-44311 Nantes Cédex 03 France	Phone +33 2 40 37 41 21 Fax +33 2 40 37 40 75	Marie.Joelle.Rochet@ifremer.fr

Name	Address	Phone/Fax	Email
Rogers, Stuart I.	Centre for Environment, Fisheries & Aquaculture Science Lowestoft Laboratory Pakefield Road NR33 0HT Lowestoft Suffolk United Kingdom	Phone +44 1502 562244 Fax +44 1502 513865	stuart.rogers@cefas.co.uk
Scott, Catherine L.	University of Liverpool Crown Street L69 7ZB Liverpool United Kingdom	Phone 151 7954382	c.l.scott1@liverpool.ac.uk
Skagseth, Øystein	Institute of Marine Research Norway	Phone +47 55 23 85 73	oystein.skagseth@imr.no
Kirk Sørensen, Thomas	The National Institute of Aquatic Resources Department of Sea Fisheries Charlottenlund Slot Jægersborg Alle 1 DK-2920 Charlottenlund Denmark	Phone +45 33963374	tks@aqua.dtu.dk
Tasker, Mark	Joint Nature Conservation Committee Dunnet House 7 Thistle Place AB10 1UZ Aberdeen United Kingdom	Phone +44 1 224 655 701 Fax +44 1 224 621 488	mark@ices.dk
Vazquez, Antonio	Instituto de Investigaciones Marinas - CSIC Eduardo Cabello 6 E-36208 Vigo Spain		avazquez@iim.csic.es
Winrow-Giffin, Alex	University of Liverpool Crown Street L69 7ZB Liverpool United Kingdom		alexwg@liv.ac.uk

Annex 2: WGECO Terms of Reference for 2008

2007/2/ACOM41

The **Working Group on Ecosystem Effects of Fishing Activities** [WGECO] (Chair: Ellen Kenchington, Canada) will meet at ICES Headquarters, Copenhagen, for 8 days from 6–13 May 2008 to:

a) review and integrate the contributions of WGITMO, WGLESP, WGZE, BEWG, WGFE, WGSE, WGMME, WGOH, WGECO to 'the 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', based on the recommendations of the Ad Hoc/Study groups on:

- Hydrographic Attributes
- Trend Analyses and Quantifying Relationships (SGSMACCC)
- Formulating Hypotheses and Predictions about Mechanisms (SGWRECC)
- Selecting Species for More Intensive Investigations
- and provide a draft final report for OSPAR;

b) prepare a draft final assessment of the environmental impact of marine fisheries as a contribution to the Quality Status Report 2010, with reference to the scoping report completed by WGECO in 2007;

c) review the progress made by WGSAM and WGFE in modelling management action (range of demersal community average fishing mortality), and associated timescales involved, to achieve the Fish Community EcoQO target of "The proportion (by weight) for fish greater than 40 cm in length should be greater than 0.3" (with a ±10% range in target values). Consider the results of the analyses undertaken by these two WGs and carry out any additional analysis or modelling required so as to complete the matrix below, which could then be used as the basis for the provision of advice to meet the EcoQO target.

Fishing mortality averaged across the seven main demersal species (cod, haddock, whiting, saithe, sole, plaice, Norway pout)	EcoQO Indicator Proportion (by weight) of fish > 40cm in length	Time to reach Indicator target
$0.85F_{pa}$	0.27	?
	0.30	?
	0.33	?
$1.00F_{pa}$	0.27	?
	0.30	?
	0.33	?
$1.15F_{pa}$	0.27	?
	0.30	?
	0.33	?

d) begin the process of developing a framework to identify methodologies to assess and quantify the efficacy of gear-based technical measures introduced to reduce the environmental impact of fishing.

e) building on previous work on ecosystem assessments during WGECO 2007 and OSPAR paper BDC 07/3/10-E, complete the process of scoring interactions between the pressure of human activities and ecosystem components, and plan the populating of cells in the assessment matrix with state or pressure indicators currently available or under development;

f) based on the process undertaken to produce the draft report described at a), make recommendations for developing capacity within ICES to monitor change and use statistical tools in relation to hydrographic change and requests in similar areas;

WGECO will report by 15 May 2008 for the attention of ACOM.

Supporting information

PRIORITY:	HIGH.
Scientific Justification and relation to Action Plan:	a) Completion of a requested two-year process in ICES to provide a background document on effects of hydrographic change for OSPAR's QSR 2010. b) Response to a request to ICES to provide a background document on effects of fishing for OSPAR's QSR 2010. c) For several years ICES has undertaken detailed evaluation of size-based metrics of fish populations, in support of management processes including the EcoQO framework of OSPAR. This builds on work in WGECO 2007 and uses results from two other expert groups to further develop the use of size based indicators of fish as performance metrics. d) request from WGFTFB, part of developing ICES capacity for advice on the ecosystem effects of fishing gears, e) There are currently no clear management frameworks within Europe which clearly and simply link the work of OSPAR to develop the EcoQO process with the objectives that underpin the developing Marine Strategy and the ecosystem-based approach to fisheries management. This ToR will further develop the simplified framework begun by WGECO in 2007, to deliver a framework that is acceptable both within national governments and in EU and OSPAR. f) The process of generating the response to the OSPAR climate change request has revealed that ICES has limited capacity in this area. This work will be considered by ConC as part of their work in improving the capacity of ICES.
Resource Requirements:	None
Participants:	Approximately 20-25. Wide ranging expertise on fisheries effects and ecosystem components required. Also familiarity with EU and OSPAR marine strategies.
Secretariat Facilities:	A large meeting room and secretariat support are required.
Financial:	None.
Linkages to Advisory Committees:	ACOM.
Linkages to other Committees or Groups:	WGFE, WGDEC, WGMME, WGSE, BEWG, WGSAM.
Linkages to other Organisations:	OSPAR, EC.

Annex 3: WGECO terms of reference for the next meeting

The **Working Group on Ecosystem Effects of Fishing Activities** [WGECO] (Chair: E. Kenchington, Canada) will meet in Copenhagen, Denmark from 1–8 April 2009 or 15–22 April 2009[1] to:

a) Define and demonstrate with selected case studies / examples the practical interpretation of the high level terminology used in the international agreements on managing marine ecosystems. Specifically these should include the broad ecosystem management concepts ‘significant adverse impacts’, ‘vulnerable marine ecosystems’, and ‘good environmental status’. This should include explicit consideration of reference conditions, thresholds and recovery rates, in relation to both ecosystem structure and function;

b) Using two existing fishing gear types, describe the significant adverse impacts of those gears for the ICES area, using the methodology developed by WGECO in 2008. Highlight issues that are specific to geographic areas and those that are generic to the gear. Based on this process recommend any modifications to the methodology required to make it operational.

WGECO will report by 15 May 2009 to the attention of the Advisory Committee.

[1] One quarter of the core members of WGECO are academics and for them to participate our meeting must be held either the week before or the week after the Easter weekend. This also gives us more time to finalize the report.

Supporting Information

Priority:	The current activities of this Group will lead ICES into issues related to the ecosystem affects of fisheries, especially with regard to the application of the Precautionary Approach. Consequently, these activities are considered to have a very high priority.
Scientific justification and relation to action plan:	Action Plan No: 1. Term of Reference a) The recent development of high level agreements by FAO, EU Maritime Strategy and IUCN have highlighted the need for a clear understanding of some broad ecosystem management concepts such as 'significant adverse impacts', 'vulnerable marine ecosystems', and 'good environmental status'. Without a clear understanding of how these can be practically interpreted and applied consistently across national boundaries, progress with the achievement of these important international commitments will be slow. WGECO have a history of working to integrate across many ecosystem components and from different national perspectives, and would welcome the opportunity to apply their knowledge to this important issue. Term of Reference b) On a request of WGFTFB, WGECO has initiated the process of developing a framework to assess the efficacy of gear-based technical measures (GBTMs) in 2008. The proposed ToRs for 2009 originate from the ongoing, mutual process of collaboration between both WGs. The exchange of expertise maximises the capability of ICES in assessing possible measures designed to reduce the ecosystem effects of fisheries. Development of the methodology needs an assessment of the current significant adverse impacts of a particular gear category for each ecosystem component in an ICES area, and a list of existing and developing GBTM's, which can practically address these impacts. WGECO has the expertise to address the first ToR, whereas WGFTFB has the experience for the latter.
Resource requirements:	None anticipated with the present ToR but may be required if additional ToR are brought forward
Participants:	The Group is normally attended by some 20–25 members and guests.
Secretariat facilities:	Assistance with editing of report and with logistics of the meeting.
Financial:	No financial implications.
Linkages to advisory committees:	There are no obvious direct linkages with the advisory committees.
Linkages to other committees or groups:	There is a strong link with WGFTFB in a common ToR. We may also have links with WGQAF.
Linkages to other organizations:	The work of this group is closely aligned with similar work undertaken by OSPAR in some areas.

Annex 4: Recommendations

We suggest that each Expert Group collate and list their recommendations (if any) in a separate annex to the report. It has not always been clear to whom recommendations are addressed. Most often, we have seen that recommendations are addressed to:

- Another Expert Group under the Advisory or the Science Programme;
- The ICES Data Centre;
- Generally addressed to ICES;
- One or more members of the Expert Group itself.

RECOMMENDATION	FOR FOLLOW UP BY:
1. Arising from ToR d): WGECO recommends that it further collaborates with WGFTFB to develop the methodology to investigate the interactions between fishing gears and ecosystem components. WGECO has developed a term of reference for each of these groups: 1) For WGECO 2009 *Using two existing fishing gear types, describe the significant adverse impacts of those gears for the ICES area, using the methodology developed by WGECO in 2008. Highlight issues that are specific to geographic areas and those that are generic to the gear. Based on this process recommend any modifications to the methodology required to make it operational.* 2) For WGFTFB 2009 *Review the framework, developed by WGECO in 2008 to identify methodologies to assess and quantify the efficacy of gear-based technical measures introduced to reduce the environmental impact of fishing. List existing and developing gear-based technical measures (GBTMs) by category, for the known interactions between fishing gears and ecosystem components tabulated in Table 6.3.1.1 of the WGECO report 2008. For each ecosystem component listed in Table 6.3.1.1, describe examples of existing methodologies used to assess any effect of gear modifications and highlight where none exist.*	WGECO, WGFTFB
2. Arising from ToRb): WGECO recommends that ICES task the WGSE, WGAGFM and the SGFIAC with providing the necessary information on the impacts of fisheries on seabirds and genetic diversity to complete the advice requested by OSPAR for the 2010 QSR.	ICES WGAGFM, SGFIAC WGSE

Recommendation	For follow up by:
3. Arising from ToRc): WGECO recommends that an ICES Study Group is established to further the development of the EcoQO on changes in the proportions of large fish in the North Sea. ICES in 2007 advised that the proportion (by weight) of fish greater than 40 cm in length should be greater than 0.3, based on the ICES Q1 IBTS survey series. WGECO considers that, both the individual stock objectives (keeping $F<F_{PA}$ and $B>B_{PA}$) and the Fish Community EcoQO should be met. Currently it is not known whether fishing each of the commercial stocks at F_{PA} is sufficient to ensure that the Fish Community EcoQO will be met, or whether additional management intervention will be required. This would be the remit for the Study Group.	ICES
4. Arising from ToRe): In recent years, WGECO and OSPAR have both developed methods to assess the interactions between pressures resulting from human activities and ecosystem components. A risk based methodology has recently been developed which significantly advances this task and addresses some of the problems associated with previous techniques. WGECO support OSPAR's proposal for a workshop in summer 2008 to assess a small number of ecosystem components in one OSPAR region to further develop the methodology and confirm whether the methodology can be used to consistently assess the degree of impact. WGECO would like to be involved in the workshop and future OSPAR research in this area to avoid developing separate, parallel work agendas. Other ICES expert groups are well placed to assist in the development of the thresholds and state and pressure indicators for the components. WGECO recommends that ICES consult with OSPAR over this issue and develop a framework for its various expert groups to provide input into the process.	ICES Possible involvement of: WGECO, BEWG, WGSE, WGEXT (aggregate extraction), WGRED, WGBEC (contaminants), WGFE, WGMHM (habitat mapping), WGZE, SGRAMA and others

Annex 5: Technical minutes of the Review Group on OSPAR's fisheries impact request

- RGFIMP
- By correspondence May 15–20, 2008
- Participants: Jae Choi (Canada), Simon Jennings (UK), Michel Kaiser(UK), Mark Tasker (Chair)
  - Co-opted members for further technical input on particular OSPAR Regions:
    - **Region I** (Arctic): Yuri Kovalev (Russia), Gudmundur Thordarson (Iceland)
    - **Region II** (North Sea): Chris Darby (UK)
    - **Region III** (Celtic Seas): Colm Lordan (Ireland), Rob Scott (UK)
    - **Region IV** (Bay of Biscay/Iberia): Manuela Azevedo (Portugal)
    - **Region V** (wider Atlantic): Tom Blasdale (UK)
- Working Group: WGECO

Terms of Reference

To formally review the draft section of WGECO dealing with the OSPAR Request on fisheries impact.

Documents under review

Section 4 of WGECO 2008 report.

Summary

At the end of the WGECO meeting, it was obvious that further technical input was required to deal with OSPAR Region V (the wider Atlantic). After discussions with the chair of WGDEEP, it became plain that it would be wise to repeat this review process with chairs of other relevant working groups, hence the list of extra co-opted members. These co-opted members without exception rose to the review challenge despite the extremely short notice, and all replied with comments that were of great use. Some of these chairs sought help from other members of their expert groups, who also supplied useful comments. These comments were all responded to later by the Advice Drafting Group. The co-opted members and others who contributed are thanked for their work.

Comments from the core review group on the WGECO text included:

- A general lack of references (WGECO appeared not to have understood their brief on this point).
- An over-use of WGRED texts-incidentally several areas were noted where these texts need improving.
- WGECO had used landing figures to describe the state of fish stocks, rather than SSB or similar.
- The balance between direct and indirect effects was very variable between sections.
- An overuse of normative rather than descriptive language in some sections.

- Billfish and tuna missing from OSPAR Region V.
- Seabed disturbance from suction dredging and mussel dredging was not included.
- Insufficient explanation of initials and acronyms.
- No standardised way of describing over-fishing.
- Genetic/phenotypic effects are missing.

Texts of letters or annotated drafts of the WGECO text are all filed on the relevant ICES sharepoint site:

http://groupnet.ices.dk/advice2008/adgfimp/Review%20Group%20documents/Forms/AllItems.aspx

Ways of dealing with these issues were noted and were passed to the Advice Drafting Group.

Points to note in the future

Much more liaison among the groups working on joint advisory texts such as this one would have helped, although this can be challenging without dedicated input or knowledge of exactly who in any particular working group (WGECO in this case) is due to be drafting original text.