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27–30 August 2001

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¹ Unable to attend.

All Member Countries were represented at the meeting.

1 INTRODUCTION

The Advisory Committee on Ecosystems (ACE) was created in 2000 as the Council's official body for the provision of scientific information and advice on the status and outlook for marine ecosystems, and on exploitation of living marine resources in an ecosystem context. ACE will provide a focus for advice that integrates consideration of the marine environment and fisheries in an ecosystem context, such as ecosystem effects of fishing. ACE will be at the forefront of the development of advice on ecosystem management.

ACE provides advice as may be requested by ICES Member Countries, other bodies within ICES, relevant regulatory Commissions, and other organizations.

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

ICES received a request from the Secretariat for the Fifth North Sea Conference to prepare an update of parts of the Assessment Report on Fisheries and Fisheries-related Species and Habitats Issues, the background document for the Intermediate Ministerial Meeting on the Integration of Fisheries and Environmental Issues (Bergen, Norway, March 1997). This report is intended to serve as a background document for the preparation of the Progress Report to the Fifth International Conference on the Protection of the North Sea, to be held in Bergen, Norway, in March 2002.

ACE reviewed a draft report prepared in response to this request. This report presents an overview of the status of fish stocks in the greater North Sea area for which advice is given by ICES, and information on the

ecosystem effects of fisheries in the North Sea. It is based on stock assessments produced by the ICES Advisory Committee on Fishery Management in 2000, as well as on recent reports of several ICES Working Groups, including the Working Group on Ecosystem Effects of Fishing Activities, the Working Group on Seabird Ecology, and the Working Group on Marine Mammal Population Dynamics and Habitats.

This report was reviewed in detail by ACE and a number of comments and additions were made, particularly regarding the impacts on various components of the ecosystem. With these amendments, ACE accepted this report for transmission to the North Sea Secretariat in Oslo. This document can be found on the ICES website at:

www.ices.dk/committee/ace/ace_reports.htm.

3 SMALL CETACEAN BY-CATCH IN FISHERIES

3.1 Request

The request from the European Commission DG-Fish, concerning the by-catch of small cetaceans in fisheries, states:

ICES is also requested to increase its efforts to provide information and advice on other fish stocks and other marine organisms than those targeted by commercial fisheries. This is an area in which the European Commission would encourage ICES to take greater initiative as well as proposing research to support the ongoing efforts to integrate environmental concern into the Common Fisheries Policy.

The European Commission would in particular be interested to receive information and advice as soon as possible during 2001 on the following:

- *Overview of fisheries that have a significant impact on small cetaceans;*
- *Overview of other sources of mortality of small cetaceans;*
- *Assess the risks created by fisheries on identified populations.*

Advice on possible remedial actions to reduce the impact of fishing, inter alia, technical measures such as changes in gear designs, fishing practice, spatial or temporal closures.

3.2 Background

Information on the by-catch of small cetaceans in fisheries in the waters of the European Union is incomplete, by fishery, by gear type, by area, by season, and over years. The information gaps can only be filled by monitoring programmes that provide adequate coverage of fisheries over large areas, and for multiple years. Northridge (1996) provides guidance on what comprises adequate coverage and this is summarized below.

Some improvement on the information and strengthened advice can be expected in the near term, as a few existing by-catch quantification programmes will provide new data. However, for many fisheries, monitoring programmes must be inaugurated, expanded in coverage, or re-established. Reliable by-catch monitoring programmes are often time-consuming to establish because funding must be secured and industry cooperation with independent observers negotiated. Once established, they need to operate for at least a few years in order to determine the degree of inter-annual variation in by-catches. Therefore, a number of major gaps in our knowledge of by-catches of small cetaceans will only be filled in the medium term.

Notwithstanding the incompleteness of data sources, the available data do allow provision of some information on by-catches of small cetaceans in Northeast Atlantic fisheries, and initial advice on mitigation measures. The information and advice will be highly uncertain. Nonetheless, ICES formulates advice within the precautionary approach (FAO, 1995; ICES, 1997, 1998) when uncertainty is high but there is the possibility of damage that is serious or difficult to reverse. In that setting, the Precautionary Approach directs that scientific advisory bodies must provide the best scientific advice possible with the information that is available, and managers must not use uncertainty as a reason to defer cost-effective actions to mitigate harmful activities.

The current scientific advice is proposed in the spirit of the request from the EC: that “ICES take greater initiative as well as proposing research ...”. As wider and more current monitoring data become available, it will undoubtedly be possible to provide additional advice on marine mammal by-catch. The future advice may identify other fisheries which present risk of undesirable rates of by-catch mortality to small cetaceans but for which data are currently unavailable, and provide more quantitative information on the benefits and costs of alternative mitigation methods to reduce by-catch when necessary. Also, the identification of explicit management targets, limits, and objectives for small cetaceans would facilitate the provision of scientific advice in the face of substantial uncertainty about by-catch rates in many fisheries. In that context, the currently available information should be viewed as the basis for scientific advice that indicates the major directions in which management needs to move, but not necessarily the endpoints at which management should be aiming.

3.3 Fisheries that have a Significant Impact on Small Cetaceans

3.3.1 What is “significant impact”

It is first necessary to establish what comprises a significant impact. For commercial fish stocks, ICES provides scientific advice within a framework where “significant impacts” are taken as impacts that produce an unacceptable risk of stock attributes falling outside precautionary reference points. For most fish stocks, two reference points are used: mature biomass, where SSB should be above a B_{pa} defined on a stock-recruit basis, and fishing mortality, where F should be below an F_{pa} defined on an equilibrium population basis. For most small cetacean populations in the Northeast Atlantic, population viability analyses have not been undertaken, so there is no current biological basis on which to set biomass or abundance reference points. Also, monitoring programmes generally are not precise enough to be likely to detect population trends on time scales sufficiently short for rapid management responses to by-catches.

However, knowledge of the basic life history parameters of species with life histories similar to those of small cetaceans does allow identification of mortality rates that, if continued, would pose risk of a steady decline in a population. These may be used as the basis for evaluating “significant impact” at present and, with further analytical work, may provide quantitative by-catch mortality reference points.

Small cetacean females, once they reach maturity, normally produce only a single calf and they often give birth at intervals longer than once per year. Most commercially exploited fishes have a completely different reproductive strategy, producing eggs in the range of 10,000–1,000,000 per female. Although other life history parameters, such as growth and age at first maturity, can be comparable, this difference in reproductive strategy means that the sustainable mortality rate for small cetaceans will be much lower than for most fish populations. Also, the ability of small cetacean populations to recover from any given percentage depletion will be much slower and less certain than for fish populations. Correspondingly, only mortality rates that are very low compared to $F_{pa,s}$ used in most fisheries advice may be considered as possibly acceptable by-catch mortality rates for small cetaceans.

There have been a number of estimates of the mortality rate sustainable by small cetaceans. All estimates indicate uncertainty in this parameter. The most recent analyses were simulations by scientific experts working with the IWC and ASCOBANS. The results demonstrated that the sustainable mortality depends on both the objective set for the population and the maximum possible growth rate of the population (R_{max}).

With regard to management objectives, the greater the population rebuilding target relative to the starting population status, the lower the mortality rate that could be sustained. The choice of target is a societal rather than scientific decision. For the purposes of their work, the IWC-ASCOBANS experts chose a target agreed by an intergovernmental meeting of ASCOBANS. This forum chose the biological objective of rebuilding to, or maintaining a population at, 80 % of carrying capacity, over an infinite time horizon. The true maximum rate of increase of the various species of small cetaceans is not known for any population in the Northeast Atlantic. Various analyses of harbour porpoise demographics have provided ranges from 6–15 %, although some of the higher estimates have been challenged on technical grounds as likely overestimates. Harbour porpoises are likely to have a higher maximum rate of increase than most other species of small cetaceans living in the Northeast Atlantic. Considering all results, these experts

concluded that they should “use an estimate of maximum rate of increase of 4 % in the simulation model, noting that it was unlikely that the actual value was less than this figure” (IWC-ASCOBANS, 2000). The estimate of 4 % is also consistent with some field studies and with the life history characteristics of many species of small cetaceans.

Using the objective of rebuilding populations to 80 % of carrying capacity, or maintaining them there, and an R_{max} of 4 %, an **annual by-catch mortality rate of 1.7 % of a small cetacean population is the maximum that could be sustained. This value is accepted as the basis for scientific advice until improved estimates of maximum population growth rates are available for these populations, or different management targets are adopted.** Moreover, the maximum rate at which severely depleted populations can rebuild may be lower than 4 %, due to demographic considerations, suggesting that by-catch rates substantially below 1.7 % per year could deter rebuilding of depleted populations of cetaceans. Also, very little is known of the population structure of small cetaceans, but numerous studies suggest that at least some species do have some population sub-structure on geographic scales less than the Northeast Atlantic or even the North Sea. Therefore, by-catch rates that are below 1.7 % on the scale of the entire Northeast Atlantic may be much higher on scales of population sub-structures.

If the maximum sustainable by-catch rate is estimated to be 1.7 % of a population annually, and this estimate is highly uncertain and takes no account of population structure, then within a precautionary approach by-catch rates well below 1.7 % annually should be considered “significant”. Current knowledge is insufficient to quantify the uncertainty in this estimate, so it is impossible at this time to specify how much lower than 1.7 % a by-catch rate should be, in order for the by-catch to be considered within precautionary limits. Nonetheless, management within a precautionary approach will strive to keep by-catch mortality well below 1.7 % per annum, in order to be confident that the true by-catch mortality is sustainable.

3.4 By-catches of Small Cetaceans in Various Fisheries

Interpreting by-catch amounts is most meaningful when done in the context of the population sizes of those species. However, population estimates are available for only a small number of small cetaceans in the Northeast Atlantic (EU waters/fisheries), as listed in Table 3.4.1.

Table 3.4.1. Abundance estimates of the most common small cetacean species in the ICES area (Hammond *et al.*, 1995; ICES, 1996). Bottlenose dolphin estimates are from Wilson *et al.* (1999) for the Moray Firth and from ICES (1996) for elsewhere.

Species	Year of estimate	ICES Area or sea area	Abundance estimate	95 % Confidence limits
Harbour porpoise	1994	IIIa + b	36,046	20,276–64,083
		IIIc	5,850	3,749–9,129
		IVa	98,564	66,679–145,697
		IVb + c	169,888	124,121–232,530
		VIIIf+g+h+j	36,280	12,828–10,2604
Bottlenose dolphin	1998	Moray Firth	129	110–174
	1993	Brittany	30	na
	1993	Mont St Michel	60	na
	1993	Arachon	6	na
	1990s	Sado Estuary	ca. 15	na
	1991/1993	Cornwall	15	na
	1994–1995	Dorset	5	na
	1991	Cardigan Bay	120+	na
	1995	Shannon Estuary	50–60	na
		Galway Bay	?	na
		Clew Bay	?	na
	1995	Dingle Bay	12	na
White-beaked and Atlantic white-sided dolphins	1994	IVa	1,685	690–4,113
		IVb	9,242	5,344–15,981
		VIIIf+g+h+j	833	159–4,360
Killer whale	1989	Northern North Sea	7,029	3,400–14,400
Common dolphin	1994	VIIIf+g+h+j	75,449	22,900–284,900

The information on by-catches of small cetaceans by various gears and fisheries is summarized in Table 3.4.2. Although some entries in Table 3.4.2. are quantitative, the list as a whole cannot be taken as a quantitative nor a complete summary of by-catches. Many fisheries that probably take some by-catch of small cetaceans have no monitoring or by-catch reporting system, and hence cannot be tabulated. For the fisheries that are included in the tabulation, the quality of the by-catch recording programmes differed greatly. In only a few cases are adequate effort data for entire fisheries available, to allow conversion of observed or reported by-catch numbers into total impacts of gears or fisheries on populations of small cetaceans. Where the conversion of by-catch rates from observed samples to an entire fishery were based on tonnes of the target species caught, rather than on direct measures of effort (such as soak time per net for gillnet fisheries), total estimates may become badly biased over time, if CPUE is declining. Also, where particular national fleets appear to have high by-catches relative to other fleets of the same gear, this is as likely to reflect differences in the quality of the observer programmes supported by the flag state as it is to reflect true differences in by-catches among similar fleets from different countries. Finally, in a few places, such as the Channel and the Baltic Sea, populations of small cetaceans have been depleted severely by by-catches or other factors in earlier decades. Hence, the occurrence of low by-catch numbers now may not indicate particularly well-controlled fisheries, but may instead indicate severe damage in the past.

Keeping in mind the preceding qualifications, a few general statements can be made about fisheries that may impact small cetaceans. First, both static and towed nets can have high by-catches of small cetaceans, as shown by some gillnet and pelagic trawl fisheries. It is impossible with available data to know whether the fisheries with the highest reported by-catch—gillnets in the central and southern North Sea west of Denmark and on the Celtic Shelf, and pelagic trawls in the Celtic Sea—are actually taking more cetaceans per unit of effort (although see earlier qualifications on effort measurement) than other similar fisheries, or whether they simply have more efficient monitoring programmes. However, the available data are sufficient to justify efforts both to reduce the by-catch of cetaceans in these fisheries to improve the status of small cetacean populations, and to allocate resources to other poorly monitored fisheries as a priority, to document the extent of the risk posed by other similar fisheries. Second, by-catches of small cetaceans are often clustered in space and time, although reliable data are too few for it to be possible to identify hotspots in advance. Third, by-catches have declined in many fisheries, usually in parallel with overall reductions in effort (but note the possibility that declining CPUE may lead to maintaining effort and associated by-catch despite declining catch).

Table 3.4.2. Summary of reports of small cetacean by-catches in fisheries in waters around northwestern Europe, including list of similar fisheries that have yet to have their small cetacean by-catch reported. ICES **stresses** that these reports differ in reliability and time frame and are therefore not always comparable. The absence of fisheries from this table should NOT be taken as evidence of the absence of by-catch in any such fishery. Generally, bottom trawl fisheries are found to take small cetaceans as by-catch very infrequently.

Gear type	Location	Target species	Country	By-catch species and estimate, source
Gillnets and tangle nets	Central/southern North Sea, Skagerrak and Kattegat	Cod, turbot, hake, sole, plaice, and lumpfish	Denmark	Harbour porpoise, mean = 6785 p.a. (CV ~ 0.12), 1992–present (Vinther, 1999)
	Central/southern North Sea	Cod, turbot, skate, sole	UK (England)	Harbour porpoise, mean ~800 p.a. (1995) to 440 (2000) (Northridge and Hammond, 1999)
	Southern North Sea		Germany	Harbour porpoise, 30–100 (estimate); 23 observed (1987–1992) Questionnaire ¹
	Celtic Sea	Hake	UK and Ireland, combined ²	Harbour porpoise, ~2,200 p.a., common dolphin “small numbers” 1995–1997 (Tregenza <i>et al.</i> , 1997a, 1997b)
	Skagerrak and Kattegat	Cod, flatfish, others	Sweden	Harbour porpoise, 53 in one ICES rectangle 1995–1996 (Carlström and Berggren, 1996)
	Baltic Sea	Herring, cod, flounder, salmon	Baltic nations	Harbour porpoise, 105 in 1987–1995 reported in Kiel Bight (Kock and Benke, 1996)
Driftnets	Baltic Sea	Salmon	Poland	Harbour porpoise, 44 in ten years (1990–present) from one area (interviews)
	Celtic Sea/Bay of Biscay	Albacore	France, UK	Common, striped, bottlenose dolphins (Goujon, 1993; Antoine <i>et al.</i> , 1997) ³
Pelagic trawls	Western Celtic Sea (ICES VIIId-e, h, j)	Mackerel, horse mackerel	Netherlands	White-sided, common dolphins (1994–1995) (Morizur <i>et al.</i> , 1997, 1999); pilot whale, bottlenose dolphin (Couperus, 1997)
	Bay of Biscay	Hake	France	Common dolphin (1994–1995) (Morizur <i>et al.</i> , 1997, 1999)
	Bay of Biscay	Albacore	France	Common, bottlenose dolphins (1994–1995) (Morizur <i>et al.</i> , 1997, 1999)
	Western Channel	Sea bass	France	Common dolphin (1994–1995) (Morizur <i>et al.</i> , 1997, 1999)
	West of Ireland, Celtic Sea, Western Channel	Mackerel	UK, France, Ireland	Common, white-sided dolphins (1992–1993) (Kuiken <i>et al.</i> , 1994; Berrow and Rogan, 1997)
	Bay of Biscay	Mackerel, horse mackerel	Spain	“Dolphins”, 24 in 417 hauls, 1996–2000 (Gorka Sancho, pers. comm.)
Gillnets and tangle nets	West of Scotland	Crayfish and dogfish	UK (Scotland)	Harbour porpoise, 162 to 22 annually 1995–1999 (Northridge and Hammond, 1999)

¹ The reliability of these estimates has been questioned.

² This fishery has changed substantially since the by-catch study. Old data may no longer apply, but no new data have been collected.

³ Fishery to close in early 2002.

Table 3.4.2. Continued.

Fisheries that have been studied, with no reported by-catch.

Gear type	Location	Target species	Country	By-catch species and estimate, source
Gillnets	Baltic Sea	Cod, herring	Denmark	None, 1992–present (Vinther, 1999)
	Shetland	Monkfish	UK	None, 1997–1998 (Northridge and Hammond, 1999)

Other similar fisheries, so far not studied, whose effort remains unquantified and whose by-catch is unmeasured.

Gear type	Location	Target species	Country	Information
Gillnets and tangle nets	Northern North Sea	Saithe, other species	Norway	Known to take porpoises (Bjørge and Øjen, 1995). No monitoring established, and no quantitative information on by-catches available.
	Southern North Sea		Netherlands	Opportunistic reports
	Southern North Sea and Channel		Belgium	Occasional – self-reporting and strandings
	Southern North Sea?	Flatfish, mixed species	France	Occasional – self-reporting
	Channel	Flatfish, spider crabs and others	France, UK	No recent records; harbour porpoise population now very depleted
	Celtic Sea	Hake, flatfish, and others	France, Spain	Occasional – self-reporting and investigation of strandings
	Baltic Sea	Salmon, cod	Baltic countries	Self-reporting
	Bay of Biscay	Numerous species	France and Spain	None observed in small Spanish study; increased frequency of harbour porpoise strandings with net marks, but may reflect increased activity to investigate strandings
	Continental shelf edge	Various	UK, Spain and others	
Pelagic trawl	West of France, UK and Ireland	Albacore	Ireland and UK	Similar to French fishery in this area (Morizur <i>et al.</i> , 1997, 1999)
Driftnets	Skagerrak, Kattegat, and Baltic Sea	Mackerel and herring? salmon?	Sweden, Denmark? Others?	
	Southern and western North Sea	Salmon and herring	UK (England)	Studies undertaken, no by-catch seen, but insufficient sampling to draw conclusions
Pound and fyke nets	Kattegat, Baltic Sea	Various	Denmark, Germany and others	Catches rare or entangled cetaceans usually released alive, mostly self-reporting
Bottom and beam trawls	All waters	Many	All coastal nations	Considered generally very low – some opportunistically reported accounts involving several species (Fertl and Leatherwood, 1997)
Longlines	All waters	Several species	All nations	A few opportunistic accounts

3.5 Overview of Other Sources of Mortality

As with population dynamics models of fish populations, natural mortality of small cetaceans includes deaths due to disease, starvation, and senescence. Predation may once have been a source of mortality, but populations of potential predators on small cetaceans (for example, killer whales) are so low that they are unlikely to pose a significant source of mortality. Recently, mortality of harbour porpoises caused by bottlenose dolphins may have increased in some limited areas (Ross and Wilson, 1996). Little is known of mortality rates due to other natural factors; nor is there any evidence that death rates due to those factors have changed in recent decades. Hence, any anthropogenic sources of mortality have to be taken as incremental to historic mortality rates, altering the population demographic parameters. There are many population dynamic processes in small cetaceans, which might show density-dependent compensatory responses to increased mortality rates. These include age of first reproduction, inter-birth interval, and calf or juvenile survivorship. Nonetheless, all these processes have limits on their ability to compensate for increased mortality rates, even if the limits are poorly known. Therefore, any anthropogenic sources of mortality should be viewed as potential stresses on the population and, if non-negligible, sources of increased risk to population viability.

Aside from by-catch, other anthropogenic sources of mortality include deaths due to collisions with vessels, excessive contaminant loads or exposure to toxic substances, and directed takes. Although collisions of ships with large cetaceans are highly publicized, there are no data and few narrative reports to suggest that vessel collisions with small cetaceans are common enough to represent an important source of mortality. With regard to contaminants, documented instances of direct mortality due to contaminant burdens are rare. However, it is documented that contaminant loads have impacted immune systems of seals in ways that may increase their vulnerability to disease and other sources of natural mortality (Mortensen *et al.*, 1992; De Swart *et al.*, 1994; Reijnders, 1986). There are also documented cases of contaminant burdens of cetacean neonates sufficiently high to decrease their viability. However, the increased risk posed to populations of small cetaceans in the Northeast Atlantic by both of these consequences of contaminants has not been quantified.

Although historically there probably were at least subsistence hunts for small cetaceans in many countries, in recent decades only the Faroe Islands has prosecuted directed hunts for small cetaceans in the Northeast Atlantic (Table 3.5.1).

Management advice on this directed fishery is provided by NAMMCO, in response to requests for advice from member states. In addition to this directed fishery, there are anecdotal reports of individual small cetaceans taken intentionally by fishers participating in fisheries for various finfish. The total number of such kills annually is unknown but is unlikely to be large.

Aside from pilot whales, ICES has not evaluated the sustainability of these catches, but they provide a context for the interpretation of by-catches of small cetaceans in fisheries for finfish target species. For species such as harbour porpoise and dolphins, clearly by-catch mortality greatly exceeds the directed take for the species as a whole. Although there is only rudimentary knowledge of population structures in these species of small cetaceans, the concentration of directed take in the Faroes means that, in all other areas, by-catch mortality is essentially the sole source of mortality in small cetaceans caused by harvesting marine resources. This, combined with the absence of evidence that small cetaceans are at risk of direct mortality due to contaminants and pollution, means that measures which decrease the mortality of small cetaceans due to by-catch will be conveyed directly into recovery of populations if they are currently below their carrying capacities.

3.6 Assess the Risk to Identified Populations

The quantitative information available is insufficient to support formal risk assessments of by-catches on small cetaceans for any species, populations, or fishery. Nonetheless, ICES advises that measures to reduce the by-catch of any species of small cetaceans in any fishery would be biologically justified, as contributing to reducing anthropogenic mortality of species that cannot support high mortality rates. Moreover, it is possible to identify fisheries and species of greatest concern, on four criteria:

Table 3.5.1. Recent catches of small cetaceans in a drive fishery at the Faroe Islands (data from NAMMCO).

Year	Long-finned pilot whale	Northern bottlenose whale	Atlantic white-sided dolphin	Bottlenose dolphin	Harbour porpoise
1995	228	5	157	0	0
1996	1,554	0	152	21	3
1997	1,162	0	350	0	0
1998	815	0	438	0	0
1999	608	0	0	0	0

- 1) by-catch rates possibly exceed rates considered to be sustainable for the species or population;
- 2) populations are severely depressed relative to historic population sizes, and by-catch mortality may be a deterrent to recovery;
- 3) populations are intrinsically small, and even low numbers of kills represent an important source of mortality to the populations.

monitoring programmes, the precautionary approach argues that:

- 4) experience drawn from similar fisheries and species in other areas should be the basis of management action until fishery-specific data are sufficient to support management actions.

Hence, where by-catch mortality rates of concern have been quantified in a specific fishery, management consistent with the precautionary approach should take mitigation actions not just in the specific fishery, but also in similar fisheries in the same or similar areas for which by-catch data are poor or unavailable.

The absence of a fishery from this tabulation may reflect the inadequacy of programmes to record by-catches, rather than the absence of by-catches of small cetaceans in that fishery. In fisheries lacking reliable by-catch

Table 3.6.1. Fisheries in the Northeast Atlantic and Baltic Sea giving the greatest cause for concern due to small cetacean by-catch. See text for the description of concern criteria.

Fishery/gear type	Location	Country	Concern criteria	By-catch	Source
Gillnets and tangle nets	Central/southern North Sea, including coastal	Denmark for cod, hake, and flatfish	1	Harbour porpoise	Danish fishery monitoring 1994–1998 (Vinther, 1999).
		UK for cod and flatfish	1	Harbour porpoise	UK fishery monitoring 1995–1998 (Northridge and Hammond, 1999).
	Kattegat, Skagerrak, and Belt Seas	Denmark for cod and flatfish	2, 4	Harbour porpoise	Danish fishery monitoring 1994–1998 (Vinther, 1999).
		Sweden for cod, flatfish, and herring.	1	Harbour porpoise	Swedish fishery monitoring in 1995–1996 (Carlström and Berggren, 1996).
	Channel and Southern Bight of North Sea	UK, France, Belgium, Netherlands, Denmark	2, 4	Harbour porpoise. Populations severely depleted.	Limited monitoring by Denmark and UK (Vinther, 1999; Northridge and Hammond, 1999). Some self-reporting from fisheries. Indirect evidence from strandings.
	Celtic Sea	UK, Ireland	1	Harbour porpoise, common dolphin	Monitoring of UK and Irish hake fishery in early 1990s (Tregenza <i>et al.</i> , 1997a, 1997b).
France, Spain		4			
Pelagic trawl	Celtic Sea, Channel, Bay of Biscay	Netherlands, UK, Ireland, France (mackerel, horse mackerel, herring, sardine, anchovy, bass, black sea bream, albacore)	1, 4	Common, striped, bottlenose, and white-sided dolphins	Limited monitoring programme (Morizur <i>et al.</i> , 1997, 1999) mid-1990s, evidence from autopsied stranded animals consistent with by-catch (Tregenza and Collet, 1998) and opportunistic reports.
Any static net, driftnet or pelagic trawl	Baltic Sea	Sweden, Denmark, Germany, Poland; southern Baltic (range of harbour porpoise)	2, 4	Harbour porpoise. Populations in Baltic severely depleted.	Several small, local monitoring or self-reporting programmes in Mecklenburg Bight, Gdansk Bay and Swedish salmon fishery.

ICES stresses that current monitoring data on by-catches of small cetaceans are inadequate to assess risk reliably. However, populations with low intrinsic rates of increase are intrinsically vulnerable to mortality elevated through human activities, including fisheries, and there are records of historic depletions of small cetacean populations in at least the Baltic Sea and the Channel. These are grounds for advising against a complacent attitude about fisheries for which there is insufficient information.

It should be noted, though, that many of the monitoring programmes that provided the data available to ICES were conducted several years ago. Some of the fisheries identified on the criteria above have already implemented measures intended to reduce marine mammal by-catch and/or effort in these fisheries has decreased, so the absolute numbers of small cetaceans killed have declined (see below). In such cases, inclusion in Table 3.6.1 is not intended to indicate that the mitigation measures are inadequate. Rather, updated data to evaluate the risk posed by the modified fisheries are not yet available. This qualitative risk designation refers to the fishery at the time that the by-catch monitoring was conducted, and to fisheries operating in settings and manners similar to those fisheries.

3.7 Discussion of Effectiveness of Mitigation Measures

When properly deployed, **acoustic deterrents** (“**pingers**”) have been shown to be effective in reducing by-catch numbers. Reviews of the effectiveness of pingers in both European and US waters generally have found them effective when properly deployed and maintained, reducing by-catch by initially as much as 90 % (e.g., Read, 2000; SMRU *et al.*, 2001). However, effective deployment and maintenance may be considered costly in time and money by fishers. For these reasons, they have not been received with enthusiasm by some industry sectors. Moreover, there have been suggestions that harbour porpoises may habituate to pingers over time, and that pingers may reduce catch rates of the target species, although neither of these suggestions is documented soundly. High densities of pingers may exclude small cetaceans from localities, eliminating their access to sites of otherwise suitable habitats. However, these localities may be only a small proportion of their total range, and are reused once pingers are removed (Larsen and Rye Hansen, 2000). In EU waters, pingers have been deployed experimentally in some Danish, UK, and Irish set net fisheries. In addition, a Danish regulation from 2000 prohibits the use of some gillnets in the North Sea from 1 August to 31 October unless pingers are employed.

Spatial or temporal closures have also been suggested as a mitigation measure for protecting small cetaceans in two contexts: “hotspots” of particularly high by-catches, and preventing by-catches from populations that are severely depleted. By-catch “hotspots” can occur because many species of small cetaceans aggregate, and

such aggregations may encounter concentrations of fishing gear. These by-catches are often localized in space and time, and depend to a large extent on local conditions. Over seasons or years it has rarely been possible to predict in advance where and when local hotspots of by-catch will occur. Therefore, it has rarely been possible to use spatial or temporal closures as a by-catch reduction tool, on scales that allow fisheries to operate under “normal” conditions (Read, 2000). Closure of fairly large areas, such as entire ICES sub-areas in the North Sea, for a period of a few months could lead to substantial reductions in by-catch, but would require major adjustments in fishery operations, and the consequences of the fishing effort being displaced in space and time would need to be considered. In future, closures might become effective by-catch reduction tools, but only if enhanced monitoring and analyses of data indicate predictable by-catch hotspots.

For areas with severely depleted populations of small cetaceans, even infrequent cases of by-catch may deter population recovery. In such cases, large-scale closures of fisheries which take small cetaceans as by-catch would be one strategy for ensuring that mortality of the depleted populations is kept as low as possible.

Technical measures with regard to gear deployment, such as numbers and lengths of nets deployed per fisher, sizes of mesh and twine, and soak duration, have been found effective in reducing the by-catch of small cetaceans in static net fisheries in the US (Read, 2000). However, the US results suggest that the effectiveness of the technical measures on both by-catch of small cetaceans and impacts on gear efficiency for target species must be evaluated on a case-by-case basis, before specific recommendations can be made. Three generalizations arise from the experience elsewhere:

- 1) generally “less is better” with regard to numbers and length of nets and soak times;
- 2) continual presence of fishers at surface driftnets or surface traps is effective in allowing the prompt release of cetaceans that are entangled;
- 3) programmes only succeed in situations where industry participants support the technical measures that they are required to use.

However, the first and third generalizations are nearly gratuitous as guidance for by-catch reduction, and the second will often not be practical.

The effectiveness of specific technical measures for specific EU fisheries has not been investigated systematically within the Northeast Atlantic. This research should be prioritized based on those fisheries causing the most significant cetacean by-catch. Until such research has been completed, it will not be possible to provide specific advice on technical measures to reduce the by-catch of small cetaceans.

ICES notes that for several years it has advised **reductions in directed effort** for many fisheries in the EU zone. To the extent that these advised effort reductions have been allocated to static net or pelagic trawl fisheries, particularly those with high by-catches, the effort reductions themselves have already contributed directly to reduced by-catch of small cetaceans as well, and can continue to do so in the future.

3.8 Advice on Mitigation Measures

Overall, ICES concludes that by-catches of small cetaceans in many fisheries, particularly but not exclusively bottom-set gillnet fisheries, are high enough that it **recommends** that mitigation measures be implemented to reduce such by-catches. The target for reductions is to bring total by-catches from all fisheries below 1.7 % annually for each species of small cetacean. However, because of uncertainties about population sizes and breeding units of all species, and about allocation of by-catch mortality of individual populations among fisheries, there is no scientific basis for advising particular reduction targets for particular fisheries. With present information, by-catches of harbour porpoise in the south-central North Sea and Celtic Shelf appear to be the most serious problem, and ICES **recommends** that particular priority should be given to reducing small cetacean by-catch in fisheries in those areas.

Although it is not possible to set by-catch reduction targets for individual fisheries with current knowledge, populations of small cetaceans are severely depleted in the Baltic Sea and the Channel and adjacent portions of the southern North Sea. ICES **advises** that reduction of by-catch of small cetaceans in these areas is a particularly high priority. In these areas, rapid (for cetaceans) and effective rebuilding of small cetacean populations requires that by-catch should be negligible, which would only be achieved with the closure of static net fisheries in these areas. However, even with negligible by-catch mortality, small cetacean populations in these areas may not rebuild, if the cause of declines were other sources of mortality, and if these causes of mortality have not changed.

ICES stresses yet again that effective measures to achieve sustainability of directed fisheries and conserve target species will contribute to reducing undesirable consequences for the ecosystem as well. Specifically, it recommends that the effort reductions advised for directed fisheries throughout the ICES area should be implemented promptly and effectively. Effective reductions in fishing effort are likely to constitute effective reductions in opportunities for the by-catch of small cetaceans (and other species) as well, serving as conservation measures for many parts of the ecosystem in addition to the target species.

ICES further **advises** that no single mitigation measure has been demonstrated to be universally superior to all alternatives, and that a mixture of measures to reduce by-catch is preferred to reliance on any single measure.

With regard to technical measures, ICES **concludes** that at present there is an insufficient basis to recommend any particular suite of remedial actions. Rather, ICES **concludes** that the effectiveness of each possible mitigation measure has been shown to be variable with fishery and local conditions, and can be greatly affected by the willingness of fishers to use the measure effectively, or cooperate with its use. With current knowledge, it appears that successful reduction of small cetacean by-catch will depend more on the degree of industry support for a programme than the specific choice among potentially effective alternatives, and the suite of potentially effective alternatives will vary with the local conditions of particular fisheries.

With regard to pingers, ICES **advises** that the balance of evidence indicates that they are effective at reducing the by-catch of harbour porpoises in bottom-set gillnets. Their use should be promoted in relevant fisheries with high by-catches of harbour porpoises. Measures should be sought to increase their reliability and convenience of use. Experience elsewhere has shown that compliance with proper usage guidelines is often poor in the absence of effective enforcement. ICES **advises** careful consideration of this issue.

With regard to closed areas or seasons, ICES **advises** that current knowledge is inadequate to identify any specific local areas or times when closures can be demonstrated to be particularly effective at reducing by-catch. Further monitoring of fisheries and analyses of data may identify such times and/or areas, however.

3.9 Recommendations for Further Research and Monitoring Efforts

The pre-eminent recommendation is for improved and expanding by-catch monitoring of fisheries. There is a particular urgency to obtain by-catch data from:

- the Baltic Sea and Channel;
- French and Spanish gillnet and tangle net fisheries in the Channel and Bay of Biscay;
- pelagic trawl fisheries in the Bay of Biscay and Celtic Sea;
- the offshore freezer-netter fleets working on the outer edge of the continental shelf west of Europe.

Key points with regard to effective monitoring programmes, as a source of data for estimating by-catches of small cetaceans in fisheries, include:

- Independent observers: Independent observer programmes are essential for reliable estimates of by-catch rates, and should be implemented in fisheries that do not have them;
- Adequate observer coverage: The requisite degree of coverage will vary between fisheries, depending on the mean catch rate of the fisheries and the

desired accuracy of the catch rate (Northridge, 1996). Typically, 10 % would be sufficient to provide estimates of reasonable accuracy on an annual or seasonal basis. If estimates are only needed over longer time periods, somewhat lower coverage is adequate. Where numbers of cetaceans killed by a fishery are likely to be lower, but even a small number may represent an unsustainable mortality rate, coverage would have to be higher;

- Adequate distribution of observers: Basic principles of survey design must be followed, with regard to stratification of observer coverage in space, time, across individual harvesters, etc.;
- Fishery effort data: Estimates of by-catch rates per net-day (or other units) cannot be converted to numbers of small cetaceans killed by a fishery, unless the total number of net days deployed by the fishery is known. If by-catch rates vary spatially or seasonally, the effort data will need to be stratified by those factors. Such data are recorded routinely by fishers in EU waters in logbooks, however in only a few fisheries are such data collated or used. Given that such records are compulsory and are submitted to EU administrators, improving collation and access to these records would aid in our understanding of the potential impact of relevant fisheries.

Some static net fisheries are prosecuted by large numbers of very small vessels, which cannot practically carry independent observers. Some inshore fisheries have been monitored by the judicious placement of observers onboard the larger vessels working in such fleets. However, efforts may need to be made to find alternative means to obtain independent and reliable estimates of small cetacean by-catch in such fisheries, possibly through the use of advanced technologies.

Not only should improved by-catch monitoring occur, but also all results of monitoring should be made available to the scientific community on a timely basis. As noted above, fisheries administrators can play a role by making effort data more accessible.

New population estimates for all small cetaceans in the Northeast Atlantic are needed as an urgent priority. This will require new surveys, which are currently under discussion. It is particularly important that populations be surveyed along the western coast of Europe, from northern Spain north to at least the area west of Scotland.

As monitoring data become available, appropriate analyses should be conducted to identify hotspots for by-catch in space and time, if such hotspots exist.

In addition, directed research on technical measures to reduce by-catch of small cetaceans is encouraged, particularly with regard to factors such as soak times and amounts of gear. The effectiveness of many technical measures is likely to be fishery specific, and the

measures are likely to impact catch rates of the target species as well. Therefore, the directed research should focus on fisheries and areas where by-catches are of particular concern, as listed above. The research should also involve the industry as participants, to ensure that the technical measures are ones that the industry is willing and able to implement effectively.

Further modelling is required to improve estimates of maximum growth rates of small cetacean populations, and corresponding estimates of maximum sustainable by-catch mortality rates. Much of the modelling must await the availability of additional data on population biology of small cetacean species. However, some useful simulation work can be done in the near term, building on recent progress with modelling pinniped populations.

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4 ECOLOGICAL QUALITY OBJECTIVES

4.1 Summary

This section deals with an aspect of an emerging area of interest to ICES—the ecosystem approach to management. In particular, it addresses the uses of expressions of ecosystem quality and ways of measuring those expressions and their uses in helping the management of human activities in relation to the marine environment. The section is divided into five main parts of differing lengths. The first part (Sections 4.3 to 4.5) covers the language, concepts, and implications of the issue; the second (Sections 4.6 and 4.7) and third parts (Sections 4.8 and 4.9) cover the application of the concept to two groups of marine organisms: marine mammals and birds. These two parts are given as responses to specific requests from the OSPAR Commission for advice. The fourth part (Section 4.10) considers whether it is possible to use existing expressions of the state of exploited stocks of fish as expressions of ecosystem quality. This part is given as a response to a request for advice from the European Commission. The final part (Section 4.11) considers application to fish and benthic communities.

The expression of ecosystem quality used until now has been “Ecological Quality Objective”. However, the language used around this rapidly developing topic has not stabilized or become consistent with similar concepts used elsewhere. Suggestions are made to improve both internal and external consistency of language. In particular, the expression and measure of ecosystem quality is now described as an Ecological Quality (EcoQ) with the EcoQO being a level aimed for on the metric describing the EcoQ. Some comparisons of language usage are also given. ICES notes that science has a distinctive role to play in the management of human activities, but that society has a roll to play also. Some practical aspects of attempting to manage human activities to achieve desired ecosystem states are discussed. ICES agrees with those who have considered EcoQs and their metrics in the past that good EcoQs should be:

- a) relatively easy to understand by non-scientists and those who will decide on their use;
- b) sensitive to a manageable human activity;
- c) relatively tightly linked in time to that activity;
- d) easily and accurately measured, with a low error rate;
- e) responsive primarily to a human activity, with low responsiveness to other causes of change;
- f) measurable over a large proportion of the area to which the EcoQ metric is to apply;

- g) based on an existing body or time series of data to allow a realistic setting of objectives.

Marine mammals are regarded by the public as an important component of the marine ecosystem that should not be greatly impacted by human activity. The section (Section 4.6) on this group starts with a review of the current status of marine mammals in the North Sea and a brief review of threats. OSPAR asked for information on the health status of marine mammals in relation to habitat quality. Little information exists in this area and suggestions are made for future approaches on this issue. Three marine mammal EcoQs are suggested (Section 4.7): a) seal population trends; b) seal breeding sites; and c) by-catch of harbour porpoises (Table 4.1.1). Further possible EcoQs were considered but were not recommended.

Seabirds are held in equal public regard as marine mammals. After a comprehensive review of the knowledge on the status of North Sea seabirds (Section 4.8), the seabird section describes seven possible EcoQs with associated reference levels, current levels, and suggested target levels (Section 4.9). These EcoQs are: 1) the proportion of oiled common guillemots among those found dead or dying on beaches; 2) mercury concentrations in eggs of selected seabird species; 3) mercury concentrations in body feathers of selected seabird species; 4) organochlorine concentrations in seabird eggs; 5) number of plastic particles in gizzards of fulmars; 6) breeding productivity of black-legged kittiwakes; and 7) seabird population trends (Table 4.1.1). Further possible EcoQs were considered but were not recommended.

ICES considers that precautionary reference points as defined by ACFM can be used as EcoQOs for target species and their implementation will help to achieve conservation objectives for the ecosystem (Section 4.10), but further notes that additional reference points should be considered as part of the ecosystem approach to fisheries management.

There are a number of important concerns about the use of EcoQ metrics for fish and benthos communities (Section 4.11). Many possible metrics have been considered. The most appropriate metrics for fish communities are the average weight and average maximum length, while the most appropriate metric for benthic communities is the presence of indicator species. Target, current, and reference levels still need to be determined for these EcoQs.

Table 4.1.1. Summary of proposed EcoQ metrics, current levels, reference levels, and suggested target levels for marine mammals and seabirds in the North Sea.

Human activity (JAMP¹ category)	EcoQ metric	Current level	Reference level	Suggested EcoQO target level
Habitats and ecosystem health—seal populations	Trends in seal population size or pup production	Variable, but most populations increasing	Declines in population of greater than 5 % is unusual	No decline in population size or pup production of ≥ 10 % over <10 years
Habitats and ecosystem health—seal population distribution	Seal breeding site distribution within the North Sea	Not presented, but easily available	As current	No abandonment of North Sea harbour or grey seal breeding sites
Fishery—harbour porpoise by-catch	Proportion of harbour porpoise population by-caught within fisheries	Varies, but is over suggested EcoQO level within North Sea	Zero	By-catch rates for harbour porpoises should be reduced to levels below 1.7 % of the relevant stock size
Contaminants—oil	Proportion of oiled guillemots among those found dead or dying on the beach	12–85 %	0 %	10 % or less
Contaminants—mercury	Mercury concentrations in eggs of selected seabird species	Varies with species	Not yet set (area dependent)	Not yet suggested
Contaminants—mercury	Mercury concentrations in body feathers of selected seabird species	Varies with species	Situation in 1900	Same as reference level
Contaminants—organochlorines	Organochlorine concentrations in seabird eggs	Varies with species	Zero	Zero (over long time scale)
Litter—plastic particles	Number of plastic particles in gizzards of North Sea fulmars	Varies, not well known	0 %	10 particles within any fulmar of a sample of 40
Fisheries—harvesting of seabird food	Index of breeding productivity of black-legged kittiwake as an index for local sandeel abundance	0.97 ± 0.28 chicks per pair	Not known	LRP ² =0.5 chicks per pair
Habitats and ecosystem health—seabird populations	Seabird population trends as an index of seabird community health	Varies with species	Not known	LRP more than 20 % decrease within 20 years

¹ OSPAR Joint Assessment and Monitoring Programme

² Limit reference point

4.2 Request from OSPAR

Two of the requests on the ICES Work Programme for OSPAR for 2001 are to develop Ecological Quality Objectives (EcoQOs) for sea mammals and seabirds in the North Sea. These EcoQOs are requested at the North Sea scale and are as follows (using the OSPAR numbering of the requests):

2.2 Further development of EcoQOs for sea mammals

- 2.2.1 *Provide a synthesis of the status of North Sea populations of sea mammals, including consideration of species that have declined or are threatened from human activities;*
- 2.2.2 *Provide a synthesis of the health status of sea mammals in the North Sea in relation to the quality of their habitat;*
- 2.2.3 *Taking into account the outcome of the Oslo Workshop on Ecosystem Approach including the background document prepared for the workshop and the outcome of the Scheveningen Workshop on EcoQOs, provide recommendations for appropriate EcoQO indices for sea mammals based on 2.2.1 and 2.2.2 and suggestions for appropriate EcoQOs for North Sea mammal populations;*
- 2.2.4 *Prepare provisional estimates for the current levels, reference levels and target levels for the EcoQO indices identified.*

2.3 Further development of EcoQOs for seabirds

- 2.3.1 *Provide a synthesis of the status of North Sea populations of seabirds, including consideration of species that have declined or are threatened by human activities;*
- 2.3.2 *Consider the use of seabirds as indicators for environmental quality and short-term and long-term ecosystem effects;*
- 2.3.3 *Taking into account the outcome of the Oslo Workshop on Ecosystem Approach including the background document prepared for the workshop and the outcome of the Scheveningen Workshop on EcoQOs, provide recommendations for appropriate EcoQO indices for seabirds based on 2.3.1 and 2.3.2 and suggestions for appropriate EcoQOs for North Sea seabird populations;*
- 2.3.4 *Prepare provisional estimates for the current levels, reference levels and target levels for the EcoQO indices identified.*

4.3 Introduction

OSPAR and the OSPAR/ICES North Sea Task Force (NSTF) have a relatively long history in the development of Ecological Quality Objectives (EcoQOs), recently as part of an approach to implementing the provisions of Annex V of the OSPAR Convention and to implementing an “ecosystem approach” as required within the Convention on Biological Diversity. Skjoldal (1999) gives a comprehensive overview of their evolution. Interestingly, the first call for a definition of terms of EcoQOs was in a draft of the European Commission Ecological Quality of Water Directive (Skjoldal, 1999). This is the predecessor of the EU Water Framework Directive that will become of growing importance for the management of the EU’s coastal waters in the near future. However, the major starting point of EcoQOs has been the mutual demand of OSPAR and the NSTF for some method that allows assessment of the ecological status of the marine environment and definition of objectives for the preferred ecological status. The basis for the concept was a request from the Third North Sea Conference, in The Hague in 1990, to develop ecological objectives. The concept was thereafter developed from 1992 onwards during a series of international workshops. Ecological Quality (EcoQ) variables and the objectives derived from them have since been a permanent item on the OSPAR agenda, receiving regular attention during workshops and meetings. The result of all these efforts is that the scientific and political community associated with OSPAR began to develop and adapt a conceptual framework for EcoQs and EcoQOs. In some countries, additional scientific effort has been directed towards the further development of actual EcoQs and EcoQOs.

In March 1997, Environmental and Fisheries EC Commissioners and Ministers from states bordering the North Sea met to lay the basis for better integration of environmental and fisheries policy. The meeting issued a Statement of Conclusions (IMM, 1997). Conclusion 2.6¹ calls for the development and implementation of an

¹ The official text of Statement of Conclusion 2.6:

2.6 further integration of fisheries and environmental protection, conservation and management measures, drawing upon the development and application of an ecosystem approach which, as far as the best available scientific understanding and information permit, is based on in particular:

- the identification of processes in, and influences on, the ecosystems which are critical for maintaining their characteristic structure and functioning, productivity and biological diversity;
- taking into account the interaction among the different components in the food-webs of the ecosystems (multi-species approach) and other important ecosystem interactions; and
- providing for a chemical, physical and biological environment in these ecosystems consistent with a high level of protection of those critical ecosystem processes;

ecosystem approach in the management of marine ecosystems. As a follow up, a Workshop on the Ecosystem Approach was held in 1998 in Oslo, Norway. This workshop concluded, amongst others, that clear objectives are needed as part of the development of an ecosystem approach. The workshop further suggested that Ecological Quality Objectives under development within OSPAR could provide a solid basis for defining clear objectives (Anon., 1998). As a result, a workshop specifically on Ecological Quality Objectives was organized in 1999 in Scheveningen, the Netherlands. A mixture of policy-makers, stakeholders, and scientists attended both workshops.

The basic ecosystem properties included in the OSPAR conceptual framework for a methodology for describing EcoQs and setting EcoQOs (Skjoldal, 1999) are:

- Diversity
- Stability
- Resilience

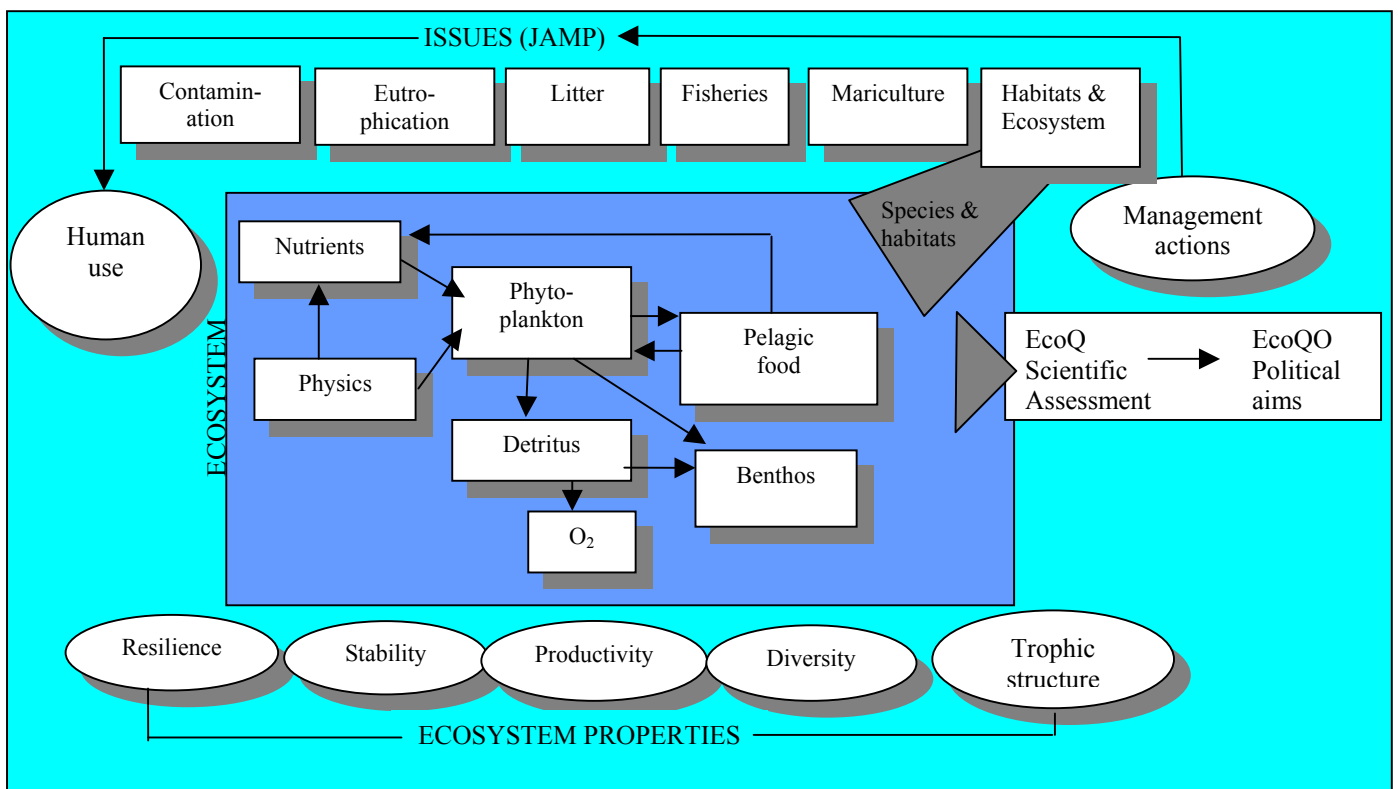
- Productivity
- Trophic Structure.

Because EcoQs have to address ecosystem properties in relation to human influences, the OSPAR Joint Assessment and Monitoring Programme (JAMP) issues were taken as a basis for covering the latter. These are:

- 1) Contaminants
- 2) Eutrophication
- 3) Litter
- 4) Fisheries
- 5) Mariculture
- 6) (Marine) Habitats and Ecosystem Health.

These issues are represented diagrammatically in Figure 4.3.1.

Figure 4.3.1. Conceptual framework for the methodology of describing Ecological Quality (EcoQ) and setting Ecological Quality Objectives (EcoQOs). EcoQ is an integral expression of the state of an ecosystem, reflecting basic ecosystem properties and human use. The human use variables are linked to the issues of the Joint Assessment and Monitoring Programme (JAMP), and provide a basis for setting objectives related to management actions.



Lanters *et al.* (1999) prepared a document that was considered at the Scheveningen Workshop. As a result, the workshop concluded that EcoQOs should be developed for ten issues (Anon., 1999). These ten issues (Table 4.3.1) cover EcoQOs at the species, community, and ecosystem levels. They also more or less cover the range from structural (diversity) to functional (processes) aspects of the ecosystem. The relevant OSPAR committee agreed that this list of ten issues would form the basis for future work (OSPAR, 2000), but did not preclude further improvement or extension of the proposed list of issues. Norway, the Netherlands, ICES, and the OSPAR Eutrophication Task Group (ETG) are now further developing proposals for EcoQOs for the set of ten issues (Table 4.3.1).

The objective of the OSPAR Biodiversity Committee is to put some clear examples of EcoQOs on the agenda of the Fifth North Sea Conference in March 2002. In this process, ICES is responsible only for the elaboration of EcoQOs for marine mammals and seabird species. All other issues fall outside the official request of OSPAR for ICES advice. However, EcoQOs in general are of importance for the ICES community. First of all, ICES could provide OSPAR with a first independent evaluation of the scientific credibility of the framework and methods being applied. Furthermore, ICES has a long history of dealing with reference points for fish populations that will be of great value when newer fields of marine science are explored.

In 1997, on a related issue the Working Group on Ecosystem Effects of Fishing Activities (WGECO) was asked to “*Develop and examine potential reference points which might be used for including ecosystem considerations in relation to the precautionary approach*”. This request was approached by considering whether the reference points already developed for commercial fish species offered sufficient conditions to ensure effective conservation of the larger ecosystem, if management were to respect the reference points fully.

This approach was justified with the reasoning that, although a few conceptual and many operational problems remained with advising on and managing fisheries in a precautionary framework, the tasks were still much simpler, and practical experience greater, with marine fisheries management than with marine ecosystem management (ICES, 1998). WGECO concluded that to ensure conservation of the ecosystem, additional reference points were required for:

- a) non-target species (by-catch and gear damage effects);
- b) ecologically dependent species (predators dependent on harvested species);
- c) species affected by scavengers (whose abundance increased by feeding on discards and offal);
- d) genetic diversity of exploited species.

When the list was completed, it was observed that conservation of each of these ecosystem components could be achieved through additional single-species reference points, where the species were carefully chosen on ecological grounds.

Reference points beyond species level were considered in depth, but were intentionally not brought forward for two reasons. First, community- and ecosystem-scale reference points were thought to be too speculative, because there was insufficient practical knowledge and theoretical basis for identifying limit or precautionary reference points. Second, notwithstanding the diverse modelling expertise in WGECO, no member was able to propose an integrative property of the ecosystem that could be shown to be at risk if the component species were being individually conserved with high probability. Both of these reasons highlighted the need for further study, because ecosystem reference points are potentially interesting, and it was suggested that the use of models may help in understanding the behaviour of ecosystem metrics (ICES, 1998).

Table 4.3.1. The ten issues for EcoQOs for the North Sea derived from the Scheveningen workshop (Anon., 1999), along with the country/organization taking the lead in further development of each target.

	Issue	Lead country/organization
1	Reference points for commercial fish species	Norway
2	Threatened or declining species	Netherlands
3	Sea mammals	ICES
4	Birds	ICES
5	Fish communities	Netherlands
6	Benthic communities	Netherlands/ETG
7	Plankton communities	ETG
8	Habitats	Norway
9	Nutrient budgets and production	ETG
10	Oxygen consumption	ETG

The issue of ecosystem objectives was revisited in the 1999 meeting of WGECO. The necessary objectives for ecosystem conservation were made more specific, to include spatial properties of populations as well as their abundance or biomass. More attention was also given to objectives for conservation of habitat features. However, with regard to emergent properties of ecosystems, WGECO again concluded “*While not ruling out the need to continue to monitor developments in this area, WGECO finds no evidence that such ecosystem properties need, or even can, be subject to direct management objectives. However, WGECO acknowledges that, even if reference points for emergent properties are not warranted by present knowledge, many measures of ecosystem properties, such as measures of diversity, can serve a valuable role in communicating with many clients of marine science*” (ICES, 2000). ACE agreed with these conclusions.

In the following introductory text, some important background issues are discussed. This is followed by sections advising on EcoQs for marine mammals and seabirds, then by advice requested by the European Commission on the use of reference points in fisheries advice. A section on further development of EcoQOs in the ICES context may be found in Section 4.11.

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4.4 Terminological Issues

Both OSPAR and ICES have been trying to place scientific advice and management decision-making with regard to marine environments and resources into a more rigorous and explicit framework. These efforts, and those of many other groups worldwide, have evolved from the meetings and agreements following from the 1992 UN Conference on Environment and Development (UNCED) in Rio de Janeiro, so it should not be surprising that many terms and phrases are used by both OSPAR and ICES (and other marine conservation and management organizations). Unfortunately, the terms have been evolving partially independently (even within different parts of ICES), so similar words and phrases often mean different things when used by different bodies. This creates potential for confusion and misunderstandings. The involvement of ICES with OSPAR’s initiative to develop EcoQOs for the North Sea makes it particularly important that terms be used in a consistent and clear manner (ICES, 2000b, 2000c; OSPAR, 2000). Although there has been a small evolution in the definition of EcoQs and EcoQOs, the main features of their definitions have hardly altered since 1992. Because EcoQOs are currently being developed under the flag of OSPAR, the definitions that came as a result of the Scheveningen Workshop (Anon., 1999) will be used (Figure 4.4.1). The following definitions apply throughout this report (ICES usages are those used throughout all ICES advice on fisheries, as summarized in Section 1 of ICES, 2001a):

Within **OSPAR, Ecological Quality (EcoQ)** is described as “*An overall expression of the structure and function of the marine ecosystem taking into account the biological community and natural physiographic, geographic and climatic factors as well as physical and chemical conditions including those resulting from human activities.*” Throughout this section, **EcoQ** is used in the sense of an element of the above definition, as ACE notes an inconsistency in the use of the term between the above definition and the following definition. An appropriate way of defining the above OSPAR concept might be to describe it as “Overall Ecological Quality”.

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

Reference points: In ICES advice regarding fisheries, **reference points** are specific values of measurable

properties of systems (biological, social, or economic) used as benchmarks for management and scientific advice. They function in management systems as guides to decisions or actions that will either maintain the probability of violating a reference point below a pre-identified risk tolerance, or keep the probability of violating a stock parameter reference point above a pre-identified risk tolerance (ICES, 2001a). There are usually two reference points given in fisheries advice for biomass and fishing mortality. In advice on non-fisheries issues, ICES terminology has been somewhat more variable, with **reference value** sometimes used in contexts identical to those where reference point is used in advice on fisheries.

Reference level: In OSPAR usage, **reference level** began as the level of EcoQ where the anthropogenic influence on the ecological system is minimal. It became clear that it could be very difficult or impossible to determine such reference levels, when systematic monitoring of properties related to the EcoQ began well after pristine conditions were perturbed. This not only applies to biological conditions, but also to naturally occurring chemical substances. Therefore, OSPAR acknowledged that a pragmatic approach might be required to establish and use reference levels. OSPAR noted that temporal trends could be informative about past conditions, and in some circumstances preliminary reference levels could be taken as the starting point of a time series. For this reason, the wording “**a** reference level” was preferred over the use of “**the** reference level” in the EcoQO definition (Anon., 1999). It should be emphasized that “reference level” should not be confused with the objective. Although the original meaning of “reference level” as defined in the context of EcoQOs had a different meaning than “reference points” used in the context of fisheries (OSPAR, 2000), the modified usage by OSPAR leads to the meaning of **reference level** being specific to each application. It appears that the criteria on which the reference level is set can change from EcoQ to EcoQ, or over time, leading to changes in the reference level as well, so in that sense reference level does function much like the concept of reference points in ICES advice. It should further be noted that a reference level may refer to a range of possible points that allows for natural variation around a point.

Target Reference Points: In ICES usage, particularly for fisheries, properties of stocks / species / ecosystems which are considered to be “desirable” from the combined perspective of biological, social, and economic considerations. Where they address biological aspects of

ecosystems, target reference points must in all cases be at least as “safe” as precautionary reference points selected on exclusively biological considerations. Beyond that conservation-based constraint, ICES has stressed that managers, decision-makers, and stakeholders have the responsibility for selecting target reference points (see Section 4.5.2). When ICES provides advice relative to **target reference points**, unless otherwise requested ICES assumes that management should be designed to achieve them on average, and hence advice is risk neutral with regard to them, as long as conservation reference points are not placed at unacceptable risk.

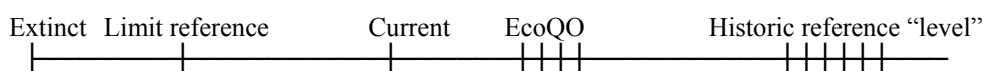
Target Levels: In OSPAR usage, target levels identify values of the EcoQ that management should be trying to maintain with high probability. In this usage, they function in a manner very similar to Target Reference Points as used by ICES. However, the request from OSPAR to ICES, as a scientific advisory body, to provide advice on suitable target levels suggests that target levels are identified through scientific endeavours. This is quite different from the ICES perspective on target reference points and the difference has not yet been resolved.

Limit Reference Point: In ICES usage, a value of a property of a resource that, if violated, is taken as *prima facie* evidence of a conservation concern. By “conservation concern”, ICES means that there is unacceptable risk of serious or irreversible harm to the resource. Outside the limit reference point, the stock has entered a state where there is evidence that:

productivity is seriously compromised, or
 exploitation is not sustainable, or
 stock dynamics are unknown.

Management should maintain stocks inside limit reference points with high probability. To account for uncertainty in assessments, ICES uses **precautionary reference points** as a basis for scientific advice, with the intent that management consistent with precautionary reference points should have a high probability of keeping a property away from its limit reference point. Limit Reference Points are based on the biology of the stock/species/ecosystem, independent of social and economic considerations. Hence, ICES has argued that they should be identified by technical experts, and has selected limit reference points for stocks on which it provides scientific advice.

Figure 4.4.1. Diagrammatic representation of an EcoQ metric with associated terminology (after AMOEBA representation, Skjoldal, 1999).



The request of OSPAR to ICES to develop EcoQOs makes it clear that the sometimes subtle differences in philosophies behind these concepts and terms need to be understood clearly. We do not think that it is possible to accurately describe historic biological reference points for a “pristine” state within an exploited ecosystem. In the following text, the philosophy behind the use of reference points within ICES fisheries advice is explained (taken from ICES, 1997).

Reference points are a key concept in implementing a precautionary approach. The following points from Annex II of the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks are relevant to the distinction between target and limit reference points:

“2. Two types of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points. Limit reference points set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield. Target reference points are intended to meet management objectives.

3. Precautionary reference points should be stock-specific to account, inter alia, for the reproductive capacity, the resilience of each stock and the characteristics of fisheries exploiting the stock, as well as other sources of mortality and major sources of uncertainty.

5. Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low. If a stock falls below a limit reference point or is at risk of falling below such a reference point, conservation and management action should be initiated to facilitate stock recovery. Fishery management strategies shall ensure that target reference points are not exceeded on average.

7. The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. For stocks which are not overfished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a predefined threshold. For overfished stocks, the biomass which would produce maximum sustainable yield can serve as a rebuilding target.

Therefore, reference points stated in terms of fishing mortality rates or biomass, or in other units, should be regarded as signposts giving information of the status of the stock in relation to predefined limits that should be avoided or targets that should be aimed at in order to achieve the management objective.”

Although not points of specific inconsistency between OSPAR and ICES, there are a few terms used in very specific and consistent ways in ICES fisheries advice,

but in the larger community of those interested in marine ecosystems and conservation the terms have a variety of meanings. In this report, the terms will always be used with the ICES meanings, unless specifically stated otherwise. For that reason, it may be helpful to explain those usages here.

Conservation is used in the sense of conserving natural resources. The resources can be used as long as the usage is at rates and in ways that do not place the resource, or the ecosystem in which it is found, at risk of harm that is serious or difficult to reverse in the short, medium or long term. Resources may be being conserved when they are in conditions quite different from their pristine states.

Sustainability is used to refer to the use(s) made of the resource, and not to the state of the resource. A strategy for use of a resource is sustainable when it could be pursued in the long term without causing unacceptable risk of a conservation problem for the resource being used, or the ecosystem in which it is found. Quite often a fishery, for example, is said to be sustainable, when, to be precise, what is meant is that the strategies used to manage and prosecute the fisheries are sustainable. By applying “sustainable” strictly to the use, and not to the resource itself, this is a slightly more restrictive use of the term “sustainable” than is encountered in some general reports on conservation of biodiversity, but is in no way inconsistent with those uses.

For example, the Convention on Biological Diversity (CBD) defines the term “Sustainable Use” to mean “the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.” As with the ICES usage, the CBD definition includes the notions of using the resource, but in ways that can be continued in the long term without causing conservation problems.

The final terminological issue relative to this material is our use of **metric** to refer to the attribute that is being considered as an indicator of an ecological quality of the system. We note that “indicator” sometimes carries a specific meaning as an “indicator species”. Therefore we use **metric** in all cases where we mean something that can be measured quantitatively (or, when appropriate, qualitatively) and can at least be considered as being a suitable way to measure the ecological property that the EcoQ is intended to capture. Where we use **indicator**, we mean for it to be interpreted in the sense of “indicator species”.

4.5 Conceptual Issues

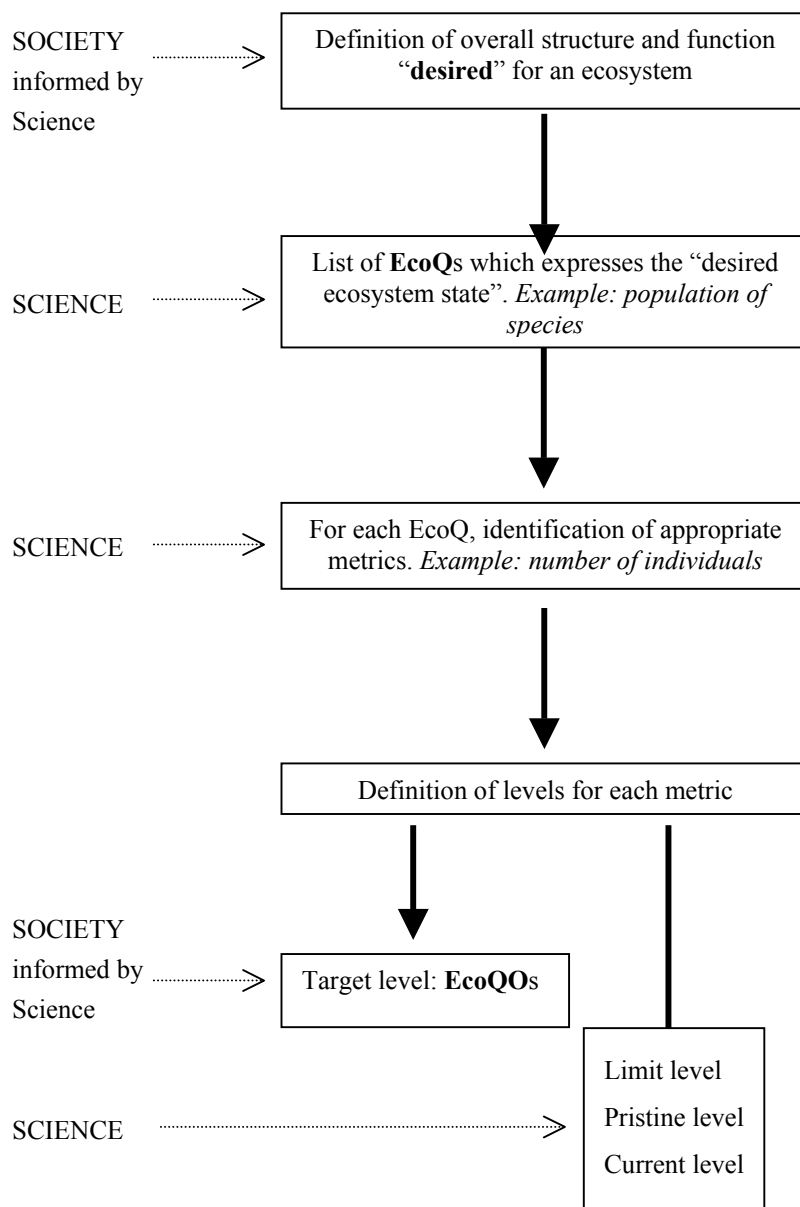
4.5.1 Interaction between EcoQ and EcoQO

As noted above, the requirement for the development of EcoQOs arises from the need to bring forward an “ecosystem approach” to environmental management.

Unfortunately, the term “ecosystem approach” has been used in a wide variety of contexts and has been imparted with a range of definitions, as have the terms EcoQ and EcoQO (Section 4.4). From the OSPAR definitions, a sequential framework for developing EcoQs and EcoQOs can be seen (Figure 4.4.1). The starting point for the development of ecosystem approaches to environmental management is to define the “overall structure and function” desired for the ecosystem being considered. The specification of this “desired ecosystem” is a societal decision, although science has some key roles (Figure 4.5.1.1). This desired overall state of the ecosystem must be expressed as a series of clear

statements that will constitute the list of EcoQs. Next, it is necessary to identify at least one metric for each EcoQ. The question of the necessary and sufficient number of metrics to ensure conservation of the system or even achieve the EcoQs specified by society, is not simple (Section 4.5.2). From this list of metrics, one must derive desired levels for various measures of the system, which correspond back to the “desired ecosystem” initially specified by society. The desired values of the metrics comprise the suite of EcoQOs. Consistent with the changing OSPAR definition of “reference level”, there is no inherent need for EcoQOs to be set always to the condition where anthropogenic influences are minimal.

Figure 4.5.1.1. Conceptual framework for the methodology of describing EcoQ and setting EcoQOs (from ICES, 2001d).



In fact, this would imply no use of environmental services such as waste treatment or food production. Rather, the “appropriate” values for the EcoQOs are determined by the overall desired ecosystem. The appropriate metrics and quantitative values for the EcoQs and EcoQOs will vary among systems and depend on the priority given to various issues. Moreover, it is implicit that the setting of EcoQOs should be done in an integrated manner, to ensure that the sets are mutually achievable and collectively sufficient to ensure conservation of the ecosystem. However, for pragmatic reasons the initial approach used at the Scheveningen workshop and continued by OSPAR in its request for advice is to develop EcoQOs for various ecosystem components in a variety of different groups (Section 4.3). The implications of a number of these issues are discussed in the following sections.

4.5.2 Role of science

The different approaches to reference points, reference levels, limits, and targets increases the potential for confusion about suitable roles for technical experts, policy-makers, and advocates of many sectors including users and non-users. Although it is inappropriate for ICES to advise on preferred governance approaches among policy-makers and public sectors, it is important that the role of science be understood in the larger process of selecting and implementing EcoQs and EcoQOs. Note that the term technical expert is used here, to make clear that “scientists” includes not just biological, physical, and chemical scientists and collaborating quantitative experts. Social sciences also have an important contribution to make to science’s role.

The selection of properties of ecosystems that are essential to their conservation is the responsibility of technical experts, as is the selection of metrics of those properties. If clients wish to have relative priorities assigned to the general properties or their specific metrics, technical experts also have a key, but not exclusive, role. Technical experts are the appropriate group to assign priorities based on the degree to which conservation of the ecosystem depends on each of various properties of the system, as well as to assign priorities among metrics based on their reliability and sensitivity. Rankings of properties and metrics based on human values is not an issue appropriate for biological and physical scientists, although social scientists may work with policy-makers and the public to clarify public opinion on such rankings.

Once a suite of properties needed for conservation of the ecosystem is identified, and metrics of the properties selected, several groups have roles in setting various benchmarks along the metrics, and identifying acceptable and unacceptable domains of the properties (Figure 4.4.1). It is the responsibility of the technical experts to specify lower (or upper) conservation limits for metrics and properties, that is, values of a metric or states of a property below (or above) which there is increasing risk

of harm that is serious or difficult to reverse. (Some properties and their metrics may have both upper and lower limits associated with conservation.) There will almost always be uncertainties with regard to determination of both conservation limits of properties and metrics, and current states of properties and metrics. Technical experts are also responsible for quantifying such uncertainties to the fullest extent possible, and selecting precautionary positions on the properties and metrics such that if management is risk neutral relative to the precautionary reference points, there will be a high probability that the conservation limits will be avoided. For many plausible candidate metrics, there is insufficient contrast in the historical data (if the data exist at all) to be informative about where the conservation limit may be, and in such instances, technical experts have special challenges in determining how to advise on managing risk.

If policy-makers or the public wish to know the state of a property prior to substantial anthropogenic perturbations, it is also a question that should be answered by technical experts. That does not mean that the question is always answerable, or that the answer, if possible to provide, is a sound basis for management. The same points apply to questions about the maximum (or minimum) value that a property or metric could assume, if management were intended to achieve the most extreme state possible for that ecological attribute of a system.

Between the states that are determined by conservation limits to be avoided with high probability and the most unaltered or extreme value possible to achieve, policy-makers and society have to choose the desired state that management should aim for. Such targets are chosen on the basis of society’s values, often as interpreted by policy-makers. Technical experts may participate in this exercise as citizens, advocating whatever point of view they may have. However, they have the responsibility to acknowledge that they are merely advocating their particular special interest (even if they believe it is an especially enlightened one), and have no special privileges at the table where competing interests are seeking consensus. It can be difficult to keep these identities distinct, because the technical experts have a role during the negotiations leading to setting management targets: that of warning when targets under consideration would place the conservation limits at unacceptable risk of being violated. Such advice has to be perceived as objective and impartial, which can be difficult when the same individuals have been involved in debates over proper values to be the basis for society’s choices. Assuming that consensus can be achieved on a set of management objectives that are mutually compatible, the technical experts have a final role to lead the translation of society’s values, often expressed qualitatively, into operational management targets, expressed in the currencies of the metrics. This may make it appear that the technical experts are setting the targets, or the EcoQOs, but their role is only as translator of society’s choices onto the biological axes that are being used.

4.5.3 Issues regarding implementation

There are clearly far more potential metrics of EcoQs that could be used in management of the North Sea than are practical, given available funds for monitoring and assessments. OSPAR will have to make some choices among them, but once made, there are a number of scientific activities that must be done. Scientists should carry out a sensitivity analysis of various methods and data sets to select on technical grounds the optimal combination for future use. This step alone may require further interaction with OSPAR, if the detailed technical review reveals unforeseen but crippling technical problems for some preferred metrics of ecological quality. Once EcoQ metrics, data standards, and calculation algorithms all have been decided upon, relevant data sets for each of them must be collected and analysed periodically. Both processes require quality control to ensure that any advice derived from such data is perfectly defensible.

There is still considerable uncertainty about the effectiveness with which such metrics may in practice measure the response of the system to human impact. Therefore, the research community should work with the scientific advisory and management framework explicitly to explore the occurrence of true hits as well as false alarms and misses in historic series of the EcoQ metric and human activity. Also, it is important to ascertain that the metrics match the set of potential impacts that management measures can address, and to evaluate the performance of EcoQO-based advice over time in improving management decision-making and actions.

There are further specific problems of scientific advice that will need to be addressed:

- 1) The selection of “appropriate” EcoQOs is not straightforward (Section 4.5.1), partly because what is “appropriate” cannot be singularly defined scientifically, and partly because there is incomplete scientific knowledge about what aspects of an ecosystem are necessary and sufficient for its conservation. Compared to single-species fisheries advice, where keeping spawning biomass large, and exploitation rates low is likely (but not guaranteed) to keep harvesting sustainable and to conserve stocks, guides to successful ecosystem management are less clear. Given the complexity of marine ecosystems, there are many properties that one might argue need to be conserved and a nearly infinite number of potential metrics of these properties. It is clear from a pragmatic point of view that we have to be selective, and have to select wisely. Although it is relatively easy to formulate important selection criteria for EcoQ metrics, applying these over a wide scale of potential metrics is by no means straightforward.
- 2) More importantly, the approach chosen by OSPAR deviates from the existing one used by ICES and its customers for commercial stocks. This is because, in

the OSPAR framework, the EcoQO (the target) is to be set relative to the current level and to a reference level that should reflect a situation when anthropogenic impact was minimal (with allowance for a pragmatic approach), rather than a limit reference point (LRP) referring to conditions considered not sustainable and posing unacceptable risk to the resource. In fact, for many potential EcoQ metrics it will be difficult, if at all possible, to define a level associated with “unsustainability” or otherwise with an unacceptable threat to the ecosystem. In the EcoQ system, the possibility of large numbers of metrics combined with poorly determined conservation limits on many of them will make any scientific advice even easier to contest by stakeholders and also by other experts. Current fisheries advice formulated in the sense of keeping the impact below some unsustainable level is obviously much easier to defend than EcoQ-based advice that points to some current and historic values whose distances from a LRP are known only vaguely or not at all. The resultant lack of defensibility might well further reduce rather than enforce the impact of scientific advice on management and therefore could easily undermine the advisory role of ICES.

- 3) By definition, any broad EcoQ metric for a community reflects the ecosystem response to a broad set of human impacts, and therefore the contribution of each activity to its present value may not be singled out easily. In fact, any particular value of a metric of an EcoQ may arise from completely different combinations of different impacts. This will make it much more difficult to predict how the metric will respond to various options to reduce one particular impact, and to assign responsibility (and associated costs) among possible contributors, when a metric does indicate a conservation problem. On these grounds, EcoQs and their metrics selected because they are responsive to a specific threat seem particularly useful.

Although the approach seems promising in principle, embarking on giving advice on EcoQOs will set high demands on developing a rigorous and defensible advisory framework, which will take considerable time. Therefore, it would seem wise to concentrate on developing a suite of EcoQ metrics first and to test their performance particularly with a view to defining potential LRPs before endeavouring recommendations on EcoQOs. It is likely that management systems, as well as scientific advisory systems, must also adjust to new and greater demands on their effectiveness, if they are to be able to enact and enforce management measures based on the best ecosystem advice possible.

4.5.4 Practical considerations regarding making EcoQs work together for integrated management

The OSPAR decision to proceed with identifying EcoQs separately for ten issues permits possibly hundreds of EcoQs to be proposed, in order to guarantee that the

entire marine ecosystem and all the processes that operate within it were covered. Although this decision was considered to be pragmatic (Anon., 1999), each EcoQ would have at least one EcoQO to be monitored and managed. Currently, fisheries managers struggle to address adequately targets for fourteen annually assessed commercial fish and benthic species in the North Sea, along with the additional seven non-assessed species, or species groups, for which Total Allowable Catches (TACs) are set. Add to these the need to account simultaneously for EcoQOs for threatened and declining species, seabird and marine mammal species, fish and benthos communities, habitats, and two ecosystem process issues, and the task of managers becomes much more complex. Where management actions will be necessary, some may be difficult, costly, and/or controversial, and for reasons of logistics or politics, it may not be possible to implement them all at once. This creates at least two classes of problems: assigning priorities and achieving intercompatibility.

The requirement to rank these EcoQs and EcoQOs so as to be able to choose which to pursue aggressively and which to defer seems inevitable. Where much effort has been invested in gaining social consensus on EcoQOs on which different sectors of society placed different initial values, and whose achievement will demand differential subsequent costs, opening a second debate on the priority of that EcoQO relative to others may be divisive. It needs to be clear in advance whose task it will be to carry out these ranking and reconciliation exercises. What will happen to the EcoQOs that are ranked low or are incompatible?

As the number of EcoQOs increases, so does the risk of redundancy or, more seriously, mutual incompatibility. In attempting, for example, to restore commercial fish stocks, and fish and benthic communities to some improved state, the population dynamics for some seabird and marine mammal species may be affected in such a way as to, at the very least, inhibit future population growth, if not cause actual population declines. In considering such potential conflicts, the logic behind the different objectives needs to be carefully maintained. The goals for commercial fish stocks and fish and benthos communities appear, at the very least, to be to return the system to a state characteristic of several decades ago. Some seabird species are currently at population sizes many times higher than they were at the start of the Twentieth Century. Much of this increase has been attributed to fishing activity: the provision of additional food resources at key times of the year through discarding, the increase in the abundance of small fish in the assemblage through size-selective fishing, and the removal of large predatory fish that may have competed with seabirds. Changes within the fish components of the ecosystem to a greater proportion of larger fish and fewer discards may render the North Sea a much more inhospitable place for some species of seabirds. Are EcoQOs for seabirds likely to reflect this, and allow for significant declines in some of our most

abundant seabird species? Or will they be set so as to try and conserve the current state?

These difficulties are nearly unavoidable, if EcoQs for the ten EcoQ issues are developed and implemented independently. This decision may prove to have been pragmatic from the point of view that it by-passed the enormous hurdle of determining one (or at most a few) holistic ecosystem objectives, if such even exist, and so allowed the process to proceed quickly. However, the same hurdle may simply be encountered later, when it comes to putting the process into practice. At that point it will be necessary to gain social consensus on ranking which EcoQOs to pursue most aggressively, and on compromises to reconcile incompatible EcoQOs. Because these are human issues, clearly social scientists need to be more involved in the EcoQ and EcoQO initiative.

To balance this pessimistic view, there are some potential steps forward. Short of the grail of one (or a very few) all-encompassing EcoQ and EcoQO, some simplification of the implementation task can be achieved by recognizing opportunities, if they exist, for one EcoQ to address more than one of the ten issues. This may be practical, regardless of whether one believes that a single well-chosen community-scale EcoQ may protect many species of fish, seabirds, marine mammals and benthos, or that an EcoQ for a well-chosen species, sensitive and vulnerable to several threats, may ensure the ecological quality of many other species and the larger community of which it is part. Also, a policy framework is developing that may guide ranking and reconciliation of EcoQs. The 1997 Intermediate Ministerial Meeting on the Integration of Fisheries and Environmental Issues laid down some guiding principles that require the development of an ecosystem approach to management, taking account of critical ecosystem processes, and involve a multispecies approach. This will be difficult or impossible to realize without giving priority to EcoQOs that are related to OSPAR's communities and ecosystem processes issues, even if they are difficult to make operational.

4.5.5 Types of EcoQ

Two basic types of EcoQ are recommended below. The first type concerns properties of a population and is designed primarily to provide a metric to help manage that organism (e.g., the state of seabird populations). The second type uses properties of an organism or population as an indicator of a wider ecological state, and may be used in order to provide assistance in managing human activities affecting that wider ecological state. The majority of indicators for seabirds are of this latter type. The seabird EcoQs were designed also to meet the OSPAR Joint Assessment and Monitoring Programme (JAMP) categories. These are: a) contaminants; b) eutrophication; c) litter; d) fisheries; e) mariculture; and f) marine habitats and ecosystem health. It is likely that further consideration would reveal further possible

EcoQs and those listed below should be regarded as first suggestions.

4.5.6 Criteria for good Ecological Quality metrics

As noted above, the concept of ecological quality objectives (EcoQOs) has been discussed in a number of documents and at a number of recent meetings (Anon., 1999; Lanfers *et al.*, 1999; Kabuta and Enserinck, 2000; ICES, 2001b, 2001c; Piet, 2001). Several key features of EcoQ metrics may be derived from these discussions. These may be summarized as follows:

Metrics of EcoQs should be:

- a) relatively easy to understand by non-scientists and those who will decide on their use;
- b) sensitive to a manageable human activity;
- c) relatively tightly linked in time to that activity;
- d) easily and accurately measured, with a low error rate;
- e) responsive primarily to a human activity, with low responsiveness to other causes of change;
- f) measurable over a large proportion of the area to which the EcoQ metric is to apply;
- g) based on an existing body or time series of data to allow a realistic setting of objectives.

ICES (2001d) used these criteria to assess the usefulness of a set of possible EcoQs on marine communities.

4.5.7 References

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4.6 Marine Mammals

4.6.1 The status of North Sea populations of marine mammals

4.6.1.1 Introduction

Several species of marine mammals are resident in the North Sea. Two are seals: harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*). Of the cetaceans, harbour porpoises (*Phocoena phocoena*) are the most abundant; white-beaked dolphins (*Lagenorhynchus albirostris*), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), and the minke whale (*Balaenoptera acutorostrata*) occur regularly over large parts of the North Sea in some numbers, and bottlenose dolphins (*Tursiops truncatus*) occur as residents in two areas. The abundance of seals is relatively well known, but there has only been one complete North Sea survey (in 1994) to assess cetacean abundance (Hammond *et al.*, 1995).

Several species of marine mammals occur in the North Sea on an occasional or temporary basis. Hooded seals (*Cystophora cristata*), killer whales (*Orcinus orca*), long-finned pilot whales (*Globicephala melas*), Sowerby's beaked whales (*Mesoplodon bidens*), northern bottlenose whales (*Hyperoodon ampullatus*), and Risso's dolphins (*Grampus griseus*) regularly enter the northwest entrances to the North Sea. Sperm whales (*Physeter macrocephalus*), which prefer deep water, have been found stranded in some numbers along the Danish, German, Dutch, and English coasts of the North Sea in some winters of the 1990s. More occasionally, the larger whales including the sei whale (*Balaenoptera borealis*), fin whale (*Balaenoptera physalus*), and blue whale (*Balaenoptera musculus*) also approach the borders of the North Sea. The common dolphin (*Delphinus delphis*) and striped dolphin (*Stenella coeruleoalba*) frequently enter both the northwest North Sea entrances and the southern English Channel waters (Hammond *et al.*, 1995) and are occasionally found as far as the Baltic Sea.

The abundance of cetaceans was assessed using figures from the most appropriate survey blocks (B-I', L and Y of Hammond *et al.*, 1995) used in 1994. Seal populations of the North Sea area (defined as OSPAR Area II) were derived from a variety of sources (ICES, 2001).

4.6.1.2 Current population sizes and trends of cetaceans

Estimates of population size and their CVs are provided in Table 4.6.1.2.1. Early planning has been undertaken

Table 4.6.1.2.1. Abundance estimates of the most common cetacean species from the SCANS Survey in the North Sea in 1994 (Hammond *et al.*, 1995). Bottlenose dolphin estimates are from Wilson *et al.* (1999) for the Moray Firth and from ICES (1996) for the Channel.

Species	Year of estimate	Abundance estimate	Confidence interval
Harbour porpoise	1994	309,000	237,000–381,000
Bottlenose dolphin			
Moray Firth	1998	129	110–174
Channel	1993	116	–
White-beaked and Atlantic white-sided dolphins	1994	11,000	5,500–16,300
Minke whale	1994	7,300	4,200–10,300

for a second survey of the North Sea and parts of the Baltic Sea, as well as for waters to the west of Britain, Ireland, and France. It is likely that there is some stock division into populations within the North Sea, but the situation is complex. As there has only been one survey, no quantitative estimates of trends in abundance are currently available.

Harbour porpoises are distributed throughout the northern North Sea and Skagerrak, but decrease in abundance off the Lower Saxony coast, are rare in the Southern Bight of the North Sea, and virtually absent in the Channel. There is some evidence that the species was more common in this latter area in the past. There has been a recent increase in strandings and sightings off the Dutch and Belgian coasts.

Minke whales in the North Sea form part of the Northeast Atlantic stock (IWC definition) that has been estimated at 112,000 animals (88,000–135,000).

4.6.1.3 Current population size and trends of harbour seals

Harbour seals are resident in several parts of the North Sea coast. Estimates of their abundance are provided in Table 4.6.1.3.1. Populations are increasing in most areas where there is information, with the exception of those in Orkney, the Moray Firth, and the Limfjord.

Table 4.6.1.3.1. Estimates of abundance and trends in size of harbour seal populations of the North Sea (see ICES (2001) for further details).

Area	Year of count	Haul-out count	Extrapolated abundance estimate	Recent trends (annual increase)
Skagerrak/Oslofjord	2000	3,938	7,000	+9.4 %
Norwegian North Sea coast	1996–1998	2,285	na	+
Scotland	1996–1999	16,134	na	+/-
England	1994–1999	3,568	na	+5.9 %
Wadden Sea	2000	18,000	na	+13 %
Limfjord	2000	495	884	-40 %
Total		44,420		

4.6.1.4 Current population size and trends of grey seals

About 95 % of the North Sea population of grey seals (61,500 animals in 1999) occurs in UK waters (Table 4.6.1.4.1). They are particularly abundant in the Orkney area. Declining pup production has been observed in most UK breeding areas since 1998, but an increasing total population size is projected until 2004.

Dutch, German, Danish, and Norwegian North Sea waters host small colonies of the species. Their total size does not exceed several hundred animals. Danish waters have been important for grey seals historically. However, grey seals were virtually extirpated in the 1930s.

4.6.2 Threats caused by human activities

Hunting was the major source of mortality for marine mammals, particularly seals, of the North Sea prior to World War II. In modern times, the main source of anthropogenic mortality is by incidental take in fisheries. Pollution may be having an indirect effect by compromising immune systems; an epizootic in the late 1980s caused mass mortality of harbour seals, particularly in the southern North Sea. The Agreement on Small Cetaceans of the Baltic and the North Sea (ASCOBANS) came into force in 1992 in order to help alleviate such threats for small cetaceans. Similarly, an agreement on seal conservation has been signed for the Wadden Sea by relevant coastal states.

Table 4.6.1.4.1. Estimates of abundance and trends in size of grey seal populations of the North Sea (recent figures from ICES (2001), older figures from ICES (1996)). The Wadden Sea figure is not complete.

Area	Year of count	Pup count	Abundance estimate	Recent trends (annual increase)
Skagerrak	2000	0	30	0
Norwegian North Sea coast	2000	21	na	+
Scotland (+Shetland)	1999 (1983)	17,287 (+1000)	57,000 (+3,300)	-
English North Sea	1999	1,346	4,500	+/-
Southwest England	1973	107	na	+
France	1993	2	na	+
Wadden Sea	2000	43+	na	+

4.6.2.1 Direct take

Hunting of cetaceans in the North Sea was limited in the past. It was confined to whaling to the north and west of Shetland and Orkney, where baleen whales were taken in small numbers. This whaling ceased early in the Twentieth Century. Minke whales are still taken by Norwegian vessels. Annual takes in the North Sea were 88–139 whales in 1998–2000.

Seal hunting was much more prevalent historically and some populations have been extirpated. Hunting of seals ended after World War II in most areas. Since then they have been taken in very small numbers only locally at irregular intervals.

4.6.2.2 Incidental mortality

Almost all fishing gear placed in areas used by marine mammals risks entangling or trapping these animals. Records of such entanglement have been collated in a number of places (e.g., Northridge, 1991). Harbour porpoise populations are threatened by by-catch in fisheries in the North Sea. Estimated takes amount to between 3–4 % of the stock size of harbour porpoises in the southern and central North Sea. This is much higher than the 1.7 % take that modelling indicates might be sustainable, as agreed by ASCOBANS (see Section 3 of this report). By-catch appears to be unevenly spread over the year, with most by-catch occurring in the turbot and cod fisheries in the third quarter. The largest fleet by-catching harbour porpoises is Danish, but by-catches by similar metiers employed by fleets of other nations are similar per unit effort (ICES, 2001). Recent declines in fishing effort may have reduced by-catches.

4.6.3 Synthesis of the health status of sea mammals in the North Sea in relation to the quality of their habitat

ACE cannot at present provide a synthesis or assessment of the health status of sea mammals in the North Sea in relation to the quality of their habitat. This is partly because there is no framework to describe either health status or marine mammal habitat quality. An ICES working group (ICES, 2001) has considered various approaches to developing this issue further and their considerations are contained in Annex 1. The group identified two ways to approach the problem. One way would be to contrast habitat quality in relatively undisturbed or pristine areas with that from areas that are more heavily used. A second method is to characterize the condition of populations using demographic and physiological parameters. An index of population condition could then be derived from this set of parameters. Given that all of the North Sea is heavily used, the second approach is the only realistic way forward. ICES suggests a number of metrics, along with discussion of their advantages and disadvantages.

4.7 Ecosystem Quality Metrics for Marine Mammals in the North Sea

4.7.1 Seal population size in the North Sea

4.7.1.1 Background

At present, most North Sea seal populations are increasing in size (see Section 4.6, above). For some populations, this increase has persisted for many years, possibly as a consequence of past reductions due to hunting and an increase in the supply of small fish. In other populations, the increase reflects recovery from widespread mortality during an epizootic in the late 1980s. Some of these rates of increase are currently high. It would be reasonable to assume that these rates of increase would slow or even reverse as the carrying capacity of the North Sea was reached. At this point, seal populations would change within the limits set by natural and other factors. Documented changes in seal populations cannot usually be explained in full due to a lack of information on how various natural and human-induced environmental factors affect their main population parameters such as reproduction, recruitment, and survival rates. The magnitude of such changes may, nevertheless, serve as an adequate EcoQ for the intrinsic health of seal populations and their habitat. This is based on the simple assumption that a pronounced negative trend in the population of any seal species could indicate that it is an undesirable effect of human activities. Ideally, and as a precautionary measure, reaching such a threshold should then trigger adequate studies targeted at revealing its underlying causes. If the change proves to be an undesired consequence of human activities, any useful mitigating measure should be identified and implemented. In some cases, monitoring the effect of these measures may benefit from defining additional and more specific EcoQs for the seal populations and/or environmental factors involved.

Where possible, e.g., grey seal pup counts in the UK and harbour seal pup counts in the Kattegat-Skagerrak could be utilized as EcoQs for population size. Under current conditions, no change or a continued increase in population size and pup production would be expected, whereas a 10 % decline in population size or pup production within a ten-year period or less should result in management considerations.

4.7.1.2 Robustness of proposed EcoQ

On a short-term scale, seal population size may not be the metric most sensitive to environmental change. Due to the longevity and delayed maturity of seals, several years are usually needed before changes in their reproduction or immature survival rates affect their breeding numbers. Substantial increases in adult mortality would have a more immediate effect. Nevertheless, rates of change in population sizes are reasonably good metrics of important changes in seal populations, where density-dependent effects may easily

reduce the usability of other population parameters such as absolute size.

The number of births is a sensitive parameter responding more rapidly than total population size to changes in habitat conditions such as food availability. Pup/adult ratio is probably a metric that will rapidly pick up impaired production in harbour seal populations where populations are surveyed during breeding and moulting seasons.

4.7.1.3 Provisional estimates for EcoQ levels in the North Sea

EcoQ title: *Seal population trends in the North Sea*

EcoQ reference level: In the absence of major mortality incidents, declines in population size or pup production of greater than 5 % per annum would be unusual in seal populations at or below carrying capacity levels.

Current level: Variable, but most populations are increasing (see Section 4.6.1).

Suggested EcoQO target level: No decline in population size or pup production of ≥ 10 % over < 10 years. Such trends would need to be present over at least three years to allow for short-term disturbance effects.

4.7.1.4 Assessment of usefulness of suggested EcoQ

This EcoQ would be relatively easily understood by non-scientists. However, changes in population size might not be sensitive to changes in a specific human activity, thus reducing its immediate usefulness to managers. Changes may or may not be tightly linked to an activity, but trends can be relatively easily and accurately measured over a large proportion of the area occupied by the North Sea population. The time series of data available is good.

4.7.2 Distribution of marine mammal populations

4.7.2.1 Background

If habitat quality deteriorates within a species' geographical range, change or reduction in the species distribution may be observed before any impact may be detected in population size. Within the North Sea, there are indications of the absence of harbour porpoises in areas formerly occupied by the species (e.g., Hammond *et al.*, 1995). However, detection of changes in cetacean distribution may be associated with complex survey methodology and high monitoring costs.

In harbour and grey seals, high fidelity to the natal site is documented, and presence/absence at breeding sites would be particularly useful as an Ecological Quality metric as there is a long time series of data in many areas

throughout the North Sea. ICES does not at present have the information available to determine the number of known, regularly occurring, breeding sites of seals in the North Sea, but these figures should be relatively easy to derive from existing national seal monitoring data. At a pristine level, no sites would be abandoned. If any breeding sites were abandoned, then this would require management action to determine the causes and to act.

4.7.2.2 Robustness of proposed EcoQ

The presence/absence of seals at breeding sites is easily detectable with cost-effective survey methods. With the fidelity for natal sites documented in harbour and grey seals, abandoning breeding sites is a strong metric of habitat degradation (or massive depletion of the population).

4.7.2.3 Provisional estimates for EcoQ levels in the North Sea

EcoQ title: *Utilization of seal breeding sites in the North Sea*

Reference level: Current level may be used as an interim reference level until information on the historic use of breeding sites is compiled for the North Sea region.

Current level: Known, but not compiled at present. Can be compiled rapidly if this is required.

Suggested EcoQO target level: No abandonment of North Sea harbour and grey seal breeding sites.

4.7.2.4 Assessment of usefulness of suggested EcoQ

This EcoQ would be relatively easily understood by non-scientists. However, changes in population distribution might not be sensitive to changes in a specific human activity, thus reducing its immediate usefulness to managers. Changes may or may not be tightly linked to an activity, but distribution can be relatively easily and accurately measured over a large proportion of the area occupied by the North Sea population. The time series of data available is good.

4.7.3 Marine mammal by-catch as metric for marine mammal population status and sustainable fisheries

4.7.3.1 Background

Incidental catches associated with fisheries can have a negative impact on marine mammal populations. Harbour porpoise by-catch has been identified as an important source of mortality, and would indicate that significant by-catches could exist for other species as well. Maximum rates of increase of odontocete populations are not known. In the absence of such

information, maximum rates of increase of 4 % have been adopted (Wade, 1998) that may be conservative for some species (Reilly and Barlow, 1986; Caswell *et al.*, 1998). As an interim measure, the Scientific Committee of the IWC advised that by-catch levels of harbour porpoises should not exceed half the maximum rate of increase (IWC, 1996), and the Committee adopted a figure of 1 % of estimated abundance as a reasonable and precautionary level beyond which to be concerned about the sustainability of anthropogenic removals (IWC, 1996). A joint IWC-ASCOBANS Working Group modelled the maximum by-catch levels of harbour porpoises required for meeting the ASCOBANS management objective (i.e., restoring populations to, or maintaining them at, 80 % of the carrying capacity), and found that the maximum annual by-catch must be less than 1.7 % to ensure a high probability of meeting this objective over an infinite time horizon. The IWC-ASCOBANS Working Group therefore advised that the ASCOBANS interim objective is not likely to be met by reducing annual by-catch to 2 % of the lower estimate of abundance and that, to meet the objective, by-catch must be reduced further (IWC-ASCOBANS, 2000). Following this scientific advice, the ASCOBANS Third Meeting of Parties in 2000 decided that 1.7 % of estimated abundance is the limit of unacceptable incidental takes of all small cetacean species in the North Sea and Baltic Sea (ASCOBANS, 2000).

By-catch levels within the North Sea are best documented for harbour porpoises. These are variable by population, but it appears that the highest by-catch level is that of harbour porpoises within the central and southern North Sea. In the combined Danish fisheries alone, the extrapolated by-catch was about 3,000 individuals in 2000. In the recent past, this figure has been as high as 8,000 per year. In addition to this, UK fisheries in the same area took in the order of 800 individuals in 1995, and 440 individuals in 1999. Total by-catch levels most likely exceed the sustainable levels for harbour porpoises in this area of the North Sea. The full impact of these by-catches cannot be evaluated because other fisheries (in particular, Norwegian fisheries) operating in the same harbour porpoise abundance area are not yet monitored for by-catches. The recent decline in by-catch levels of Danish and UK fisheries is a result of reduced fishing efforts (see Section 3).

4.7.3.2 Robustness of proposed EcoQ

Obtaining by-catch statistics for porpoises is costly and involves onboard observers. However, statistics from independent observer schemes are regarded as reliable and, when all fisheries in an area are adequately monitored, by-catch levels are good metrics for anthropogenic mortality and population status. By-catches are direct effects of human activity and immediate responses in by-catch levels may be expected from management actions targeted at fishing operations.

4.7.3.3 Provisional estimates for EcoQ levels in the North Sea

EcoQ title: *Harbour porpoise by-catch in the North Sea*

Reference level: Pre-fishery by-catch levels were zero.

Current level: This cannot be calculated until all relevant fisheries operating in the North Sea are adequately monitored.

Suggested EcoQO target level: By-catch rates for harbour porpoises (or sub-populations) should be reduced to levels below 1.7 % of the relevant stock size.

4.7.3.4 Assessment of usefulness of suggested EcoQ

With the exception of the complexity underlying the suggested EcoQO target level, this EcoQ would be relatively easily understood by non-scientists, and is very sensitive to changes in a specific human activity. Changes are tightly linked to specific fishing activity. Evaluation of both by-catch and the background population size and structure is both difficult and costly, however, but trends could be measured over a large proportion of the area occupied by the North Sea population. The time series of data available is not good.

4.7.4 Human activities for which no suitable marine mammal EcoQs have yet been found

ICES considered a number of further possible EcoQs for marine mammals. These included the following suggested EcoQs that were rejected:

- Cetacean population trends. This was not adopted as there is only one cetacean population estimate (see Table 4.6.1.4.1) that was very costly to obtain. In addition, confidence limits on the estimate are so high that such surveys would be required at annual intervals over a long period to be able to detect any change with a reasonable degree of confidence.
- Cetacean distribution. An atlas of cetacean distribution will be published in the UK in the near future. However, it is difficult to distinguish between changes in survey effort and changes in distribution, particularly at the edge of current ranges.
- Cetacean and seal contaminant loads. Some high levels of contaminants have been recorded in neonate dolphins. These loads appear to derive from female dolphins unloading contaminants into their first-conceived foetus. At present, too little is known about pollutant regulatory processes of cetaceans, and the risks that various loadings might carry. ICES

considers that other top predators (birds) may be easier to monitor and understand.

4.7.5 References

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4.8 Marine Birds

4.8.1 Status of marine birds in the North Sea

Marine birds (here including wildfowl and shorebirds as well as traditional seabirds) are some of the more prominent members of the marine community of the North Sea (ICES Divisions IIIa, IVa, b, and c, VIII d and e), and consequently their numbers are relatively easy to survey. These surveys are reported in a number of places, often on a national basis. A consequence of this is that it is not always possible to provide comparative up-to-date totals of some species. Here, ACE presents information on the current population sizes of seabirds, wildfowl, and waders found in the North Sea, and attempts to cast these current numbers in terms of the birds' historical abundance (which for some species is dramatically different from that at the present). The best information is available for seabird species that breed or for shorebirds and wildfowl that winter around the North Sea. Where possible and appropriate, estimates of other populations are also presented. It is important to know the status of marine birds that occur in the North Sea if they are to be used in setting Ecological Quality Objectives.

4.8.2 Seabirds in the North Sea

All countries surrounding the North Sea have programmes that collect information on numbers of breeding seabirds. Unfortunately, it was not possible to bring together all information on the most recent national estimates of numbers, particularly for the UK (where a complete re-census of colonies is under way). Due to this incompatibility and incompleteness of information between countries, ACE has used the most recent published estimates of breeding numbers for the whole North Sea (Dunnet *et al.*, 1990). Population estimates of seabirds at sea in the North Sea as a whole have most recently been summarized by Skov *et al.* (1995). These data were derived from seabird surveys carried out from 1979 to 1994 in the North Sea. Several sampling methods were used to produce estimates of each species at sea over a year: counts from land, aerial total counts, aerial transect counts, ship total counts, and ship transect counts. A Geographical Information System mapping routine was used to perform a detailed stratification of species distributions within predefined sectors in the North Sea. Density and population estimations were carried out for each sector while information on numbers of birds that would be expected to be associated with breeding colonies of seabirds in the study region were derived from the United Kingdom Seabird Colony Register and other sources (see Lloyd *et al.*, 1991; Grimmet and Jones, 1989; Hälterlein and Steinhardt, 1993). These data are presented in Table 4.8.2.1 along with an indication of the overall trend of the breeding population in the North Sea. Summaries of trends and geographical variations appear in the text below.

4.8.3 Trends in status of seabirds in the North Sea

Northern fulmar (*Fulmarus glacialis*)

Fulmars have increased in numbers in the North Sea quite dramatically since the early part of the Twentieth Century (Fisher, 1952). The rate of increase has slowed in the 1990s compared with the 1950s and 1960s. In France (where it first colonized in 1960), the (small) population has stabilized or even decreased slightly in the 1990s, while in the UK the overall increasing trend has also peaked recently in, for example, Shetland. However, significant population growth has occurred in Norway in recent years. The North Sea population increase that had continued rapidly from 1900 to at least 1980 may now have ceased.

Manx shearwater (*Puffinus puffinus*)

A bird breeding mainly in western parts of the British Isles, the small population of Manx shearwaters (< 200 pairs) in the Channel increased in the late 1990s. The small population in Shetland has been severely reduced by mammals introduced to its breeding islands.

European storm-petrel (*Hydrobates pelagicus*)

European storm-petrel populations that breed in the Northern Isles of Scotland (probably numbering in the low thousands) have not been adequately surveyed in the past. Their status here is being assessed currently and overall trend data are not available.

Leach's storm-petrel (*Oceanodroma leucorhoa*)

The status of the very small Leach's storm-petrel population in the North Sea is also poorly known and is also currently being investigated.

Northern gannet (*Morus bassanus*)

Numbering in excess of 80,000 breeding pairs, northern gannets have been increasing everywhere in the North Sea in recent decades (at a rate of 0.5–3 % per annum between 1990 and 1999; Upton *et al.*, 2000), probably partly as a result of feeding on discarded fisheries waste. At Runde, Norway, just north of the North Sea, gannets have been increasing steadily by as much as 10 % per year since they established there in 1946.

Table 4.8.2.1. Population figures for seabirds on North Sea coasts. Wintering counts are of individuals; breeding data are nesting pairs except for auks, which are individuals. Breeding data are from Dunnet *et al.* (1990) for all species except northern gannet, the sources here being Murray and Wanless (1997) and Thompson *et al.* (1996); winter data are from Skov *et al.* (1995) and are modelled estimates based on known average densities in winter months in different areas of the North Sea. Recent (approximately the past decade) trends of breeding populations (where known or suspected) are indicated. German trends are from Hälterlein *et al.* (2000).

Species	Wintering population	Breeding population	Breeding trend
Northern fulmar	3,744,000	307,599	=
Manx shearwater	500	ca. 250	=
European storm-petrel	0	low 1000s	
Leach's storm-petrel	0	low 100s?	
Northern gannet	157,800	60,326	+
Great cormorant	14,315	2,222	+
European shag	29,115	19,804	+
Arctic skua	0	3,194	-
Great skua	1,000	7,303	+
Mediterranean gull	0	ca. 150	+
Little gull	5,370	40	+
Black-headed gull	?	129,342	=
Mew gull	175,530	73,332	
Lesser black-backed gull	15,315	49,311	+
Herring gull	971,700	237,114	=
Yellow-legged gull	?	10s	+
Great black-backed gull	299,900	24,436	+
Black-legged kittiwake	1,032,690	415,427	-
Gull-billed tern	?	<100	? -
Sandwich tern	0	30,547	=
Roseate tern	0	36	-
Common tern	0	61,487	=
Arctic tern	0	74,729	=
Little tern	0	2,335	
Common guillemot	1,562,400	680,434 ind	+
Razorbill	324,000	73,115 ind	+
Black guillemot	6,595	23,741 ind	=
Little auk	852,690	0	
Atlantic puffin	26,000 (early winter) 74,600 (late winter)	225,957 ind	+

Great cormorant (*Phalacrocorax carbo*)

Great cormorant populations can fluctuate markedly from year to year. An increase was recorded in French colonies between 1987 and 1998 and there have been large increases (up to 30 % growth per year) over the past three decades, mainly in Denmark, Germany, and the Netherlands (van Eerden and Gregersen, 1995). This has been mirrored in southern parts of the UK, but northern Scottish (including Orkney and Shetland) populations have shown marked decline over the same period (Budworth *et al.*, in press).

European shag (*Phalacrocorax aristotelis*)

European shag breeding numbers in the North Sea are relatively variable within wide limits. In the past decade, there has been some overall population growth in French and Norwegian colonies, while counts at UK North Sea colonies indicate stability over a similar time period. Colonies in southwestern Norway have increased, while those in the much larger colony at Runde (just north of the North Sea) have decreased by a mean of 5 % per year since 1975.

Arctic skua (*Stercorarius parasiticus*)

Most Arctic skuas breeding around the North Sea do so in Shetland and Orkney, with small populations in Norway and northern Scotland. The limited evidence available suggests that after some decades during which numbers increased, numbers have been declining since 1990; for example, at five monitored plots in the Orkney Islands, they have declined by 54 % since then (Upton *et al.*, 2000).

Great skua (*Stercorarius skua*)

Great skuas are also confined mostly to Orkney and Shetland. Overall, an increase in breeding numbers here has occurred in the past ten years, but there have been some recent, localized decreases.

Mediterranean gull (*Larus melanocephalus*)

The Mediterranean gull breeds in France, the UK, the Netherlands, and Germany in increasing numbers.

Little gull (*Larus minutus*)

Small, but increasing, numbers of little gulls breed in the Netherlands.

Black-headed gull (*Larus ridibundus*)

Breeding numbers of black-headed gulls at colonies can be variable from year to year, but coastal colonies in Scotland have probably declined over the past decade. Larger colonies in eastern England have increased over

the same period, but the Wadden Sea population seems to have remained relatively stable (Rasmussen *et al.*, 2000).

Mew gull (*Larus canus*)

Over the past five to ten years there have been moderate, localized increases in monitored mew gull colonies in Scotland, but overall UK North Sea populations appear to be relatively stable. Numbers in the Wadden Sea almost doubled in a similar time frame, but Norwegian populations have declined by around 5–10 % per year over the past decade; in some cases these declines have persisted from the 1970s.

Lesser black-backed gull (*Larus fuscus*)

The most southerly populations of lesser black-backed gulls in the North Sea appear recently to have been relatively stable, for example, in France since 1988. However, the species has increased dramatically in the Wadden Sea since 1990 (a total increase of 150 % from 1990–1995), and numbers have continued to increase gradually in eastern England. In southeast Scotland (Isle of May), breeding numbers tripled between 1987 and 1999, following cessation of a cull of breeding adults on the island (Harris *et al.*, 2000). Some colonies in Norway have decreased in recent years, but this has been offset by population growth in others. The overall population trend in the North Sea would appear to be one of slight population growth.

Herring gull (*Larus argentatus*)

Data from the past ten years suggest a levelling off of earlier trends of both population decline and growth in various parts of the North Sea. Wadden Sea populations have declined slightly, while numbers in France have remained fairly stable over the past decade. In most Norwegian areas, the species has increased by 6–7 % annually since the late 1980s.

Yellow-legged gull (*Larus cachinnans*)

Small, but increasing, numbers of this species, only recently identified as a separate species from herring gull, breed in France, southern England, the Netherlands, and Germany.

Great black-backed gull (*Larus marinus*)

Breeding numbers of great black-backed gulls increased markedly in Norway (up to 18 % per year in some areas) and the German Wadden Sea in the past decade. The limited evidence available suggests that populations elsewhere are increasing slowly. This is true for the southeastern North Sea, notwithstanding a period of population stability in France from 1987–1998. Some major colonies in Orkney declined between 1984 and 1997 (Upton *et al.*, 2000); however, there have been

some large increases in breeding numbers in Norway since the late 1980s (and earlier).

Black-legged kittiwake (*Rissa tridactyla*)

Black-legged kittiwakes have been declining in the North Sea as a whole for the past fifteen years or so. A census of the Shetland population in 1999 indicated a decline of 71 % since 1981 (Thompson *et al.*, 1999). In northeast Scotland, breeding numbers declined by 53 % between 1992 and 1999 (Upton *et al.*, 2000). Similarly, the Isle of May population (southeast Scotland) halved between 1990 and 1999 (Harris *et al.*, 2000). Those at Runde, Norway (just north of the North Sea) have increased by 4.3 % per year since 1980.

Gull-billed tern (*Gelochelidon nilotica*)

Small numbers of gull-billed tern breed on Wadden Sea shores.

Sandwich tern (*Sterna sandvicensis*)

The available evidence suggests that the North Sea population of Sandwich terns has remained fairly stable since 1990. Local fluctuations probably represent movement among colonies; for example, the peak in numbers in the Wadden Sea in 1994 was coincident with a decline in UK breeding numbers in the same year (Upton *et al.*, 2000).

Roseate tern (*Sterna dougallii*)

Roseate terns continue to retain a precarious hold in the North Sea; nesting pairs ranged from 74 in 1988 to 47 in 1999 (Upton *et al.*, 2000). Some of the recent decline in North Sea populations may reflect emigration to the relatively successful colonies in Ireland.

Common tern (*Sterna hirundo*)

More than 50 % of North Sea common terns breed in Norway, where numbers have decreased by 5–15 % per year in most areas for the past 10–25 years. Since the 1980s (and earlier), colonies here have significantly decreased in size. Similarly, in the German Wadden Sea, numbers have significantly decreased in the past decade. In the UK, population size appears to have increased, while in France it has remained stable over the same time period. The extent to which the variation in breeding numbers reflects movement between colonies is not known.

Arctic tern (*Sterna paradisaea*)

The population of Arctic terns in the North Sea is probably relatively stable following a large decline in the early 1990s.

Little tern (*Sterna albifrons*)

Around half of North Sea little terns breed in the Wadden Sea. Over the past ten years, the population in the German Wadden Sea has increased significantly; no data on population trends in Denmark are available. Numbers in both France and the UK also appear to have grown modestly.

Common guillemot (*Uria aalge*)

The great majority of common guillemots in the North Sea breed in the UK. Here, they have increased markedly since the mid-1980s; in southeast Scotland and northeast England, annual population growth was 3.9 % and 4.8 %, respectively (Upton *et al.*, 2000). The small population in France has also been increasing since 1955. Common guillemots at Runde, Norway (just north of the North Sea) have decreased by 2.2 % per year since 1980.

Razorbill (*Alca torda*)

Although few data are available from the smaller colonies in the Channel, at Helgoland and in Norway, UK data indicate that razorbills have increased in the North Sea over the past fifteen years. Scottish colonies as a whole have increased at between 3.1 % and 41 % per year since 1986 (Upton *et al.*, 2000).

Black guillemot (*Cepphus grylle*)

The few data available suggest that black guillemot numbers in the North Sea have remained relatively stable over the past fifteen years.

Atlantic puffin (*Fratercula arctica*)

The small Atlantic puffin population in the Channel has remained stable over the past decade, but breeding numbers on the UK coasts of the North Sea have increased greatly over the past fifteen years. Numbers at Runde have increased slightly since 1980.

4.8.4 Wildfowl wintering in or migrating through the North Sea

The status and trends in numbers of divers, grebes, and selected wildfowl wintering in the North Sea were identified by Skov *et al.* (1995). Populations for several seasons were available for some species, and so the season with the highest population total has been reported in Table 4.8.4.1. Data for Brent goose, long-tailed duck, and shelduck were extracted from Delaney *et al.* (1999) using protocols described for wintering waders (see Section 4.8.5). The status and population trends of wintering wildfowl on North Sea coasts are shown in Table 4.8.4.1.

4.8.4.1 Trends for wintering and migratory divers, grebes, and wildfowl in the North Sea

Divers and grebes

The status of divers and grebes in the North Sea is given in Table 4.8.4.1. Approximately 50,000 red- and black-throated divers (*Gavia stellata* and *G. arctica*), 14,000 great-crested grebes (*Podiceps griseigena*), and 2,000 red-necked grebes (*Podiceps grisegena*) winter in the North Sea, predominantly inshore along southern North Sea coasts and the Kattegat (Skov *et al.*, 1995). Great-northern divers (*Gavia immer*) are rare, with only 900 birds wintering in the region, mostly along sheltered rocky coasts in the far northwest of the North Sea. The regular monitoring of wintering seabirds in Norway has documented a significant decrease in numbers of red-necked grebes in Rogaland (Anker-Nilssen *et al.*, 1996). For other North Sea areas, there are no available data on trends in the numbers wintering.

Brent goose (*Branta bernicla*)

Approximately 227,000 Brent geese winter in the North Sea, coming from populations that breed in Svalbard and Siberia. They are mainly distributed among the larger estuaries in the southern North Sea. The populations are increasing following a population reduction caused by hunting and a disease affecting *Zostera*, their main food plant (Scott and Rose, 1996).

Common shelduck (*Tadorna tadorna*)

The number of shelducks in the North Sea is approximately 114,000 (derived from data in Delaney *et al.*, 1999; Pollit *et al.*, 2000). Shelducks occur in estuarine habitats and so are mainly found in the southern North Sea. Almost the entire northwest European population gathers in the Wadden Sea to moult (Scott and Rose, 1996). The population increased by 50 % between the late 1960s and the late 1980s, but is now thought to be stabilizing (Scott and Rose, 1996). Pollit *et al.* (2000) showed that common shelducks along North Sea coasts in the UK were approximately stable over the past decade.

Greater scaup (*Aythya marila*)

There are approximately 14,000 scaup wintering in the North Sea, with the majority of them occurring in the Kattegat, Firth of Forth, and Voordelta (Skov *et al.*, 1995). Trends over the whole North Sea are unknown, although the numbers in the Firth of Forth have declined following reductions in discharges of waste grain from distilleries (Kirby *et al.*, 1993).

Common eider (*Somateria mollissima*)

The population of common eiders wintering in the North Sea numbers approximately 462,600 birds, with most of them occurring in the Kattegat and along shallow coasts along the Wadden Sea and the Scottish firths (Skov *et*

Table 4.8.4.1. Peak numbers of divers, grebes, and wildfowl on North Sea coasts during winter; figures are individual birds in 1994/1995. Data are from Skov *et al.* (1995) for most species, but from Delaney *et al.* (1999) for Brent goose, long-tailed duck, and shelduck.

Species	Peak numbers in winter	Trend
Red- and black-throated divers	48,495	
Great northern diver	905	
Great-crested grebe	13,900	
Red-necked grebe	1,975	
Brent goose	227,000	+
Common shelduck	114,000	=
Greater scaup	13,665	
Common eider	462,590	
Long-tailed duck	11,576	=
Black scoter	570,310	=
Velvet scoter	121,430	=
Common goldeneye	16,400	+
Red-breasted merganser	9,855	=
Goosander	3,230	=

al., 1995). Overall trends of birds wintering in the North Sea are unknown, although declines have recently been recorded in the Dutch Wadden Sea following collapses in the stocks of the species' shellfish prey.

Long-tailed duck (*Clangula hyemalis*)

Long-tailed duck numbers in the North Sea were approximately 11,600 birds (Delaney *et al.*, 1999), although this is probably an underestimate owing to many birds being offshore when land-based counts are conducted (Pollit *et al.*, 2000). Kirby *et al.* (1993) estimated the population as around 20,000 birds. Within the North Sea, they are concentrated in the Scottish firths, particularly the Moray Firth (Pollit *et al.*, 2000). Their populations are unknown, but are believed to be stable (Scott and Rose, 1996).

Black and velvet scoter (*Melanitta spp.*)

There are approximately 570,000 black scoters (*Melanitta nigra*) and 121,000 velvet scoters (*Melanitta fusca*) wintering in the North Sea. The majority of them spend the winter in the Kattegat, Danish west coast, Wadden Sea, and Voordelta (Skov *et al.*, 1995). Their populations are reported to be stable (Scott and Rose, 1996).

Common goldeneye (*Bucephala clangula*)

The number of goldeneye wintering in the North Sea is approximately 16,400, with most birds being found in the Kattegat, Voordelta, and British estuaries and coasts (Skov *et al.*, 1995). A large proportion of the northwest European population winters on freshwater lakes and reservoirs, and numbers at sea are increased considerably during freezing weather. The numbers wintering in northwest Europe have increased over the past decade by as much as 50 % (Scott and Rose, 1996).

Red-breasted merganser (*Mergus serrator*)

The number of red-breasted mergansers wintering in the North Sea is approximately 10,000 birds (Skov *et al.*, 1995) and these were mainly found in British estuaries and firths. The population wintering in northwest Europe is believed to be relatively stable (Scott and Rose, 1996).

Goosander (*Mergus merganser*)

Approximately 3,200 goosander winter in the North Sea (Skov *et al.*, 1995), and a large proportion of the European wintering population inhabit freshwater lakes and reservoirs and the Baltic Sea. The population wintering in northwest Europe is considered to be largely stable (Scott and Rose, 1996).

4.8.5 Waders wintering in the North Sea

Wintering waders and wildfowl are counted every month between September and March in the UK (organized by the Wildfowl and Wetlands Trust, the British Trust for Ornithology, the Royal Society for the Protection of Birds, and the Joint Nature Conservation Committee) and more widely in January as part of the International Waterbird Census (coordinated by Wetlands International).

Data from these schemes were extracted for the winter of 1994/1995 from Delaney *et al.* (1999) and Pollit *et al.* (2000). This year provided the only available snapshot of wader numbers during a typical winter (1996 data are available in Delaney *et al.* (1999), but this was a relatively cold winter and waders may have moved into the Irish Sea, thereby rendering the results from that year somewhat atypical). Counts represent summed peak counts rather than average counts, and so will represent overestimates, particularly for more mobile wader and waterfowl species. Delaney *et al.* (1999) provide country totals, and since some countries have estuarine coasts outside the North Sea (UK and France), the totals overestimate species status in the North Sea. Wader count data from the Atlantic coast of France could not be excluded from the North Sea total. However, estuary counts were available for the UK (Pollit *et al.*, 2000), allowing western British counts to be excluded from the North Sea totals. Hence, the wader totals for the British North Sea coast were calculated by summing the totals counted at estuaries on the east coast and the Channel in the winter of 1994/1995. These represent numbers only at internationally or nationally important sites and do not include numbers of waders dispersed among smaller, less important sites (e.g., sanderling). Further analyses of the original data would be required to improve these estimates. It should also be noted that the numbers of waders using North Sea coasts on migration and in winter comprise only a small component of the meta-populations of these species, which use wider European/African/Asian migratory flyways. The status and trends of wintering wader populations on North Sea coasts is shown in Table 4.8.5.1.

4.8.5.1 Summary of trends of numbers of waders wintering in the North Sea

Eurasian oystercatcher (*Haematopus ostralegus*)

Numbers of Eurasian oystercatchers have gradually increased since the 1970s in the UK and the population was larger than in all previous years in 1997. The Wadden Sea holds almost half of the northwest European total, and the UK holds about 30 %. In 1995 and 1996, numbers in the Wadden Sea declined somewhat and this decline was matched by increases in France, the non-Wadden Sea Netherlands, and the UK. This shift in abundance is almost certainly the result of recent cold winters.

Table 4.8.5.1. Status and trends of selected wintering estuarine waders on the North Sea coast in 1994/1995. Note that these are peak migratory counts, so they may be overestimates. Data are from Delaney *et al.* (1999) and Pollit *et al.* (2000).

Species	Population	Trend
Eurasian oystercatcher	772,000	+/=
Ringed plover		=
European golden plover		=
Grey plover	77,000	+
Northern lapwing		=
Red knot	219,000	=
Sanderling	11,000	=
Dunlin	656,000	=
Black-tailed godwit		+
Bar-tailed godwit	62,000	=
Eurasian curlew	289,000	+/=
Common redshank	30,000	=
Common greenshank		+
Ruddy turnstone		=

Ringed plover (*Charadrius hiaticula*)

Populations of ringed plovers have generally been stable since the 1970s. However, numbers in the UK have been dropping since the early 1990s, following peak abundance in 1990. A particularly sharp decline in the UK was recorded between 1998 and 1999.

European golden plover (*Pluvialis apricaria*)

In 1995–1996, the distribution of European golden plovers shifted from the UK towards France and the Netherlands. This shift presumably reflected the harsh winter of 1995–1996. No long-term change in the North Sea population is evident.

Grey plover (*Pluvialis squatarola*)

There has been a long-term increasing trend of grey plovers in the UK, amounting to over 50 % since 1970. In the cold winters of 1995–1996, fairly substantial shifts away from the Wadden Sea towards France and the non-Wadden Sea Netherlands were noted. These were local shifts in abundance that do not appear to have impacted the long-term increasing trend, however.

Northern lapwing (*Vanellus vanellus*)

The North Sea populations of northern lapwings appear to be stable, despite a shift in range eastward and southward following cold winters.

Red knot (*Calidris canutus*)

Populations of red knots in the UK and in the Wadden Sea are either stable or declining slightly. A decline is more evident in the Wadden Sea, and the decline there may reflect extensive shellfish harvesting by humans, which disturbs the birds' feeding grounds.

Sanderling (*Calidris alba*)

In the UK, the sanderling populations have fluctuated considerably since 1969, but there does not appear to be any long-term trend. Substantial increases in France and the Wadden Sea in 1995–1996 more than compensated for decreases in the UK.

Dunlin (*Calidris alpina*)

Populations of dunlins in the North Sea area have not displayed any trend since 1969, though there have been local fluctuations that seem to reflect eastward and southward movements to avoid cold winters.

Black-tailed godwit (*Limosa limosa*)

Black-tailed godwits have been increasing in western Europe for most of the Twentieth Century. This increasing trend is still apparent in the UK and the Wadden Sea.

Bar-tailed godwit (*Limosa lapponica*)

Bar-tailed godwits have fluctuated in abundance, but no trend is apparent for the North Sea area since 1969. As with many waders, birds move from the Wadden Sea to the UK and to the south during cold winters.

Eurasian curlew (*Numenius arquata*)

There had been an increasing trend in Eurasian curlew populations between about 1980 and 1995. In 1995, numbers decreased in the UK and the Wadden Sea, as well as in other parts of western Europe. It is not clear, owing to missing data, whether these declines represent shifts to the south. Numbers seem to have increased again in the UK in 1998, but then declined in 1999. Nevertheless, the 1999 number in the UK is equal to the 1969–1999 mean.

Common redshank (*Tringa totanus*)

Common redshank populations have been stable since 1969. There have, however, been decreases in 1995–1996 in the whole North Sea area. These declines seem to be related to the cold winter, and the numbers have not completely recovered in these areas. Nevertheless, 1998–1999 yielded totals close to the 1969–1999 mean.

Common greenshank (*Tringa nebularia*)

Common greenshanks have been increasing as a passage migrant in the UK over the past ten years.

Ruddy turnstone (*Arenaria interpres*)

Ruddy turnstone numbers in the UK have been declining since about 1989, when a peak was recorded. Counts in the UK in 1999 were close to the 1969–1999 mean. Recent decreases in UK numbers seem to have been compensated for by increases in France and the non-Wadden Sea Netherlands.

4.8.6 References

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4.9 Ecosystem Quality Metrics for Seabirds in the North Sea

4.9.1 Oil pollution

4.9.1.1 Background

The use of dead or dying seabirds found on beaches as indicators of oil pollution at sea has been reviewed in a number of recent publications (Camphuysen and van Franeker, 1992; Dahlmann *et al.*, 1994; Camphuysen, 1995, 1998; Wiens *et al.*, 1996; Furness and Camphuysen, 1997; ICES, 2000; Camphuysen and Heubeck, 2001). There is evidence to show that the proportion of oiled beached seabirds gives a reasonable

index of the numbers of oil slicks at sea, although factors such as wind direction and numbers of seabirds dying from starvation or disease can confound the picture in the short term (Stowe, 1982). However, surveys of beached seabirds provide clear evidence of long-term trends in oiling rates of seabirds (Figure 4.9.1.1.1) and variation in oil impacts between regions (Figure 4.9.1.1.2).

Standards for conducting beached bird surveys have been established by OSPAR (OSPAR, 1995), but nevertheless surveys around the North Sea could be more frequent and better coordinated, perhaps on a monthly basis. Currently only one international survey occurs each year (in February), with surveys at other times being more systematic in some countries than others. Monitoring is already included in the Trilateral Monitoring and Assessment Programme (TMAP) in the Wadden Sea.

4.9.1.2 Robustness of proposed EcoQ

The proportion of beached common guillemots that are oiled broadly reflects the density of shipping traffic in the North Sea (Figure 4.9.1.1.2) and can be used as an index of oil pollution in the waters used by common guillemots. There have been clear reductions in this proportion and that of other species in one area adjacent to some of the main shipping lanes in the North Sea (Figure 4.9.1.1.1). This reduction reflects efforts in the Netherlands and more widely to reduce oil pollution from shipping. There appears to be a reasonably tight linkage in time between the efforts to reduce oil pollution and the decreasing proportion of oiled birds, although data on the proportion of oiled beached birds are only available after efforts to reduce oil discharges started.

This proposed EcoQ metric would be relatively easy to measure and has a reasonably long history. As can be seen in Figure 4.9.1.1.1, the index is subject to short-term variation. Thus, a number of years of data would be required before further trends could be detected, or before managers could be sure that they were moving towards or achieving the EcoQO target level. Camphuysen and van der Meer (1995) indicate that a decrease in oil pollution will be detected with a probability of 90 % after about fourteen years, although for some species this time may be nine years. There are two main known sources of noise in the data: major oil pollution incidents and major non-oiling mortality events ("wrecks"). The former will inflate proportions oiled, while the latter will deflate any index. Camphuysen *et al.* (1999) reviewed mass mortality incidents (including large-scale oiling incidents) and showed that in the ICES area these occurred mostly in autumn and winter and that common guillemot was the most frequently affected species. An EcoQ metric of the proportion of beached common guillemots that are oiled could be applied across the North Sea.

Figure 4.9.1.1.1. Trends in oil rates in razorbills, common guillemots, black-legged kittiwakes, and *Larus* gulls stranded at the mainland coast in the Netherlands, 1979–1995. Data from Camphuysen (1995).

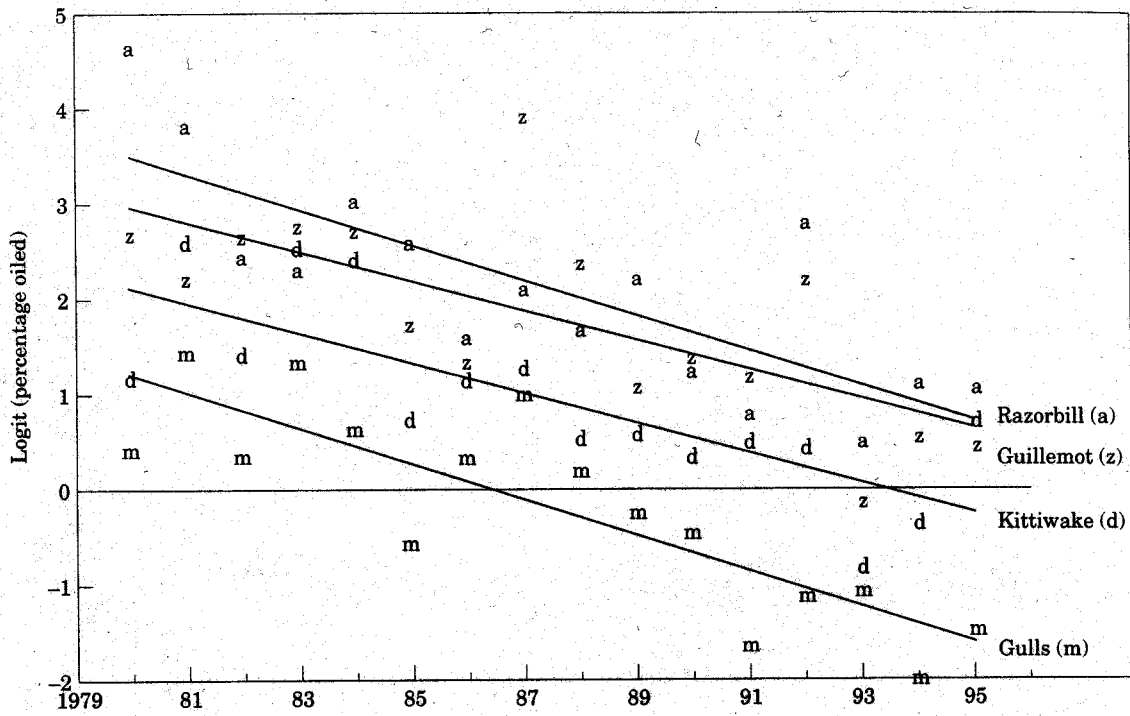
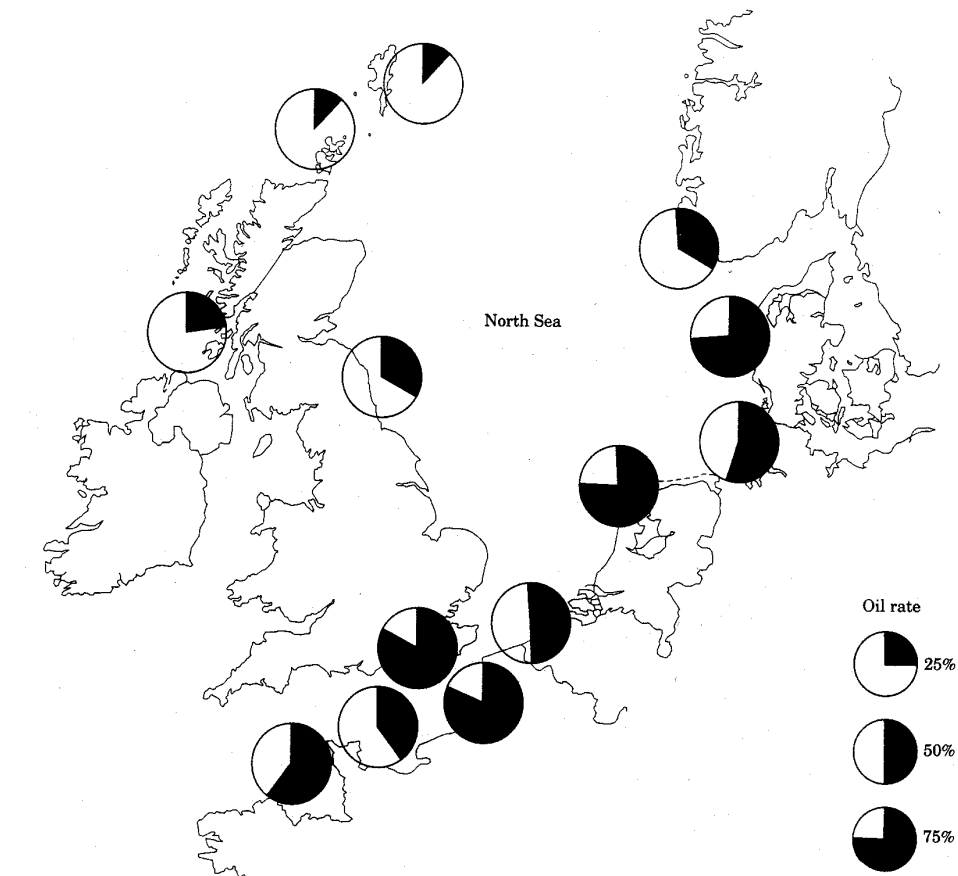


Figure 4.9.1.1.2. Variation in the proportion of beached common guillemots that are oiled (oil rate) in western Europe. Data from Camphuysen (1995).



4.9.1.3 Discussion

Total seabird mortality from small, frequently unattributable, oil slicks is believed to be higher than that from the larger, high profile oil spills that attract great public attention. Nevertheless, no studies have been able to document that there are, at present, any measurable effects of oil pollution on the overall populations of seabirds in the North Sea. This proposed EcoQ metric is therefore designed to monitor longer-term trends in background oil pollution rather than its effects on seabird populations.

It was noted that some oil spills can have a large effect on more localized populations of seabirds. However, it would be difficult to set EcoQs based on absolute numbers killed in any incident due to a number of factors. First, there is insufficient information on the biological sub-division of seabird populations in the North Sea. Secondly, in most instances it is impossible to know accurately the total number of birds that have been killed in any one incident as the proportion of birds killed that arrive ashore may be heavily influenced by weather conditions (Stowe, 1982).

A further use of beached birds in aiding in the managed reduction in oil spills comes through the chemical fingerprinting of oil from carcasses. This permits the identification of the source of oil on the birds and can be used in prosecutions for discharge of oil at sea (Dahlmann *et al.*, 1994); it can also be used to provide guidance to where efforts to further reduce oil pollution might be best targeted.

ACE considers that the common guillemot represents the best species to provide an index of oiling as they represent a large proportion of the overall number of birds, they are widely distributed, and they are relatively susceptible to oiling as they spend most of the time on the water rather than flying.

4.9.1.4 Provisional estimates for EcoQ levels in the North Sea

EcoQ title: *Proportion of oiled common guillemots among those found dead or dying on beaches*

Reference level: 0 %

Although there are a very few natural oil seeps in the North Sea, the level of oiling likely to be attributed to them will not be detectable from beached guillemots. Therefore, the reference level prior to human influence is 0 %.

Current level: 12–85 %: There is wide geographical variation in oiling rates of guillemots in the North Sea (Figure 4.9.1.1.2).

Suggested EcoQO target level: 10 % or less, to be achieved in all areas of the North Sea.

The overall objective is a reduction in the levels of oil pollution in the environment. It is probably impossible to reduce oil spills to zero. ACE therefore believes that a 10 % oiling rate is an achievable and practical target level in the medium term. The wide geographical variation of current levels of oiling in the North Sea will make this target more easily achieved in some areas than others. Oil pollution that affects seabirds comes from a variety of sources including all forms of shipping, from oil exploration, production and transport, and from land-based sources. All of these sources of oil will need to be addressed to meet this EcoQO target level.

4.9.1.5 Assessment of usefulness of suggested EcoQ

ACE considers that the proportion of oiled guillemots among those found dead or dying on beaches is an appropriate and useful index of oil pollution in the North Sea. The metric is readily understandable by non-scientists and managers, and is demonstrably sensitive to management activities, i.e., minimization of oil spills. Furthermore, the effectiveness of management activities can be demonstrated within a short time frame (ten years). Additionally, standard methods for conducting beach surveys have already been established by OSPAR, a time series of existing data is available, and the data come from a large number of geographical locations throughout the North Sea.

4.9.1.6 References

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4.9.2 Mercury

4.9.2.1 Background

Mercury is a highly toxic metal that is introduced into the environment by human activities at a rate that exceeds natural inputs (Fitzgerald, 1995; Fitzgerald and Mason, 1998). Mercury concentrations tend to increase up food chains, and are much higher in most marine food chains than in most terrestrial or freshwater ones (ICES, 2000). Mercury concentrations are high in seabird eggs and in seabird feathers (Lewis *et al.*, 1993; Monteiro and Furness, 1995; Becker *et al.*, 1998). Many studies demonstrate that mercury concentrations in seabird eggs and feathers reflect dietary intake (Lewis and Furness, 1991, 1993; Burger, 1993; Becker *et al.*, 1993a, 1993b; Stewart *et al.*, 1997; Monteiro *et al.*, 1998; Bearhop *et al.*, 2000a, 2000b, 2000c; Monteiro and Furness, 2001),

though this is complicated by a pattern of storage of mercury in soft tissues between moults and excretion of most of the body burden of mercury into growing feathers during the moult (Furness *et al.*, 1986; Braune and Gaskin, 1987a, 1987b; Hario and Uuksulainen, 1993), which in most seabirds occurs primarily after the breeding season. Mercury levels in seabird eggs provide a very reliable measure of trends over years in local contamination since seabirds feed close to their breeding colony during the period of egg formation. This also makes eggs very suitable for comparisons between localities as well as over periods of years (Thyen and Becker, 2000). Mercury levels in body feathers reflect mercury in the seabird diet over the summer period prior to moult (Thompson and Furness, 1989; Furness *et al.*, 1986; Bearhop *et al.*, 2000c). By selecting particular seabird species with clearly defined diets, it is possible to monitor mercury contamination in a range of food chains. For example, some seabirds feed predominantly on epipelagic fish, other species feed on mesopelagic fish, others on intertidal molluscs, and so on (Monteiro *et al.*, 1995; Thompson *et al.*, 1998a, 1998b). Analysis of body feathers of seabird study skins in museum collections has demonstrated changes in mercury contamination over the last 150 years in a number of food chains and geographical regions (Figure 4.9.2.1.1), including the North Sea (Thompson *et al.*, 1992a, 1992b, 1993a, 1993b, 1998a; Furness *et al.*, 1995; Monteiro and Furness, 1997; Monteiro *et al.*, 1999).

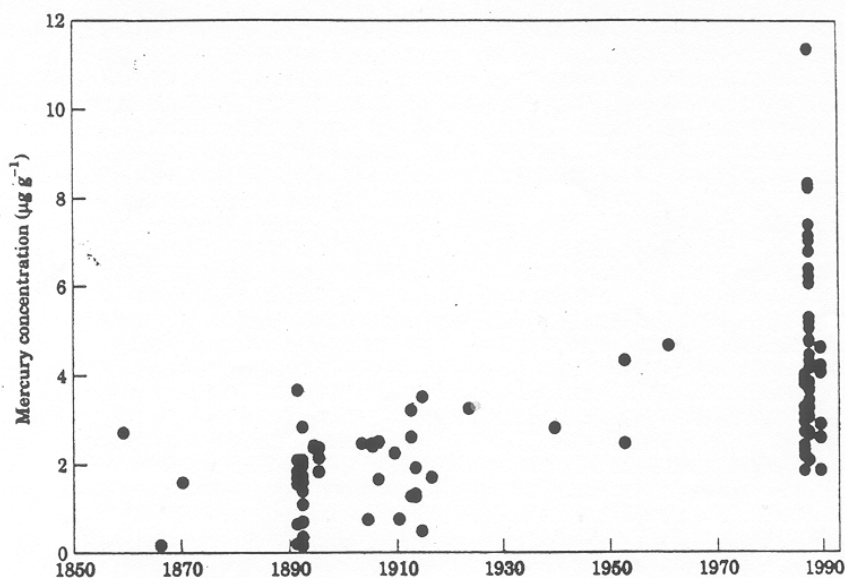
4.9.2.2 Robustness of proposed EcoQ

Mercury levels in birds are measured using a well-established methodology (Appelquist *et al.*, 1984; Thompson and Furness, 1989; Burger, 1993; Becker *et al.*, 1994; Bearhop *et al.*, 2000a) and the close relationship between levels in birds and in their food is widely documented (Monteiro *et al.*, 1998; Monteiro and Furness, 2001). The literature on mercury in seabirds is very extensive and detailed. Unlike fish and marine mammals, seabirds do not show accumulation of mercury with age so sampling does not need to take account of bird age except to separate chicks and older birds (Furness *et al.*, 1990; Thompson *et al.*, 1991). The use of seabird eggs to monitor mercury is already implemented in the current Trilateral Monitoring and Assessment Programme (TMAP) in the Wadden Sea and relevant JAMP guidelines exist (OSPAR, 1997).

4.9.2.3 Discussion

Given that mercury input to ecosystems tends to be predominantly anthropogenic and that analysis of feathers from seabird study skins shows approximately a four-fold increase in mercury levels over the last 150 years in many North Sea seabird species, an EcoQ to reduce mercury contamination should be a high priority. The analysis of seabird eggs and body feathers provides a robust way to measure trends in mercury contamination.

Figure 4.9.2.1.1. Mercury concentrations in body feathers of Atlantic puffin from southwest Britain and Ireland from 1850 to 1990. From Thompson *et al.* (1992a). Similar trends can be described for the North Sea (Furness *et al.*, 1995).



4.9.2.4 Provisional estimates for EcoQ levels in the North Sea

EcoQ titles: Mercury concentrations in eggs of selected seabird species; Mercury concentrations in body feathers of selected seabird species

Reference level:

Reference levels can be obtained from body feathers of seabirds collected before 1900. These reference levels vary considerably between seabird species, depending on diet and trophic status, and to a small extent between regions according to local natural sources of mercury (e.g., upwelling of Atlantic water). For many UK seabirds, reference levels (defined as levels in birds collected before 1900) are about one quarter of the current levels in each species.

Current level:

Current levels of mercury vary between seabird species and between regions. For common terns in the Wadden Sea in 1997, they varied between 275 ng g⁻¹ and 1016 ng g⁻¹ fresh mass in egg contents. For Eurasian oystercatchers in the Wadden Sea in 1997, they varied between 169 ng g⁻¹ and 353 ng g⁻¹ fresh mass in egg contents. For seabird body feathers, current levels have been reported in a large number of recent publications. Examples for body feathers of adult seabirds include great skua, mean 7 mg kg⁻¹ fresh mass feather (over 100 sampled), increasing by 0.4 % per year from 1900–2000; northern gannet, 8 mg kg⁻¹ fresh mass feather, increasing

by 0.3 % per year from 1900–2000; black-legged kittiwake, 3.3 mg kg⁻¹; common guillemot, 1 mg kg⁻¹. More pelagic species (e.g., Atlantic puffin) show higher rates of increase, around 1–1.5 % per year.

Suggested EcoQO target level:

The target level should be the reference level for mercury in seabird feathers. In the case of eggs, a target level could be set once it is known where the monitoring will take place geographically.

4.9.2.5 Assessment of usefulness of suggested EcoQ

Mercury is introduced into the marine environment by human activities at a rate that exceeds the natural inputs and, therefore, management actions to control these inputs can be put into place. Scientific studies have shown that mercury concentrations in seabird eggs and feathers reflect dietary intake and, therefore, monitoring of eggs and feathers provides a measure of trends over years in local contamination as seabirds feed close to their colonies during the period of egg formation. This can be easily explained to, and understood by, the public and by managers. Sampling can be carried out relatively easily (particularly for feathers where permits are not usually required) and appropriate analytical methods are available and in use. Data are available from ongoing monitoring programmes within the North Sea and historical data are also available.

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4.9.3 Organochlorines

4.9.3.1 Background

Marine pollution with environmental chemicals is a worldwide problem, endangering marine organisms and ecosystem health. Persistent toxic substances such as organochlorines, which decompose only slowly, are of special concern. These substances may affect all ecosystem levels. Seabirds may be harmed, for instance, via impairment of reproduction through eggshell thinning or embryonic mortality (e.g., Furness, 1993; Becker *et al.*, 1993).

The use of seabirds as monitors of marine contamination with organochlorines such as PCBs, DDT and its metabolites, HCB, HCHs, and others has been advocated many times (Gilbertson *et al.*, 1987; Becker, 1989, 1991; Furness, 1993; Barrett *et al.*, 1996; Becker *et al.*, 1998; ICES, 2000) and is implemented already in some current monitoring programmes in the North Sea. Monitoring of contaminants in seabirds is highly desirable as a cost-effective and informative procedure indicating change in marine contamination.

Advantages in the use of seabirds as indicators of organochlorine contamination have recently been reviewed (ICES, 2000) and include the following features of seabirds: well-known taxonomy and biology, tendency to accumulate high concentrations, ease of sampling (eggs), known foraging range and diets, resistance to toxic effects, and low variance of contaminant levels within the population. Consequently, seabirds offer some advantages compared to physical or other marine biotic samples when organochlorine monitoring is needed.

4.9.3.2 Robustness of proposed EcoQ

Levels of organochlorines in seabirds show an immediate response to changes in contaminant loads in the marine environment; consequently, they clearly indicate changing levels (e.g., Thyen and Becker, 2000) and reflect changes in anthropogenic discharges and emissions of organochlorines. In this way, the effectiveness of measures of reduction of contamination can be demonstrated. Trend data are available for various parts of the North Sea for nearly forty years.

OSPAR (1997) has published guidelines for sampling and analysing (using gas chromatography) seabird eggs. The key compounds are PCBs, DDT and metabolites, HCB, and HCH isomers, which can be analysed synchronously using the same analytical procedure. There is a clear parameter signal, as eggs can only be taken in the breeding season, thus reducing the effects of seasonal variation. The objective is relevant to the North Sea, where organochlorine inputs remain high (De Jong *et al.*, 1999). Monitoring can investigate temporal and spatial variations as well as local contaminant inputs, as seabirds forage in restricted distances from colonies during the period of egg formation. Foraging ranges vary between species, but are generally well known. Studies in the southern North Sea show clear local differences in contamination between colonies. In the Wadden Sea, the common tern and the Eurasian oystercatcher were chosen in 1996 as monitoring species for organochlorines in the international Trilateral Monitoring and Assessment Programme (TMAP).

4.9.3.3 Discussion

Current programmes demonstrate clearly the value of seabird eggs to indicate spatial and temporal trends in marine contamination with organochlorines (Becker *et al.*, 1998; Thyen and Becker, 2000). In the southern North Sea there has been a decreasing trend in organochlorine levels in seabird eggs since the early 1990s (Figure 4.9.3.3.1), but locally there are high levels (Figure 4.9.3.3.2) which, however, do not seem to be harmful to the birds during reproduction.

Sampling of seabird eggs as a means of monitoring seabird contamination with organochlorines should be developed into integrated marine pollution monitoring programmes, with the selection of appropriate locally common and internationally widespread monitoring species. A proposed list of species to be used for monitoring in the North Sea is given in Table 4.9.3.3.1. In addition to the organochlorines, some other relevant contaminants such as mercury can be analysed using the same samples.

Figure 4.9.3.3.1. Temporal trends in PCB contamination of Eurasian oystercatcher and common tern eggs from selected breeding sites of the Wadden Sea (TMAP). FW=fresh weight of egg content (Thyen and Becker, 2000).

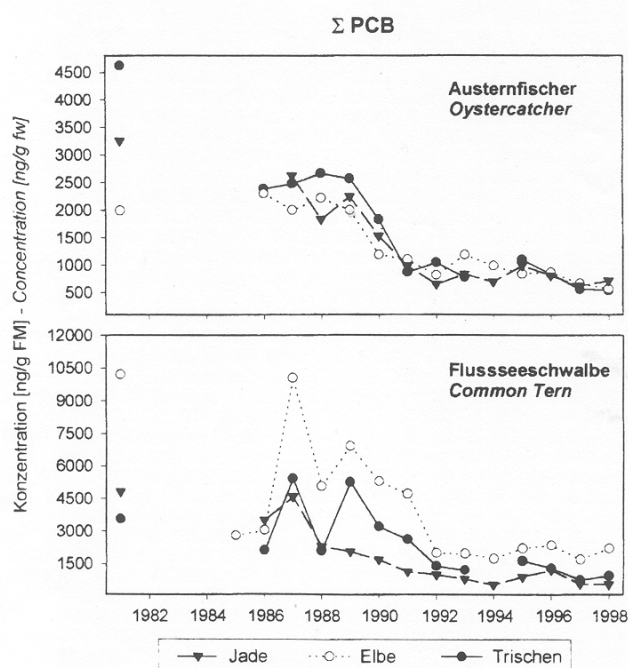
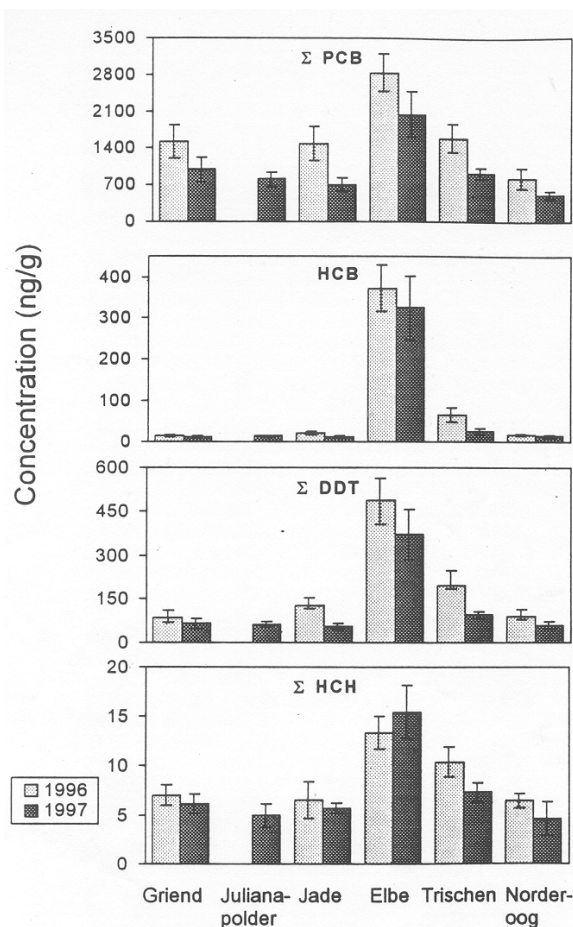


Figure 4.9.3.2. Spatial variation in organochlorine contamination of common tern eggs in 1996 and 1997 from breeding sites of the Wadden Sea (TMAP). Mean concentrations (ng g⁻¹ egg fresh mass) and 95 % confidence intervals are presented. N = 10 eggs each. From Becker *et al.* (1998). Methods and expressions are those in use in the TMAP.



4.9.3.4 Provisional estimates for EcoQ levels in the North Sea

EcoQ title: Organochlorine concentrations in seabird eggs

Reference level: 0 ng g⁻¹ egg fresh mass. Levels are zero as these are man-made chemicals only produced during the past century.

Current level: (ng g⁻¹ egg fresh mass, southern North Sea, range of 6–7 sampling sites, data from 1997, Becker *et al.* (1998); CT = common tern; EO = Eurasian oystercatcher):

ΣPCBs: CT 702–2042 (ng g⁻¹ egg fresh mass); EO 492–1055 (ng g⁻¹ egg fresh mass)

DDT and metabolites: CT 56–371 (ng g⁻¹ egg fresh mass); EO 22–103 (ng g⁻¹ egg fresh mass)

HCB: CT 11–325 (ng g⁻¹ egg fresh mass); EO 4–60 (ng g⁻¹ egg fresh mass)

ΣHCH: CT 5–15 (ng g⁻¹ egg fresh mass); EO 3–10 (ng g⁻¹ egg fresh mass)

Suggested EcoQO target level: 0 ng g⁻¹ egg fresh mass, but presumably this target could not be achieved until some decades from now as these persistent chemicals have long half-lives.

4.9.3.5 Assessment of usefulness of proposed EcoQ

The use of seabird eggs as monitors of marine contamination with organochlorines has been advocated many times. The compounds are man-made and have only been produced during the past century. Their input to the marine environment can, therefore, be subject to management actions. Managers and the public can easily understand the need for action. OSPAR has published guidelines for sampling and analysis of seabird eggs and a body of data already exists. Monitoring can investigate temporal and spatial variation and trends, but the effectiveness of management actions in achieving the proposed target levels would take many years owing to the long half-lives of the compounds.

4.9.3.6 References

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Table 4.9.3.3.1. Seabird species suggested as monitors of marine contamination by organochlorines and mercury in the North Sea. Information on population size and trend, clutch size, diets, and feeding range is presented in ICES (2000). Common tern and Eurasian oystercatcher are already in use for monitoring in the Wadden Sea TMAP.

Species	Population size	Trend	Clutch size	Feeding range	Diet
Northern fulmar	307,600 pairs	++	1	wide-ranging pelagic	zooplankton, offal, discards, fish, squid
Northern gannet	43,800 pairs	++	1	wide ranging	sandeel, sprat, herring, mackerel, discards
European shag	20,000 pairs	=	3–4	rocky coastal	sandeel, sprat
Black-legged kittiwake	415,500 pairs	+/=	2	wide ranging	small fish, zooplankton
Common tern	61,500 pairs	+/=	2–3	coastal	small fish
Common guillemot	340,000 pairs	+	1	inshore/offshore	fish, especially sandeel, sprat
Eurasian oystercatcher	?	+?	3–4	coastal, intertidal areas	shellfish, intertidal and terrestrial invertebrates

4.9.4 Litter—Plastic particles in stomachs of seabirds

4.9.4.1 Background

Seabirds ingest plastic particles floating in the seas and oceans, presumably confusing them with food (Furness, 1985a, 1985b; van Franeker, 1985; Ryan, 1987, 1988). Some kinds of seabirds regurgitate pellets of indigestible stomach contents, and so lose these plastic pellets. However, certain kinds of seabirds, especially Procellariiformes, accumulate these fragments of plastic in their stomach (gizzard) and retain them for many months or years (Ryan and Jackson, 1987; Ryan, 1988). Procellariiformes have a constriction between the proventriculus and gizzard that makes it very unlikely that plastic reaching the gizzard will be regurgitated (Furness, 1985b). Over many months, plastic fragments become abraded to a size that will eventually pass out of the gizzard into the intestine and will be voided in the faeces. Large quantities of plastic retained in the gizzard can reduce the ability of a bird to process food, and so can lead to a deterioration in body condition, although it is not easy to demonstrate this from field studies that correlate plastic load with body condition or mass (Furness, 1985b; Ryan, 1987; Spear *et al.*, 1995). This may be due to the death of birds that suffer deterioration in body condition, but this has not been demonstrated by experiment or field study. In addition to the effect on stomach function, plastic particles adsorb toxic chemicals such as PCBs (Ryan *et al.*, 1988; Mato *et al.*, 2001) and so their ingestion by seabirds will tend to elevate burdens of these chemicals in the birds. Plastic particles in the oceans are both the industrial raw material (plastic pellets) and fragments of broken used plastic items. Seabirds will ingest both types, with some evidence for selection according to colour (Blight and Burger, 1997; Moser and Lee, 1992). Studies show that seabirds in all the world's oceans contain plastic particles. In the North Sea, the only abundant Procellariiform seabird is the northern fulmar, so this species would be the one to sample to measure plastic burden. It is known to ingest plastic (Furness, 1985a; van Franeker, 1985; Camphuysen and van Franeker, 1997).

4.9.4.2 Robustness of proposed EcoQ

Numbers of plastic particles per bird vary enormously between individuals within a population, so that moderately large sample sizes (approximately 40 individuals) are required to provide a small standard error of the mean to permit trends to be measured over time or between regions. Most studies of plastic loads in seabirds have used samples of seabirds found dead or collected for other purposes, so that bias in sampling may affect results (for example, birds found dead on beaches tend to include high proportions of juvenile birds which may have less plastic than found in mature birds). This is not necessarily a major limitation, since birds can be classified by age group and other criteria to reduce or eliminate this potential bias. There is evidence

of an increase in amounts of plastic in seabirds from a long-term (fourteen-year) study of western North Atlantic seabirds (Moser and Lee, 1992), from studies in other oceans (Robards *et al.*, 1995), and from comparisons of samples of particular species collected in the same region in different years or decades. If the plastic burden was so high that it caused a significant increase in mortality of birds with large burdens, then sampling could overestimate plastic pollution if birds found dead on beaches were sampled (these would over-represent individuals with high loads of plastic), whereas it could underestimate plastic pollution if breeding birds were killed as a sample (these would not contain birds in poor condition due to plastic as such birds would be unlikely to breed due to poor condition).

Sampling of northern fulmars could be done by collecting fresh corpses from beaches around the North Sea, as this would provide large sample sizes, and classification of these birds into age classes would quantify differences related to age group. Northern fulmar is one of the more commonly found dead birds on North Sea beaches. It would not be ethically acceptable to kill healthy birds to assess plastic loads on a regular basis, but samples of birds killed by accident (e.g., through longline by-catch mortality) might be useful to calibrate the bias in plastic loads of birds found dead compared to birds sampled alive. The northern fulmar is the most frequently caught bird in the Norwegian longline fishery in the northern North Sea and Norwegian Sea.

4.9.4.3 Discussion

Given that the harmful effects of ingested plastic in seabirds have been established as affecting body condition and increasing the uptake of several toxic chemicals, and that plastic particle pollution is generally increasing in the world's oceans, this EcoQ should be given a high priority, despite the fact that our present knowledge of plastic particle burdens of northern fulmars in the North Sea is rather limited.

4.9.4.4 Provisional estimates for EcoQ levels in the North Sea

EcoQ title: *Numbers of plastic particles in gizzards of northern fulmars classified by age group and cause of death*

Reference level: 0 %

Since plastics are not naturally occurring, all plastic found in seabird stomachs is due to human activity.

Current level: Not accurately known. Northern fulmars were sampled in the early 1970s and early 1980s. At Shetland, thirteen breeding adult birds had a mean of 10.6 plastic particles, with a maximum of 40, in the early 1980s (Furness, 1985a). On the coast of the Netherlands, 65 birds found dead on beaches had a mean of 11.9

plastic particles, with a maximum of 96, also for birds sampled in the early 1980s (van Franeker, 1985). However, Bourne (in van Franeker, 1985) found only 1–2 plastic particles per bird in fulmars examined in the early 1970s. Given the apparent increase in plastic particle pollution in oceans and seas worldwide, and the likely adverse effects on seabirds, the current level in fulmars should be established as a matter of high priority.

Suggested EcoQO target level: Since all plastic is anthropogenic, the target should be at as low a level as possible. For practical reasons, it cannot be set at zero, since such a low target would be unrealistic. Study of the lowest amount that influences body condition or significantly increases the uptake of toxic chemicals is required to provide the means to set a target at a level somewhat below the lowest amount found to cause harm to seabirds. In the absence of such data at present, a provisional target level can be suggested as follows. Studies detecting effects on body condition of seabirds reported loads of around 10–100 plastic particles in the most contaminated individual birds. Thus, the target should be clearly less than that range. ACE suggests that, until data are available on the amount of plastic that affects northern fulmar body condition or contaminant uptake, a target should be set at a maximum of no more than 2% of individuals having ten or more plastic particles within a sample of at least 50 northern fulmars. This would represent a considerable reduction from levels found during the early 1980s, and so probably an even larger reduction from present-day levels.

4.9.4.5 Assessment of usefulness of suggested EcoQ

Seabirds ingest plastic particles floating in the sea and, as plastics are man-made and not naturally occurring, all plastic found in seabird stomachs is due solely to human activity. Inputs to the marine environment can therefore be controlled by human management intervention. There are, however, few data available on the number of plastic particles in the stomachs of seabirds in the North Sea and the significance of the occurrence of plastic particles in seabird stomachs is not fully known. The lack of scientific data makes the setting of appropriate environmental standards and management decisions difficult. There is, however, an apparent increase in plastic particle pollution in the North Sea that is becoming unacceptable to society and robust monitoring methods and programmes are required. The amount of plastic particles in northern fulmars may provide a useful index of plastic pollution in the North Sea, but further studies are required.

4.9.4.6 References

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4.9.5 Harvesting of seabird food—Sandeels

4.9.5.1 Background

Sandeels are among the most abundant fish in the North Sea and dominate the summer diets of many marine vertebrates (Furness and Tasker, 1997), especially in the northwest of the region where there are few sprat or juvenile herring to provide alternative prey. Sandeels therefore represent an important component of ecological quality in the North Sea. A large industrial fishery also harvests sandeels and there is potential for this to reduce ecological quality through localized over-exploitation (Furness, 1999a, 1999b). Stocks of sandeel are extremely difficult to assess owing to fluctuations in recruitment, their high, variable natural mortality rate, and their burrowing behaviour (Gislason and Kirkegaard, 1996). At present, sandeel stocks are estimated on a broad spatial scale (Gislason and Kirkegaard, 1996) despite evidence for finer-scale population structure (Pedersen *et al.*, 1999). Regional stock assessments are therefore desirable, particularly in environmentally sensitive areas that occur at smaller spatial scales (Furness and Tasker, 2000). An EcoQ that provides both a recognition of biological impact and a surrogate measure of local declines in sandeel stocks has clear value for ecologically sensitive fisheries management.

4.9.5.2 Robustness of the proposed EcoQ

The productivity of black-legged kittiwakes has the potential to provide an appropriate EcoQ for sandeel abundance, with variations in productivity indicating changes in the abundance and distribution of the sandeel stock. The productivity of black-legged kittiwakes is more sensitive than that of most other seabird species to changes in prey availability due to their relatively small size, short foraging range, surface-feeding habits, and limited scope to increase foraging effort (Furness and Tasker, 2000). In the northwestern North Sea, kittiwakes are largely dependent on sandeels for food owing to the low availability of alternative small, schooling fish. Black-legged kittiwake productivity is correlated with sandeel abundance in the North Sea and in Shetland (Furness, 1999a) and variation due to other factors such as predation and storms can generally be recognized and controlled. Changes in black-legged kittiwake productivity and sandeel abundance occur within a single summer and so provide an immediate annual index of sandeel abundance (Furness, 1999a). Productivity is easy to measure and a time series of data is available from most of their North Sea breeding range to provide current levels of the EcoQ (Upton *et al.*, 2000). Monitoring will continue in the future according to an agreed protocol. Black-legged kittiwake breeding distribution in the North Sea is largely confined to northeast England and Scotland (Lloyd *et al.*, 1991), owing to their dependence on cliffs for nesting habitat. They have a limited foraging radius that is generally within 50 km of their colony (Furness and Tasker, 2000), so the EcoQ is confined to the northwestern North Sea. There is limited spatial

overlap of sandeel fishing and black-legged kittiwake foraging areas during the breeding season, as most fishing effort is directed at offshore sandbanks (Wright and Begg, 1997; Furness and Tasker, 2000).

4.9.5.3 Discussion

Black-legged kittiwake productivity has the potential to provide a reasonably robust EcoQ for sandeel stocks that have a great significance as a component of the marine food web and are difficult to quantify by conventional means. The limited geographical scope of the EcoQ, owing to the constraints of black-legged kittiwake nesting habitat and foraging ranges, does reduce its value over the North Sea as a whole. However, black-legged kittiwake productivity provides a valuable EcoQ for fisheries operating inshore near seabird colonies such as Wee Bankie and Shetland. These are areas where ecologically sensitive management of sandeels is important, and kittiwake productivity provides a valuable tool to inform stock management as well as an indicator of ecological quality.

4.9.5.4 Provisional estimates for EcoQ levels in the North Sea

EcoQ title: *Local sandeel availability to black-legged kittiwakes and other predators*

Reference level: No quantitative reference level can be presented.

Current level: The current level of productivity in the northwestern North Sea is 0.97 ± 0.28 (CV) chicks per pair, based on colonies in the northwestern North Sea from 1986–1996, but excluding Shetland where predation by great skuas and atypically low sandeel availability has reduced breeding success (Furness, 1999b).

Suggested EcoQO target level: The target level for black-legged kittiwake productivity is a minimum average of 0.5 chicks per pair. The EcoQO would not be met if productivity fell below this level. This is a level that was judged to reflect a favourable ecological quality of sandeel.

4.9.5.5 Assessment of usefulness of suggested EcoQ

Black-legged kittiwake productivity has the potential to provide a robust EcoQ for sandeel stocks, which are difficult to measure by conventional means. The productivity is relatively easy to measure and some data are already available. Changes in productivity and sandeel abundance occur within a single summer and so provide an immediate annual index of sandeel abundance. This would, however, be applicable only to the foraging areas of the birds and not to the North Sea as a whole. Furthermore, no information is available on

the levels of regional sandeel stocks and the kittiwake productivity that they support in the absence of anthropogenic influence.

4.9.5.6 References

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4.9.6 Seabird population trends as an index of seabird community health

4.9.6.1 Background

At North Sea latitudes, environmental variability is expected to be relatively large and, hence, at any one time most seabird populations will be either increasing or decreasing. Consequently, healthy seabird communities in the North Sea are also characterized by significant population changes within limits set by natural factors. Documented changes in seabird populations cannot usually be explained in full due to a lack of information on how various natural and human-induced environmental factors affect their main population parameters such as reproduction, recruitment, and survival rates. Obviously, there is no need to initiate intensive research aimed at explaining all changes in seabird numbers. The magnitude of such changes may, nevertheless, serve as an appropriate EcoQ for the intrinsic health of seabird communities. This is based on the simple assumption that a pronounced negative trend in the population of any seabird species could indicate that it is an undesirable effect of human activities. In other words, when a certain level of population change is reached, the public concern is regarded to be so great that it represents a provisional reduction of ecological quality. Ideally, and as a precautionary measure, reaching such a threshold should then trigger adequate studies targeted at revealing its underlying causes. If the change proves to be an undesired consequence of human activities, useful mitigating measures should be identified and implemented. In some cases, monitoring the effect of these measures may benefit from defining additional and more specific EcoQs for the seabird populations and/or environmental factors involved.

4.9.6.2 Robustness of proposed EcoQ

On a short-term scale, seabird population size is not the parameter most sensitive to environmental change. Due to the longevity and delayed maturity of most seabirds, several years are usually needed before changes in their reproduction or immature survival rates affect their breeding numbers. Nevertheless, changes in population sizes are reasonably good indicators of important changes in seabird community structure, where density-dependent effects may easily reduce the usability of other population parameters. Furthermore, the population size of breeding birds and birds wintering in coastal areas is far easier to monitor extensively throughout the geographical range of the target populations.

4.9.6.3 Provisional estimates for EcoQ levels in the North Sea

EcoQ title: Seabird population trends

Reference levels: Variable, but largely of unknown magnitude.

Current level: Variable, see Sections 4.8.3, 4.8.4, and 4.8.5.

Suggested EcoQO target level: $\leq 20\%$ decline over ≥ 20 years (more details below).

Setting a target level for a population change that warrants further research and management intervention in this context is no straightforward task. However, the criteria used to identify bird species of European conservation concern based on the definition of a moderate decline (Tucker and Heath, 1994) are useful for this EcoQ. This would mean that a reduction in the population of a seabird species deserves special attention if it has, over a period of less than 20 years, declined in size or range by at least 20 % in 33–65 % of the population or by at least 50 % in at least 25 % of the population. This criterion has been proposed to the OSPAR Biodiversity Committee for use in other parts of the Northeast Atlantic. Assessed on the background of the known trends for seabird populations in the North Sea (Sections 4.8.3–4.8.5), ACE finds that this suggestion sets a reasonable target level for the proposed EcoQO. It is not very different from the target level suggested by Anker-Nilssen *et al.* (1996) to identify the need for more detailed studies or management actions, although they argued that also positive trends of similar magnitude deserve attention. In such cases, ACE recommends that the attention be primarily addressed to explain increases in species that could conflict with other seabird populations that are falling under the target level.

4.9.6.4 Assessment of the usefulness of suggested EcoQ

The non-scientist would easily understand the proposed EcoQ(s), however, not all changes in the EcoQ could be ascribed to a manageable human activity: in many cases this EcoQO would have to act as a trigger for further research. Changes may or may not be tightly linked in time, but in most cases they are relatively easily and accurately measurable. If a suite of single species seabird EcoQs were chosen, then a large proportion of the area would be covered. There are good time series available.

4.9.6.5 References

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4.9.7 Human activities for which no suitable seabird EcoQs could be found

Meaningful or appropriate EcoQs could not be derived for a number of the categories considered. These categories included:

- 1) Eutrophication: the effects of eutrophication on seabirds are not well known.
- 2) Mariculture: the scale of this interaction appears to be comparatively small in ecosystem terms.
- 3) By-catch of seabirds: the effects are considered to be localized and sporadic.
- 4) Increase in seabird food supply: it is difficult to predict the size of the population decline that would result from better management of fish stocks and fisheries in the North Sea through, for instance, the avoidance of capture of undersized or non-target fish or through reduction in overall fishing mortality.
- 5) Hunting/harvesting: there is currently little, if any, hunting of breeding seabirds in the North Sea.
- 6) Disturbance: while human recreational usage of the North Sea and its coasts is intensive and in some areas is sufficient to reduce the habitat available for use by seabirds, e.g., loss of breeding areas on beaches for Kentish plover (*Charadrius alexandrius*) and little tern, it is difficult to distinguish the signal coming from such disturbance from the number of other factors affecting seabirds. Thus, while EcoQOs could be set as targets for the management of the individual species, this would not be useful in managing for reduction in disturbance.
- 7) Introduced/conflicting species: ACE considered that an EcoQ using seabirds to indicate the state of islands in relation to introduced mammals would not improve on surveying for the introduced mammals directly. An index of numbers of islands without introduced mammals could be derived and could be used as an index of progress in ridding islands of introduced and invasive species.
- 8) Climate change: as the linkages between climate change and seabird dynamics are mainly through several lower trophic levels, and seabirds have quite robust mechanisms to buffer themselves against such perturbations, it is unlikely that seabirds would provide a strong EcoQ in relation to impacts of climate change. The most likely responses of seabirds to climate change will probably be modulated through effects of changes in food fish distributions and abundance.

4.10 Use of Precautionary Reference Points as EcoQs

4.10.1 Request from the European Commission concerning the use of precautionary reference points as EcoQOs

EC DG Fish requested ICES to respond to the following question:

Can the precautionary reference points (F_{pa} and B_{pa}) as currently defined by ACFM serve as Ecosystem [sic] Quality Objectives EcoQOs?

4.10.2 Background

Consideration of the issue of “reference points which include ecosystem considerations” started within ICES in 1997 (ICES, 1998). This request was approached by considering whether the reference points already developed for commercial fish species would help to ensure effective management of the ecosystem. This approach was justified with the reasoning that, although a few conceptual and many operational problems remained with advising on and managing fisheries in a precautionary framework, the tasks were still much simpler, and the practical experience greater, with marine fisheries management than with marine ecosystem management.

4.10.3 Response to request for advice

ACE recommends that if reference points were used as intended in management, and the spawning stock biomass of target species increased until $SSB > B_{pa}$, fisheries would already be much further on the way towards meeting any specified ecosystem objectives and the ecosystem effects of fishing would be greatly reduced. The management of fishing effort at levels which deliver a high probability that SSB exceeds B_{pa} for target species is likely to ensure their effective conservation in relation to the objectives of the ecosystem approach to fishery management. Thus, **the precautionary reference points as defined by ACFM can be used as EcoQOs** (EcoQs in the sense of the other parts of this report) **for target species, and their implementation will help to achieve conservation objectives for the ecosystem. However, management to B_{pa} will not ensure complete ecosystem integrity** (e.g., it does not address problems of local extirpation of species such as skates and rays, nor local depletions of targeted species).

Additional reference points for fish populations should be considered as part of the ecosystem approach to fisheries management (ICES, 1998, 2000). Those that have been identified as necessary are reference points for:

- 1) Non-target fish species taken as by-catch or killed by the gear (this includes species that may be targeted in some fisheries but for which ACFM has not determined reference points (ICES, 1997));
- 2) Ecologically dependent fish species (species that are so tightly linked ecologically to the target species that changes in the abundance/distribution of the target, which do not approach B_{pa} , may still compromise the status of the ecologically dependent species);
- 3) Genetic health of fish populations (the Convention on Biological Diversity explicitly recognizes the need to conserve genetic diversity).

It is important to emphasize that these potential reference points relate to single-species objectives for the conservation of the fish component of the ecosystem rather than integrated community metrics as discussed in Section 4.11. ICES has previously concluded that reference points as in 1), above, are necessary for benthic species, and as in 2), above, for seabirds, and is further developing its advice on these topics. ICES will return to this issue often as results of scientific investigations and reviews become available.

4.10.4 References

ICES. 1997. Report of the ICES Advisory Committee on Fishery Management, 1997. ICES Cooperative Research Report, 223.

ICES. 1998. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 1998/ACFM/ACME:1.

ICES. 2000. Report of the ICES Advisory Committee on the Marine Environment, 2000. ICES Cooperative Research Report, 241: 9–26.

4.11 Consideration of Possible EcoQs for Fish Communities and Benthos Communities

4.11.1 Introduction

In the context of the overall work on the development of EcoQOs, ICES was requested to consider possible EcoQs for fish and benthos communities. This is a general request for information based on the role of ACE as the primary source of scientific information on the status and outlook for marine ecosystems, as agreed at the 2000 Statutory Meeting of ICES:

ACE will have the primary responsibility for scientific information and advice on the status and outlook for marine ecosystems, and on exploitation of living marine resources in an ecosystem context. ACE will provide a focus for advice that integrates consideration of the marine environment and fisheries in an ecosystem context, such as the ecosystem effects of fishing. ACE

will be at the forefront of the development of advice on ecosystem management.

The request is similar to term of reference e) of the 2001 meeting of WGECO (ICES, 2001):

Based on previous considerations of community metrics and ecosystem reference points, provide recommendations on the development of EcoQOs for fish and benthic communities.

4.11.2 Background

In 1997 and 1999, the Working Group on Ecosystem Effects of Fishing Activities (WGECO) considered reference points for individual fish species and for fish communities. For individual species, WGECO reported that the reference points already developed for commercial fish species would deliver a high probability of achieving conservation objectives for target stocks (if $SSB > B_{pa}$), and that consistently maintaining biomass above the reference points would be the main change to management practices that would ensure conservation of the ecosystem. Moreover, WGECO could not propose a community property that would be at risk when individual species were maintained above their reference points.

However, WGECO also concluded that additional reference points would be needed as part of an ecosystem approach to fisheries management. WGECO did not consider that it was appropriate to provide reference points for fish communities, because scientific understanding of the responses of the emergent properties of these communities (e.g., production, production:biomass ratios) was so poor.

WGECO reconsidered its previous deliberations on community metrics and ecosystem reference points at its 2001 meeting, in order to provide recommendations on the development of EcoQs for fish and benthic communities.

4.11.3 Response to request

Before providing recommendations on the development of appropriate EcoQs for fish and benthic communities, it is important to recognize that there are three key concerns that relate to the application of EcoQs to these communities. These concerns are:

- 1) The selection of “appropriate” EcoQs is not straightforward because there is no singular scientific definition of “appropriate”. This is because there is incomplete scientific knowledge of the properties of an ecosystem that are necessary and sufficient for its conservation. Moreover, “appropriate” conveys the human values that society attaches to ecosystem properties, and choosing what is “appropriate” is a decision to be made by society.

- 2) By definition, any broad EcoQ metric for a community reflects the ecosystem response to a broad set of human impacts, and therefore it may not be possible to identify the contribution of each activity to its present value.
- 3) The OSPAR decision to proceed with identifying EcoQs for ten separate issues means that it is possible for more than 100 EcoQs to be proposed. As the number of EcoQs increases, so does the risk of redundancy or, more seriously, mutual incompatibility. In attempting, for example, to restore commercial fish stocks, and fish and benthic communities to some improved state, future population growth of seabirds or marine mammals may be affected by reductions in discarding.

4.11.4 EcoQs for fish communities

The ecological quality of fish communities can be described by a broad array of metrics including the relative abundance of individuals, their species membership, the biological traits of individuals and their life history strategies. The number of metrics that provide appropriate EcoQs is, however, restricted by the information that is available for these communities from existing surveys, the understanding of the processes involved, and the difficulty associated with communicating complex metrics effectively. For example, life history characteristics that involve fecundity are available for only a few species, and body condition and growth are not known for all species. When data for a specific variable are known for only a subgroup of species, it must be judged whether the subgroup is representative of the fish community.

WGECO completed a thorough review of the array of metrics that could be used to describe fish communities (ICES, 2001). Possible metrics were scored using a three-point scale, on the basis of whether they met the following criteria:

- 1) relatively easy to understand by non-scientists and those who will decide on their use;
- 2) sensitive to a manageable human activity;
- 3) relatively tightly linked in time to that activity;
- 4) easily and accurately measured, with a low error rate;
- 5) responsive primarily to a human activity, with low responsiveness to other causes of change;
- 6) measurable over a large proportion of the area to which the EcoQ metric is to apply;
- 7) based on an existing body or time series of data to allow a realistic setting of objectives.

The criteria were based on the desirable features of EcoQs as reported at a series of recent meetings.

Of the more than fifty metrics for fish communities, only 21 were considered to have any practical utility. The others could not be used at all, or were usable only after extensive additional research and monitoring, and were disregarded in further analyses. The list of 21 potential metrics was further reduced, by removing metrics that failed to meet one or more criteria.

The following metrics were considered potentially useful:

- 1) length frequency (percentage composition by size class; slope of size spectrum);
- 2) mean length/weight of fish within specified limits;
- 3) presence of indicator/charismatic/sensitive species;
- 4) species abundance (k-dominance curves; species composition);
- 5) maximum length (weighted mean L_{\max} of community);
- 6) mean and distribution of "body condition".

Several of the aspects of the fish community represented by these different metrics appeared to be related and could be traced to fishery-induced size-specific mortality which changes the size structure of all the species and populations that form a community.

Therefore, the proposed metrics for the North Sea fish community are the average weight of individual fish and the average maximum length. From a conservation perspective, appropriate EcoQOs would move these metrics towards a larger proportion of large fish and would improve fisheries yields. Neither metric would discriminate between treatments which simply allowed individuals of exploited species to grow larger (and live longer, i.e., lower mortality) and treatments which changed the species composition towards a higher proportion of species with larger maximum possible weights and lengths (redistributing mortality across species and away from those with greater maximum sizes).

In conclusion, for fish communities, the average weight of fish and average maximum length of fish are the two metrics which met the scientific standards required and are considered to be suitable metrics of community structure. They describe key features of the relative abundance and size distribution of the community.

While the average weight of fish and the average maximum length of fish are considered to be good EcoQ metrics for fish communities, research is needed to quantify accurately the association between these EcoQs and fishing effort, to determine reference, current, and target levels and to determine the management responses that are needed to modify current levels. Since all fish sampling methods are strongly size and species selective, monitoring of the average weight of fish and average

maximum length of fish would have to be based on data from a survey that uses standard gears and protocols (e.g., the International Bottom Trawl Survey (IBTS)).

4.11.5 EcoQs for Benthic communities

In considering the broad aims of ecosystem management with reference to the benthos, the most important community metrics appear to be the species composition (including the presence of fragile, opportunistic, and keystone species), productivity, and trophic structure.

However, ACE emphasizes that few, if any, metrics that are possible to measure on a routine basis can provide a holistic picture of the benthic community. This is largely the result of sampling constraints. Thus, meiofauna, macro-infauna, and epibenthos of soft sediments are rarely recorded in the same surveys, and usually not in a way that would allow synthesis of the data into a "community picture". The situation is even more problematic when one considers hard substrates not amenable to grab or core sampling.

Given these problems, there are two possible approaches to setting EcoQOs: 1) to focus on one aspect of the benthic community, and assume that if this component meets the EcoQ, then other parts of the community will also conform, and 2) to set EcoQs for each component of an area—meiofauna, infauna and epifauna of sediments, sessile epibiota, and mobile epifauna for rocky areas. The latter approach would greatly increase the number of EcoQs required and would be expected to involve problems of consistency among components in their response to management measures.

WGECO completed a thorough review of the array of metrics that could be used to describe benthic communities. Possible metrics were scored using a three-point scale, on the basis of whether they met the seven criteria described above. Of these, only fourteen metrics could be used at all, or could be used without extensive additional research and monitoring. The list of fourteen potential metrics was further reduced to one, by removing metrics that failed to meet one or more of the seven criteria.

The remaining metric, the presence of indicator or sensitive species, was identified as a good metric of ecological quality in benthic communities. There are several indicator species, often consisting of habitat-forming species such as corals and epifaunal organisms, that are known to be sensitive to bottom fishing disturbance. The use of indicator species obviates the need to identify all species in benthic samples. However, in some benthic communities, there may be no obvious indicator species, suggesting that an EcoQ based on sensitive or indicator species may not be comprehensive. Also, some epifaunal species that may make good indicators may have been removed by past fishing practices, yet present fishing practices may continue to impact benthic ecosystem function.

WGECO also identified three metrics for benthic communities that may be developed further. These scored quite high in the WGECO assessment, but not as high as the presence of vulnerable or indicator species. These metrics were biomass, k-dominance curves, and the presence of non-indigenous species. WGECO concluded that the adoption of these as metrics of benthic EcoQ may address some of the shortcomings of the application of “the presence of indicator or sensitive taxa”.

Biomass per m² is an aggregate measure of the benthic community that does not necessarily require all species to be identified. Biomass is also a component of benthic productivity, a parameter that is difficult to measure directly. Disadvantages of using biomass as a metric are that environmental and anthropogenic impacts on biomass variations may be confounded, and that time series of benthic biomass estimates are not available in most locations.

K-dominance curves are obtained by plotting cumulative ranked abundance against the log of species rank, and the shape is a direct function of species relative abundance. K-dominance curves may provide a useful measure of changes in species diversity in benthic communities. Perturbations allow a subset of tolerant species to persist while the intolerant species disappear or become rare, so the curve is expected to change in a predictable direction in response to disturbance. Shifts in k-dominance curves have been demonstrated in response to pollution and to experimental beam-trawling disturbance. A potential disadvantage of k-dominance curves is that the graphical representation is somewhat difficult to comprehend and to communicate to policy-makers and other non-specialists.

The presence and abundance of non-indigenous species may also be a useful metric of ecological quality. Non-indigenous species, both invertebrate and fish, have been widely spread by the discharge of ships' ballast water and in some areas have markedly altered benthic food chains and community structure. The spread of non-indigenous species is clearly caused by human activity, but it can be very difficult to manage this activity and the invasion of indigenous species is unlikely to be reversible.

The three additional metrics described here (biomass, k-dominance, and presence/absence of non-indigenous species) are potentially useful measures of ecological quality in parts of the benthic community. However, their practical utility is limited by the history and intensity of benthic sampling. While these metrics are most applicable to the benthic macrofauna and epibenthos, in principle they could also be applied to the meiobenthos, but there has been much less sampling to support their use in this part of the benthic community.

Since biomass, k-dominance curves, and the presence of non-indigenous species do not meet all the desirable criteria for EcoQs, the inclusion of these additional metrics provides a weaker basis for ensuring effective ecosystem management. This does not mean that it is necessarily a bad approach, but ACE expects it to be an approach with higher risk than one which could be implemented if more metrics met the required criteria.

As with the proposed EcoQs for fish communities, research is needed to quantify accurately the association between the proposed EcoQs for benthic communities and fishing effort, to determine reference, current, and target levels and to determine the management responses that are needed to modify current levels.

4.11.6 Summary

There are a number of important concerns about the use of EcoQ metrics for fish and benthos communities. The most appropriate metrics for fish communities are the average weight and average maximum length, and the most appropriate metric for benthic communities is the presence of indicator species. Target, current, and reference levels still need to be determined for these EcoQs.

4.11.7 References

- ICES. 1998. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 1998/ACFM/ACME:1.
- ICES. 2001 Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2001/ACME:09.

Request

To present an overview of progress in the ICES work on the topic of marine habitat classification and mapping during 2000–2001.

Source of the information presented

The 2000 report of the Study Group on Marine Habitat Mapping (SGMHM), the 2000 report of the ICES Advisory Committee on the Marine Environment (ACME), the 2001 reports of the Working Group on Marine Habitat Mapping (WGMHM), the Working Group on Ecosystem Effects of Fishing Activities (WGECO), the Benthos Ecology Working Group (BEWG), the Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT), and the Workshop on Deep-Seabed Survey Technologies, material on physical habitat mapping from the 2001 ACME meeting, and ACE deliberations.

Status/background information

During the period 2000–2001, several relevant meetings have taken place: 1) the OSPAR/ICES/EEA Workshop on Marine Habitat Classification, held in Southampton, United Kingdom, in September 2000; 2) the Workshop on Deep-Seabed Survey Technologies, held in Bergen, Norway, in January 2001; 3) the Theme Session on Classification and Mapping of Marine Habitats, held during the ICES Annual Science Conference in Bruges, Belgium in September 2000; and 4) the meeting of the WGMHM in Galway, Ireland, in 2001.

As part of its scientific objectives, ICES aims for the development of a classification system and maps of marine habitats of coastal areas, continental shelves and slopes, and the open ocean.

In order to define the intrinsic value of a habitat and its management requirements, a classification system must first be established for the ICES area, with subsequent habitat mapping.

Increasing human impacts such as fishing, shipping, land reclamation, and offshore oil drilling have resulted in environmental pressure on marine areas. The international community has reacted by committing itself to a number of international agreements (e.g., OSPAR Convention 1992, Annex V) specifying that a precautionary approach be adopted to prevent areas from suffering irreversible ecological damage. As human-induced changes of the marine environment are known to have potentially large-scale impacts, it is important to develop a classification system that is valid at an international scale.

ICES recognizes the need for marine habitat mapping in relation to marine biodiversity and the conservation of marine habitats. ICES will need to cooperate with its partner organizations (e.g., OSPAR and the EEA), which are also active in this field. In this section, recent developments in marine habitat classification and mapping are discussed as part of the ongoing work of ICES and its partner organizations in this field.

5.1 Developments in Marine Habitat Classification

In different parts of the world, initiatives are being taken to develop habitat classification systems to serve as a common language for those who are involved in protecting and conserving threatened ecosystems. Two of these initiatives are described here: the EUNIS classification system and the ARC system.

5.1.1 EUNIS

At the initiative of the European Environment Agency (EEA), the EUNIS habitat classification has been developed. Davies and Moss (2000) presented a description at the 2001 WGMHM meeting in Galway. EUNIS stands for European Nature Information System and aims to provide a common framework for a European habitat classification, for terrestrial as well as aquatic ecosystems. This classification builds upon the CORINE/Palearctic classification. The classification of marine habitats is largely derived from the BioMar project (Connor *et al.*, 1997a, 1997b), while classification systems developed by HELCOM for the Baltic Sea, by the Barcelona Convention for the Mediterranean Sea, and by OSPAR for the Northeast Atlantic are slotted in.

Within EUNIS, marine habitats are distinguished at different levels. At the upper level, marine habitats are distinguished from the groups of terrestrial habitats (in total nine). At the second level, the water column is distinguished from the seabed, while the key criteria for further division are depth and substrate. This results in seven main categories of marine habitats at level 2 (Figure 5.1.1.1). In the next level (level 3), physical conditions are introduced, including salinity and exposure. An example of level 3 is given in Figure 5.1.1.2. From level 4 on down, biological characteristics of the habitat start to play a role. Special attention was paid to the EUNIS classification of pelagic habitats and the mapping difficulties expected in a system as dynamic as the pelagic ecosystem. It was concluded by the WGMHM that as long as the existing units sufficiently express the dynamics of the system, the classification system will not need extra units.

Figure 5.1.1.1. EUNIS Habitat Classification: criteria for marine habitats to Level 2, resulting in seven main categories.

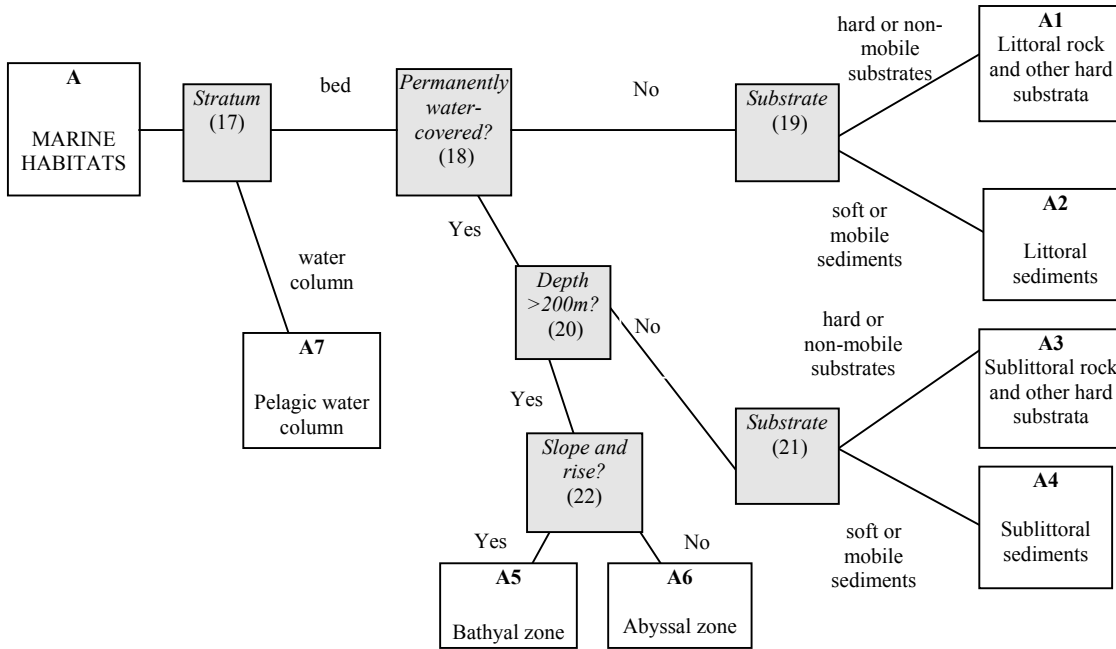
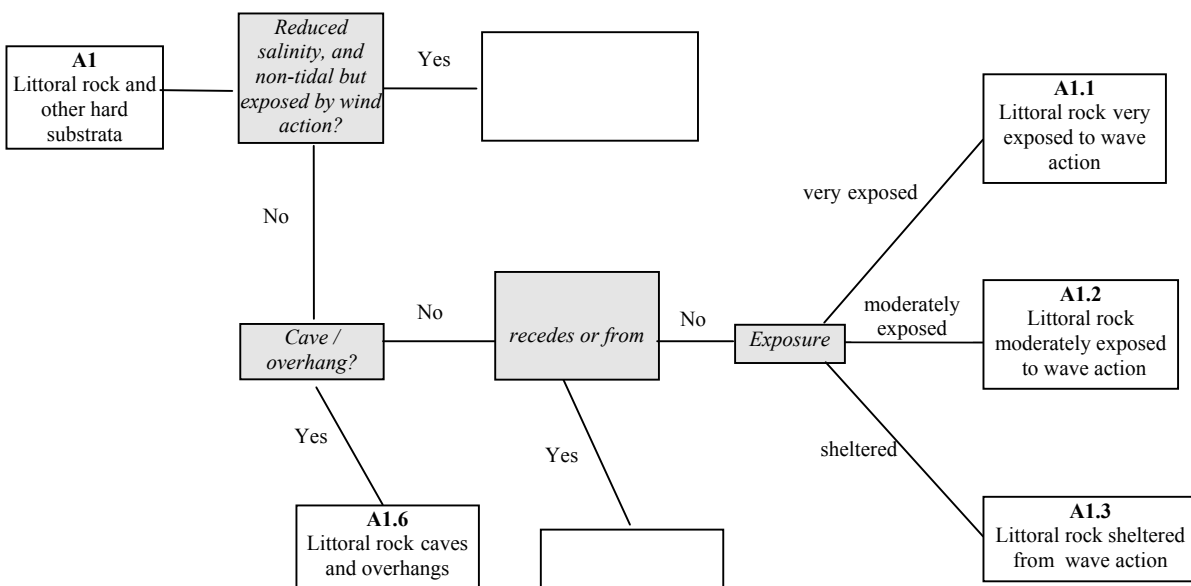


Figure 5.1.1.2. EUNIS Habitat Classification: criteria for littoral rock and other hard substrata (A1) to Level 3.



5.1.2 ARC classification under development

Sponsored by the Ecological Society of America and NOAA's Offices of Habitat Conservation and Protected Resources, discussions have started in the United States during the Aquatic Restoration and Conservation Workshop (ARC) to develop a framework for a national marine and estuarine ecosystem classification system to be used for monitoring habitats, in order to help managers in protecting and conserving threatened ecosystems. As the EUNIS classification does not provide for a number of major habitat complexes in the USA (coral reefs, mangroves), it was decided to explore the feasibility of a classification system better adapted to North American conditions. Starting from the consensus that a classification system would provide a useful common language for a description of habitat and a framework for interpretation of ecological function, ARC developed a prototype of a marine and estuarine habitat classification system (Allee, 2000). This prototype is still very much under discussion. It has the following principles:

- The system is a blend of theoretical and pragmatic, as well as physical and biotic structuring variables.
- It distinguishes up to thirteen levels (Table 5.1.2.1).
- The twelfth level considers substratum and ecotypes.
- The thirteenth level considers modifiers and eco-units:
 - Possible modifiers may be temperature, local energy regimes, salinity, history of extreme events, etc.
 - An eco-unit is the smallest element of the ecosystem as a whole. It represents the biological community that is the product of the physical and biotic variables above it, and is the closest approximation of the ultimate conservation target.
- The classification system is structured to allow aggregation at different levels depending on the amount of data available on an ecosystem.
- Aggregating at higher levels results in more general information. However, as more specific information becomes available, more specific categorization can occur. This was necessary because the amount of information available on many ecosystems is limited. To accommodate this practical need, the position in the hierarchy of some of the variables is somewhat arbitrary and is based on the probability of the information being available.

Table 5.1.2.1. Proposed Marine and Estuarine Ecosystem Classification System (Table 1 from Allee, 2000).

1. Life Zone	1a. Temperate 1b. Tropical 1c. Polar
2. Water/ Land	2a. Terrestrial 2b. Water
3. Marine/ Freshwater	3a. Marine/Estuarine 3b. Freshwater
4. Continental/ Non-Continental	4a. Continental 4b. Non-Continental
5. Bottom/ Water Column	5a. Bottom (Benthic) 5b. Water Column
6. Shelf, Slope, Abyssal	6a. Shallow – on or over the continental shelf; < 200 m 6b. Medium – on or over the continental slope; 200–1000 m 6c. Deep – on or over the rise and deeper features; > 1000 m
7. Regional Wave/ Wind Energy	7a. Exposed/Open – open to full oceanic wave or wind energies 7b. Protected/Bounded – protected from full wave or wind energies
8. Hydrogeomorphic/ Earthform Features	8a. Continental – Nearshore (surf zone); Inshore (rest of shelf); Straight or partially enclosed shorelines; Lagoons; Fjords; Embayments; Estuaries – Shore zone; Offshore zone; Delta; Carbonate settings; Outer continental shelf; Upper continental slope; Upper submarine canyon 8b. Non-Continental – Island (Volcanic; Low); Atoll; Submerged reef types
9. Hydrodynamic Features	9a. Supratidal – above high tides 9b. Intertidal – extreme high to extreme low water 9c. Subtidal – below extreme low water 9d. Circulation features – e.g., eddies
10. Photic/ Aphotic	10a. Photic 10b. Aphotic
11. Geomorphic Types or Topography	11. Cliff; Bench; Flat; Reef flat; Spur-and-Groove; Sand bar; Crevice; Slump; Rockfall; Terrace; Ledge; Overhang; Steeply sloping; Riverine; Fringe; Inland; Beach face; Dunes
12. Substratum and Eco-type	12a. Substratum (Not limited to this list) – Cobble; Pebble; Sand; Silt; Mud; Bedrock; Peat; Carbonate; Boulder; Biogenic; Organic; Anthropogenic 12b. Eco-type (Not limited to this list) – Coastal; Soft bottom; Hard bottom; Water column; Beach; Mangrove; Wetland; Seagrass bed; Coral reef; Kelp bed; Mud flat
13. Local Modifiers and Eco-unit	13a. Modifiers (Not limited to this list) – Temperature; Local energy regimes – waves, tides, current; Salinity; Nutrients; Alkalinity; Roughness/relief; Dynamism; Edge effects – from adjacent areas; Anthropogenic disturbances; Biological interactions; Extreme events – history 13b. Eco-units – Unlimited representation of species resulting from modifiers applied at the above hierarchical levels.

The classification systems EUNIS and ARC were first discussed by the Study Group on Marine Habitat Mapping (see ICES, 2000a). In 2001, WGMHM was asked to prepare material for a discussion on the various classification systems, their advantages and disadvantages, to be dealt with by ACME. WGMHM stated that: “The present state of the United States of America (USA) habitat classification work was unclear to the Working Group”; and WGMHM has only considered the development of a single classification system (EUNIS) over its two-year rapid development.

WGMHM acknowledged that, whilst it is not finished, it has achieved a good consensus on the structure to EUNIS level 4 and much of level 5. Whilst further development is important, the perceived shortfalls in the system are in the Baltic and Mediterranean, where WGMHM is lacking in specific knowledge to resolve these issues, and in the more detailed aspects for the Northeast Atlantic. There has been some input by a few representatives from Baltic countries at previous meetings, however, they were not represented at the 2001 meeting to attempt to resolve the difficulties.

WGECO, in its review of the EUNIS scheme in its 2001 report, concluded that:

- It is important that habitat maps are based on a logical classification of the marine environment. This is available as the EUNIS habitat classification scheme, and further efforts to populate the lower hierarchical levels should be encouraged.
- It was also recommended that future developments of the EUNIS classification scheme take into account habitats influenced by human activity.

The Benthos Ecology Working Group (BEWG), in its 2001 report, recommended that further refinement of the EUNIS classification should be encouraged, and could be facilitated by testing of the classification in the North Sea Benthos Project.

WGMHM recommended facilitation of further refinement of the EUNIS pelagic classification. To this end, WGMHM put forward a list of names of experts to be consulted. This list includes experts on benthopelagic, pelagic, and neuston habitats.

Finally, WGMHM proposed a shift of emphasis from the classification subject toward the development of habitat maps. These maps will then be used to further test and develop the EUNIS system.

5.2 Developments in Habitat Mapping

Several habitat mapping projects within the ICES area are running or planned, for example, projects in the UK, Norway, Belgium, the Netherlands, and Canada. Most of these are small-scale mapping projects using different classification systems. More information about the

projects can be found in the 2000 SGMHM and the 2001 WGMHM reports.

On the basis of a review of these projects, WGMHM recommended:

- 1) To continue with high-resolution mapping, by extending coverage to the whole of the North Sea and possibly the Irish Sea.
- 2) To review existing coarse-grid map systems currently in use to aid the selection of WGMHM standards for low-resolution synoptic mapping at the ICES regional scale.
- 3) To produce low-resolution, broad-scale, coarse-grid maps of habitats for the whole ICES area to a mapping standard to be set by WGMHM. Production of these synoptic maps will require the provision of either low-resolution data or completed maps from various participating countries. Within this map, local/regional mapping initiatives could be represented.
- 4) To request the submission of national status reports on mapping and classification.
- 5) To explore the setting up of a data exchange platform to service the above initiatives. This should result in the establishment of an ICES habitat mapping meta-database containing standardized and verified meta-data. This should provide information on: difficulties in coupling mapping projects, common problems in classification, data handling and quality issues, development of common goals, potential overlap with existing projects, intercalibration of classification and mapping, and development of potential quality checks.

5.2.1 Habitat mapping techniques

ICES (2000b) described several techniques for mapping the shape of the sea floor and for determining the physical properties of sediments of the surface. From these data, marine habitat classification and mapping can be developed. Advantages and disadvantages are inventoried between the so-called swath systems, including side-scan sonar (qualitative data), multiple narrow-beam swath bathymetry (quantitative data) and seismics on one side and the single-beam “echo-sounder” systems on the other side.

The swath systems are most likely to provide the best high-resolution maps of the seabed, particularly over a wide area (swath widths that vary between 30 m and 500 m). They offer the ability to discriminate small habitat (seabed) features (0.3 m to 1 m) and are able to provide information on sediment dynamics and geological evolution. The disadvantages associated with swath systems are their high costs, the time-consuming post-processing, and the experience needed for interpretation.

Single-beam systems such as fish-finder echo-sounders, RoxAnn®, and QTC-View® are useful for reliably detecting gross differences in substrate type, i.e., between rock, sand, and mud. The costs of single-beam systems are much lower and they are generally simple to operate. The disadvantage of single-beam sounders is that they require intensive calibration (ground truthing) when being used to discriminate seabed biotopes. The “echo” beam often has a large acoustic footprint (typically 4 m²), which results in low resolution of seabed features.

A general conclusion is that the high spatial resolution of side-scan sonar systems and their consequent ability to discriminate small-scale habitat features (0.3–1 m), together with providing information on habitat stability, makes them most suitable for detailed biotope mapping applications, while the single-beam sediment discrimination systems (e.g., RoxAnn) are useful for detecting gross differences in substrate.

WGMHM recommended that ICES support the recommendations of the Workshop on Deep-Seabed Survey Technologies and that the results be presented to the 2001 ICES Annual Science Conference.

Based on the WGMHM review, ACE recognized the following:

- 1) A wide range of survey techniques is used for collecting data: remote sensing (e.g., aerial/seabed) and sampling (ROV, grab, core, trawl, etc.). Each technique needs standards for data collection, storage, and interpretation.
- 2) The interpretation of each technique will give rise to a series of classes which needs to be consistently derived by different workers.
- 3) There is a need for a consistent means of integrating these data and/or correlating the classes derived from the different sampling techniques (e.g., acoustic and benthic sample data).
- 4) There is a need to integrate data from different techniques to produce interpreted maps, e.g., of habitats.
- 5) Full integration should lead to a robust habitat classification enabling the use of remote and sample data to be matched to a single classification system.
- 6) Large-scale integration of data from different projects and across countries will require:
 - common data formats;
 - common data interpretation;
 - sharing of data;
 - cooperative programmes between organizations/countries;
 - research.

The Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT) recommended that agreement be sought on the nomenclature to be used at level 3, and that following this ICES Working Groups (BEWG, WGMHM, etc.) should concentrate on the task of prioritizing biotopes that are rare (e.g., bioherms) or under threat (e.g., herring spawning beds) under the level 3 classification, rather than simply commenting on any proposed complete and cohesive classification system at the more detailed levels. WGEXT also recommended that BEWG give consideration to the validation of identified biotopes within the proposed classification system.

Furthermore, the Benthos Ecology Working Group (BEWG) recommended that:

- The integration of data from infauna samples (e.g., from grabs) and epibiota samples (e.g., from videos and trawls) remains a significant issue to be addressed in developing a satisfactory classification of sediment communities. More studies are required where data from the two perspectives (sampling approaches) are collected at the same sites to develop a better understanding of their inter-relationship.
- The integration of benthic sample data with data from acoustic seabed surveys, seabed geology, bathymetry, and hydrography in GIS systems should be pursued, both to develop marine habitat maps and to facilitate the spatial analysis of the different data sets.

5.2.2 Use of habitat mapping

In all reports on habitat mapping, the final use of the maps in a management context is mentioned or discussed. WGMHM mentioned the following examples as potential and/or known uses of habitat mapping:

- Fishery-related issues, e.g., essential fish habitats;
- Biodiversity issues/biological resource management, e.g., Special Area of Conservation (SAC) management;
- Determining conservation value based on spatial extent and distribution of habitats and species;
- Risk assessment;
- Spatial modelling for management and/or decision support systems and to give a greater understanding of the ecosystem;
- Conflict resolution;
- Environmental Impact Statements (EIS) and contaminant/pollution monitoring;
- Long-term monitoring programmes;
- Stratified design of monitoring programmes;
- Geohazard identification;

- Excellent communication tool for education, increasing public awareness, informing policy-makers and stakeholders;
- Resource valuation resulting in greater integrated management.

WGMHM also concluded that there is a need to focus on the end use of the mapping effort supported by habitat classification to understand how best the US contribution can be integrated.

The Working Group on Ecosystem Effects of Fishing Activities concluded that:

- 1) The scale at which effective management will take place is at one or more square kilometres, but the habitat resolution required for this is at EUNIS levels 4 and 5, which is expected to be on the scale of a few metres. There is therefore an inherent mismatch between management needs and the ability of EUNIS to provide appropriate information at this scale. WGECO therefore recommends that EUNIS apply a higher degree of standardization to the habitats at levels 4 and 5.
- 2) WGECO also recommended that, where possible, habitat maps be prepared using descriptors of biological communities as well as the physical substrate. The biological information will be required by environmental managers in order to effectively manage activities which have explicit spatial dimensions.
- 3) Finally, WGECO recommended that effective management of many types of impact requires spatially explicit information on both the extent of the threat, and the habitats threatened. Habitat maps provide this in an accessible form. WGECO urged that more use be made of GIS to assist management decisions, and suggested appropriate methodologies to facilitate movement in this direction.

The Benthos Ecology Working Group found that it was relatively easy to use levels 1–3 of EUNIS, but the information was so general that the exercise was of little practical value. According to BEWG:

- 1) The strong temporal variation (related to, for example, changes in climate or human impact) of some benthic habitats and, hence, benthic communities needs to be considered when elaborating the lower levels of the EUNIS habitat classification. Such temporal variation, together with the limitations of performing large-scale mapping studies, suggests that the classification units should not be too specific. Maps demonstrating the “potential communities” within a particular habitat may be preferable to presenting very refined maps that represent specific communities valid only at one point in time (i.e., from one sampling event).

- 2) Additionally, there is a need to specify those habitats which are regularly disturbed (e.g., estuaries occasionally receiving huge amounts of sediment from freshwater runoff; habitats that are periodically anoxic) and to distinguish them from similar habitats that remain more stable over time. The former will support more opportunistic communities compared with more stable habitats.
- 3) To integrate data sets of different kinds (infaunal/epifaunal), different methods (acoustic/visual) and different approaches (biological/physical/geological), procedures or guidelines need to be developed. Furthermore, the scaling of different data sets should be taken into account. At an early stage, the sampling techniques of institutions (countries) supplying such data sets should be reviewed and only data sets with comparable methods should be selected. GIS should be the usual instrument (or tool) to join the data sets mentioned above. Correlations between biotic and abiotic factors and the identification of indicator species (*sensu* characteristic species for communities or impacts) should be carried out using multivariate statistical techniques.

There are several known and potential uses of habitat mapping, including fishing activities, however, the expectations for using EUNIS especially in the usability of maps for items concerning dynamic activities, e.g. mobile fishing gear, cannot always be too high. The further development of a pelagic component in EUNIS might serve as a good development for using classification and mapping also from a fisheries impact perspective.

5.3 Conclusions

Having considered the above material, ACE agreed to the following conclusions:

- 1) EUNIS classification at level 3 is suitable for use as a template for the development of a classification system to cover the entire ICES area.
- 2) There is flexibility for the inclusion of new units at levels 4 and 5 in the existing framework, and good consensus on the structure to levels 4 and 5 has been achieved.
- 3) Many potential uses of a habitat mapping scheme require that classification at levels 4 and 5 is sufficiently well standardized so that aggregation from base scales of metres to user scales of kilometres to tens and hundreds of kilometres is straightforward. Usability of habitat classification systems would also benefit from the use of descriptors of biological communities as well as physical substrates in the preparation of habitat maps.
- 4) The classification system to be developed must both serve as a solid basis for primary classification of

large-scale areas and also allow a sufficient amount of detail to be of use in restricted areas. A hierarchical system with nested maps can fulfil this requirement.

- 5) Mapping activities should be carried out from coarse to fine, as follows:
 - a) start with the production of large-scale (predicted) biotope maps based on physical characteristics of the area in combination with biological ground-truth sampling;
 - b) suitable techniques for coarse mapping are the single-beam sediment discrimination systems, such as fish-finder echo-sounders, RoxAnn® and QTC-View®; the systems are not expensive and are simple to operate, but need intensive calibration;
 - c) refine the large-scale biotope maps to produce small-scale maps by overlaying them with biological field data;
 - d) detailed biotope mapping applications can be done with swath systems, such as side-scan sonar, multiple narrow-beam swath bathymetry, and seismic side-scan sonar; their costs are high and post-processing is time-consuming and needs experience for interpretation; other techniques are remote video recording, grab sampling, etc.
- 6) In collecting biological data, attention should primarily focus on the shelf seas and the slope, as these are the marine areas that experience the greatest pressure from human activities.
- 7) There is a need to focus on the end use of the mapping effort, while the practical value has yet to be demonstrated.
- 8) There is a need for exploring the establishment of a data exchange platform and a habitat mapping meta-database containing standardized and verified meta-data. This should provide information on: difficulties in coupling mapping projects, common problems in classification, data handling and quality issues, development of common goals, potential overlap with existing projects, intercalibration of classification and mapping, and development of potential quality checks.
- 9) There is a need for developing a habitat classification system in the context of habitat diversity and further determining whether it will be possible to quantify habitat diversity (e.g., index of habitat diversity) similarly to a species diversity index.

Recommendations

ICES recommends continuation of the development of a marine habitat classification system for the ICES area, taking the EUNIS classification as a template, and further building on the classification at levels 4 and 5. In particular, ICES recommends that priority be given to standardization of habitat classification at levels 4 and 5, in ways that facilitate the aggregation of units from scales of metres to scales of kilometres and tens of kilometres.

ICES recommends continued participation in the evaluation of EUNIS level 3, by mapping and testing including continuation and expansion of the North Sea mapping pilot studies and the development of thematic deep-water maps.

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Background

Since the UN Conference on Environment and Development (UNCED), held in Rio in 1992, there has been a great deal of attention focused on issues dealing with biological diversity. This conference led to the Convention on Biological Diversity (The Rio Convention). The objectives of this Convention are “the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources”. The Convention addresses all aspects of biological diversity: genetic resources, species, and ecosystems.

In order to implement the Convention on Biological Diversity, several international and national action plans have been put forward. In Denmark, the Danish National Forest and Nature Agency has to develop an action plan on conservation and management of biological diversity in marine areas covering the Baltic Sea, Belt Sea, Kattegat, Skagerrak, and parts of the North Sea. To obtain inspiration for this work, the Danish National Forest and Nature Agency requested ICES in 2000 to contribute with a selected overview of the present status of international and national biodiversity action plans.

Based on this request, an overview paper on existing international and some national programmes relevant to biodiversity, as well as suggestions for the development of a national plan for the preservation of biodiversity in marine waters, was prepared by ICES Secretariat and approved by ACME in late 2000.

The report contained “an overview of national and international plans for conservation and management of marine biological diversity”, but did not provide a comprehensive overview of all existing plans on the conservation of biological diversity. The report also has a deliberate bias towards national plans from countries in the vicinity of Denmark due to the similarity in natural conditions and environmental management structures among these countries. A review of action plans from a much wider area would have been preferable. The prime aim of the report has been to provide a basis for discussion of the management of biological diversity, rather than to provide specific recommendations on how to implement actions. More general principles for developing plans on biological diversity are discussed in the report.

With this report as a starting point, ACE considered the role of ICES in studies and the provision of advice on biodiversity issues.

The Role of ICES in Biodiversity Issues

The meaning of biological diversity has changed over time. During the 1970s, when biological diversity was one of the “hot” issues, the understanding of the term was usually equal to species diversity. Since then, the definition of the term has broadened and, in the Convention on Biological Diversity, the term means “the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (Rio Convention, 1992). In essence, biological diversity according to this interpretation is defined on the levels of: 1) genes, 2) species, and 3) ecosystems, including habitats and seascapes.

The very broad definition of biological diversity has strong implications for the plans to conserve and manage biological diversity. It is not just a matter of species richness and abundance.

Species diversity is not an independent issue, but an integral component of the ecosystem approach to ocean management and is, as such, already a part of the ongoing activities taken care of by ACE. Biodiversity is linked to Ecological Quality (EcoQ) and is highly relevant for the ongoing process of defining Ecological Quality Objectives (EcoQOs). ICES should play a major role in the definition of marine EcoQOs and in estimating the current level, reference level, and target level for the EcoQO indices identified. For the actual choice of EcoQOs, ICES could provide advice on identifying endangered or keystone species. The work of setting EcoQOs has already been initiated for marine mammals and seabirds. Habitat mapping is also important to biological diversity issues and is taken care of by an ICES Working Group. This is also the case for the work on non-indigenous marine species. Moreover, ICES-coordinated surveys, monitoring, and data management provide a solid basis for the evaluation of agreed EcoQOs

A Mini-Symposium on Defining the Role of ICES in Supporting Biodiversity Conservation was held at the 2000 ICES Annual Science Conference to consider what ICES can contribute to the knowledge and conservation of biodiversity, and what conservation biology means in ICES activities. At the Mini-Symposium there was strong agreement that ICES must give more prominence to biodiversity in both its science and advisory activities. Supported by the recommendations from the Mini-Symposium, two Theme Sessions on the “Use and Information Content of Ecosystem Metrics and Reference Points” and “Sustainable Development and Conservation of Natural Resources of Coastal Zones” were convened at the 2001 ASC. Another Theme Session

for 2002, on experience with and perspectives on Marine Protected Areas, was also proposed.

Further Development in Biodiversity Conservation Action Plans

Recognizing that the fishing sector affects biodiversity, the European Commission has developed a Biodiversity Action Plan for Fisheries (Anon., 2001). The overall objective was “to define and identify, within the current legislative framework, coherent measures that lead to the preservation or rehabilitation of biodiversity where it is perceived as being under threat due to fishing or aquaculture activities”. Three areas were identified as requiring action as regards fisheries:

- 1) To promote the conservation and sustainable use of fish stocks and feeding grounds through control of exploitation rates and through the establishment of technical conservation measures to support the conservation and sustainable use of fish stocks.

- 2) To reduce the impact of fishing activities and other human activities on non-target species and on marine and coastal ecosystems to achieve sustainable exploitation of marine and coastal biodiversity.
- 3) To avoid aquaculture practices that may affect habitat conservation through occupation of sensitive areas, pollution by inputs and outputs from fish farms, and genetic contamination by possible releases or escapes of farmed species or varieties.

An overview of national action plans from countries in the vicinity of Denmark is given in the biodiversity issues report from ICES.

Reference

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ANNEX 1

STATUS OF MARINE MAMMAL HEALTH IN RELATION TO HABITAT QUALITY

1 INTRODUCTION

The health of free-ranging marine mammals may be discussed at two levels: at the level of the population and at the level of the individual. At both levels, the health status is a very complex concept and requires further specifications and definitions. The concept of habitat quality is also very complex and includes a very wide range of factors that may impact the health of marine mammal individuals or populations. The links between habitat quality and marine mammal health are not well described, and the Working Group on Marine Mammal Population Dynamics and Habitats (WGMMPH) felt unable to provide a synthesis of the status of North Sea marine mammals in relation to the quality of their habitat, unless the concepts of "health status" and "habitat quality" are further specified in the request. Two aspects frequently associated with habitat quality are chemical pollution and noise. The WGMMPH therefore referred to a review of effects of chemical contaminants and acoustic disturbance on marine mammals made by the Working Group on Marine Mammal Habitats (WGMMHA) in 1998 (ICES, 1998).

In its 1998 review of acoustic disturbance, WGMMHA concluded that tolerance to acoustic disturbance may be high in some marine mammals, but anthropogenic noise in the oceans represents an increasing problem. In general, the response thresholds are often low for variable and increasing sounds, intermediate for steady sounds, and high for pulsed sounds. However, WGMMPH noted that recent information indicates that anthropogenic noise may result in behavioural changes that are more significant than recognized previously (e.g., Schick and Urban, 2000; Miller *et al.*, 2000), and perhaps in some instances may contribute to fatalities (e.g., Frantzis, 1998).

A very large number of chemical elements and compounds may have an effect on marine mammals, and new compounds are added to this list at increasing speed. WGMMHA restricted its 1998 review to the contaminants that were most likely to cause effects. WGMMHA found it likely that, in particular, the non-*ortho* and mono-*ortho* substituted chlorobiphenyls could cause effects detectable at the level of the population in some contaminated areas. However, WGMMHA concluded that the extent of these effects is unclear, despite some experiments linking contaminants to sub-cellular, cellular, or systemic level effects (e.g., Bergman and Olsson 1985; De Guise *et al.*, 1995a, 1995b; De Swart *et al.*, 1994, 1996; Ross *et al.*, 1996). Although suppression of population growth and fecundity rates have been reported for marine mammal populations resident in contaminated areas (e.g., grey and ringed seals in the Baltic Sea, harbour seals in the Wadden Sea), there is no well-defined cause-effect relationship linking specific contaminants to population-level effects.

WGMMPH reiterated the need for further research on cause-effect relationships linking contaminants to effects in marine mammals, and discussed a possible concept for assessing the health status of marine mammals in relation to habitat quality. This is based on a discussion of Reijnders (2001).

2 CONCEPTS FOR EVALUATING ANIMAL HEALTH STATUS IN MARINE MAMMALS

Assessment of the health status of marine mammals in relation to the quality of their habitat can basically be approached in two ways. One method would be to determine habitat requirements of marine mammals in "low disturbed" or pristine areas and test to what extent the requirements are fulfilled or a deviation from a required state occurs. The other method is to characterize the condition of populations in demographic and physiological terms. Through measuring variables indicative of both sets of parameters leading to an index for population condition, the state of health or condition of the population in question can be assessed and monitored. The first approach requires assessment of the critical habitat in low-disturbance or undisturbed ecosystems. It will be difficult to find any of those systems and to describe a so-called t_0 situation may be too complex. Therefore, the second approach was chosen for further elaboration.

2.1 Population Condition

An index for the condition of a population should include a measure of the recuperative power of the population in question. For example, a population may exhibit a "normal" growth rate after a catastrophe, however, if the immune system of the individuals is significantly challenged, e.g., by contaminants, it is evident that additional stress from, e.g., disturbance will be less likely to be absorbed without effect. A specific example is the crash of a reindeer population (Klein, 1968). This population showed a rapid increase and would have been rated high in terms of population condition, but proved to be unable to recover from a crash after environmental perturbation. The inclusion of a measure of recuperative power or resilience should apply to both the demographic and the physiological conditions. For clarity, resilience could be defined as the power of the individual, or a population, to recover from environmental disturbance, and will indicate the ability to absorb perturbations.

2.2 Demographic Condition

Caughley (1977) suggested expressing demographic condition by a single statistic that combines the vigour of each age and sex class in the population. He proposed the

use of the survival-fecundity rate of increase, called r_s . This r_s is calculated from age-specific survival and fecundity schedules under the conditions a population experiences at a given point in time. This is an attractive concept because it describes the average reaction of members in a population to the integrated action of all environmental variables. Measurement of r_s is difficult and therefore r (average r) is introduced, which is the observed rate of increase. The drawback is that this gives a vigour averaged over a period of time instead of a momentary state.

As explained earlier, a single figure for demographic vigour can be misleading and therefore the use of a combination of demographic parameters has been suggested as being more useful in assessing demographic vigour (Eberhardt, 1977; Hanks, 1981). The events, often observed in a sequence, in a mammalian population with a changing demographic vigour have been used as indices. Such a sequence of events when vigour declines would be in the order: increase in juvenile mortality > increase in age at first reproduction > decline in fecundity > increase in adult mortality. In other words, if a change in juvenile mortality occurs, this would be the proximate expression of a changing trend in the rate of increase. In addition to the importance of monitoring juvenile mortality as a sensitive index for demographic vigour, it can also be concluded that the last parameter a population should "give away" is an increase in adult mortality.

2.3 Physiological Condition

Commonly used indices of physiological condition in mammalian species are: deposited fat reserves, adrenocortical hypertrophy, physical and chemical blood parameters, urinary excretion of hydroxyproline, and body growth.

2.3.1 Deposited fat reserves

Deposited fat reserves as a percentage of carcass weight provide a measure of physiological condition. In large mammals this is often substituted by the kidney fat index (KFI). This index is obtained by expressing the perinephric fat weight as a percentage of the kidney weight. The use of the KFI is based on the assumption that the kidney weight is a constant function of body size. This is demonstrated in many ungulate species (e.g., Smith, 1970), but may not hold for species where seasonal fluctuations in kidney weight occur (Hanks *et al.*, 1976). The applicability of this measure has therefore to be checked for marine mammals.

Bone marrow fat content (BMF), expressed as a fat percentage of the marrow, is an additional alternative to deposited fat reserves. The apparent relation between KFI and BMF offers a useful field guide to decide for either of the two analyses (Brooks *et al.*, 1977). The sequence of fat metabolization provides another opportunity to assess physiological condition. It has been

found in ungulates that rump fat disappears first, followed by subcutaneous fat, visceral fat, and finally marrow fat.

Several studies on marine mammals have indicated the potential for using body mass as an indicator of health or condition. This holds for harbour, grey, southern elephant, and Antarctic fur seals.

Further studies on lipokinetics in marine mammals are required to assess the value of using the above-mentioned indices in measuring marine mammal health.

2.3.2 Adrenocortical hypertrophy

Adrenal hypertrophy and hyperplasia are responses of the body to stress, and increased adrenocortical tissue has a direct relation to adrenal weight. A clear example of this in marine mammals is the adrenocortical hyperplasia found in Baltic seals, reflecting a disease syndrome caused by chemical pollution (Bergman and Olsson, 1985).

It is known that a variety of factors can influence adrenal weight, including low temperature, sexual activity, photoperiod, diet, and population density. Therefore, further studies are needed to establish the relation between adrenal weight and physiological condition.

2.3.3 Blood chemistry haematology and clinical chemistry

A number of studies have been carried out on physical and chemical blood parameters in large mammals. Many of these have provided baseline values for a number of parameters, and for marine mammals increasing data sets are becoming available (Engelhardt, 1979; Bossart and Dierauf, 1990; Roletto, 1993). It is beyond the context of this summary to describe and assess the potential of the many available parameters to serve as indices for physiological condition. Suffice to say that no single parameter should be used in isolation. Equally, no single value should be used because most values are subject to multifactorial influences, and only the evaluation of a full set of routine diagnostic parameters may enable a control for that.

For pragmatic reasons, WGMMPH concentrated in the first instance on three categories of health/condition characteristics: 1) reproduction and early development, 2) function of the immune system, and 3) diseases. This choice was based on ongoing developments in understanding the responses of marine mammals to toxic compounds. In the ecotoxicological field that includes studies on marine mammals, progress has been made to identify response variables and endpoints to be used in assessing reproductive, immune system, and other disorders (Reijnders *et al.*, 1999; Bjørge *et al.*, 1999). It is emphasized that the significance of identifying a set of measures to assess endocrine, immune, and other health disorders goes beyond merely assessing effects of

environmental pollution. Whatever environmental factor is studied, it is equally important to try to distinguish between effects caused by that specific factor and by other stresses.

WGMPH used the set of parameters listed in Reijnders *et al.* (1999) and evaluated whether they are satisfactory for the purpose of assessing health status.

2.3.4 Urinary excretion of hydroxyproline

Hydroxyproline is an amino acid and its secretion is related to the rate of collagen metabolism. Low excretion is associated with malnutrition. Based on this concept, the hydroxyproline-creatinine index (HCI) was developed. The HCI index is the amount of hydroxyproline related to the concentration of creatinine in a sample of urine. Basically, a high HCI can be equated with good condition as manifested by the rate of growth (Malpas, 1977). However, this concept has been criticized and further studies are required to assess its true value and applicability in marine mammal studies.

2.4 Body Growth

A measure of an animal's growth in weight, length, height, and girth can provide criteria for assessing physiological condition. This is based on the concept that reduced weight at age or reduced growth rates are linked with poor condition. The value of using body weight as a criterion for growth rate and nutritive status has been clearly demonstrated for ungulates (Klein, 1970). The use of the von Bertalanffy growth equation to measure growth has been suggested, however, its biological significance has been questioned (Hanks, 1972).

Attempts to relate weight, length, and girth in deer and other ungulates resulted in the formula: $W = a + LG^2$ (W is total body weight (kg), L is total length (cm), and G is girth (cm)). This relationship was highly significant (Riney, 1960). However, in studies on impalas, Hanks *et al.* (1976) demonstrated that changes in fat reserves can occur without expressing themselves in the external appearance of animals. He found that, although the equation mentioned showed a highly significant relationship, the relationship between the same linear measurements and the kidney fat index (KFI) gave a much lower correlation. This implies that animals with identical weight and girth measurements can still differ substantially in deposited fat reserves. This renders the use of body growth as an index for physiological condition questionable.

In summary, population condition may be best described in terms of demographic condition (vigour) and physiological condition. It is evident that confounding factors, such as the influence of sex, age, and seasonality, have to be taken into account when values for these indices are established.

Of the several indices discussed for demographic vigour, it is concluded that rate of increase and juvenile mortality would be practical and sensitive indicators for changes in demographic vigour. Physiological condition may be best described in terms of deposited fat reserves, expressed in fat content of body mass preferably, and a set of haematology and clinical chemistry blood parameters.

Data on KFI and BMF can only be obtained through studies on dead marine mammals, of which the collection of a sufficient number of adequate samples may be complicated or hardly possible. It is therefore suggested to concentrate on developing the use of fat per cent of body mass, and clinical chemistry and haematology blood parameters.

WGMPH emphasized that the assessment of population condition or health should be done through the integration of an assessment of demographic vigour with an assessment of physiological condition. Only a matrix of indices derived from both assessment procedures will enable a comprehensive diagnosis, which a single statistic will never achieve.

2.5 Habitat Quality and Marine Mammal Health

In the above sections, WGMPH elaborated the indices that may be the most powerful. In order to relate health to habitat quality, an assessment either of the way that changes in habitat quality affect "normal" health parameters, or an assessment of the prevailing parameters and actual habitat characteristics in populations with different status, has to be made. WGMPH suggested the latter, owing to a preference to investigate environmental factors that could affect population health, rather than predict the consequences of effects.

The approach suggested is basically to take account of the health parameters of marine mammals which have been exposed and the environmental variables (habitat characteristics) which are associated with exposure. By choosing populations of one species exhibiting different status (gradients of condition), it will be possible to investigate the impact of differences in habitat quality on health parameters. Populations in "good condition" could serve as model populations to determine the quality of the habitat characteristics, and a sum of environmental attributes.

The complicating factor is the decision on which environmental attributes are relevant in this respect. It is reasonable therefore to depart from classifying factors that are known as threats to marine mammal populations. As elaborated in Reijnders *et al.* (1993), they can be conveniently grouped in terms of the immediacy of their effect into:

- 1) Immediate threats
 - results of harvesting or incidental mortality in fisheries;
- 2) Intermediate threats
 - results of habitat degradation (environmental contaminants), effects of commercial fisheries on food availability, effects of natural changes in food availability and food quality, disturbance (human presence and noise), changes in the physical environment;
- 3) Longer-term threats
 - climate change (affecting distribution and abundance, increased incidence of epizootics);
 - genetic diversity (loss of genetic variability leading to lower ability to respond to environmental change).

Each of these threats has to be evaluated for a specific population in a given area, and rated according to estimated environmental stress. The sum of these stresses will give an index of the quality of the habitat in question. This will be a complicated task, but initially a qualitative rating will be useful to start to build such a framework. Furthermore, the rating might be facilitated by analysing simple mathematical models of the processes involved when a known threat exerts a known effect.

In many cases, changes in environmental factors and responses by populations cannot be measured directly owing to a long latency period between a change in the factor and the response. It is therefore suggested to assess the influence of habitat quality on health parameters by using the concept of a dose-response curve, where an index of population condition is expressed against an index of habitat quality.

Again here, a model such as that developed by Anderson and May (1978) could be used to take account of the effects of a combination of stresses and their additive, multiplicative, and interactive effects, as elaborated for effects of combinations of contaminants (Harwood *et al.*, 1999).

WGMMPH realized that the implementation of the suggested conceptual framework is a laborious and complicated task. However, WGMMPH believed that the only way to make progress in relating marine mammal health to habitat quality is to try to express marine mammal health in terms of physiological response parameters, reflecting the influence of habitat quality. Starting with populations in areas where good population data as well as data on habitat characteristics are available should show the potential of this concept. If successful, this system ultimately will provide us with a powerful monitoring instrument that through its "early warning" characteristics enables management decisions to be made at the appropriate time.

There is a need to analyse existing data using a multi-factorial analysis to show which environmental parameters could be correlated to various health aspects of marine mammal populations. Simple and general models should be used to test assumptions or hypotheses. Then a Bayesian approach can be applied to test for best fit of the different models or correlations. It was suggested that, with sufficient preparatory work in advance, the complex question of animal health relative to habitat quality could be addressed based on current data, and this could be a subject for a future special workshop. However, there is a need for describing the mechanisms whereby specific contaminants impact the marine mammals on sub-cellular, cellular, and systemic levels. A description of these mechanisms is required to understand the causes and dynamics of the effects of contaminants at the levels of both the individual and the population.

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ANNEX 2

TITLES OF RECENTLY PUBLISHED ICES COOPERATIVE RESEARCH REPORTS

No.	Title
222	Report of the ICES Advisory Committee on the Marine Environment, 1997
223	Report of the ICES Advisory Committee on Fishery Management, 1997 (Part 1 and Part 2)
224	Ballast Water: Ecological and Fisheries Implications
225	North Atlantic-Norwegian Sea Exchanges: The ICES NANSEN Project
226	Report on the Results of the ICES/IOC/OSPARCOM Intercomparison Programme on the Determination of Chlorobiphenyl Congeners in Marine Media—Steps 3a, 3b, 4 and Assessment
227	Tenth ICES Dialogue Meeting
228	Report of the 11th ICES Dialogue Meeting on the Relationship between Scientific Advice and Fisheries Management
229	Report of the ICES Advisory Committee on Fishery Management, 1998 (Part 1 and Part 2)
230	Working Group on Methods of Fish Stock Assessment—Reports of Meetings in 1993 and 1995
231	Status of Introductions of Non-Indigenous Marine Species to North Atlantic Waters 1981–1991
232	Diets of Seabirds and Consequences of Changes in Food Supply
233	Report of the ICES Advisory Committee on the Marine Environment, 1998
234	Report of the Workshop on Ocean Climate of the NW Atlantic during the 1960s and 1970s and Consequences for Gadoid Populations
235	Methodology for Target Strength Measurements (with special reference to <i>in situ</i> techniques for fish and micronekton)
236	Report of the ICES Advisory Committee on Fishery Management, 1999 (Part 1 and Part 2)
237	Seventh Intercomparison Exercise on Trace Metals in Sea Water
238	Report on Echo Trace Classification
239	Report of the ICES Advisory Committee on the Marine Environment, 1999
240	Report of the Young Scientists Conference on Marine Ecosystem Perspectives
241	Report of the ICES Advisory Committee on the Marine Environment, 2000
242	Report of the ICES Advisory Committee on Fishery Management, 2000 (Part 1)
243	Report of the 12 th ICES Dialogue Meeting (First Environmental Dialogue Meeting)
244	Report of the Workshop on Gadoid Stocks in the North Sea during the 1960s and 1970s. The Fourth ICES/GLOBEC Backward-Facing Workshop
245	The Annual ICES Ocean Climate Status Summary 2000/2001
246	Report of the ICES Advisory Committee on Fishery Management, 2001 (Part 1, Part 2 and Part 3)
247	Effects of Extraction of Marine Sediments on the Marine Ecosystem
248	Report of the ICES Advisory Committee on the Marine Environment, 2001

ACRONYMS

ACE	Advisory Committee on Ecosystems	KFI	kidney fat index
ACFM	Advisory Committee on Fishery Management	LRP	limit reference point
ACME	Advisory Committee on the Marine Environment	MAFF	Ministry of Agriculture, Fisheries and Food (UK)
ARC	Aquatic Restoration and Conservation Workshop	NAMMCO	North Atlantic Marine Mammals Commission
ASC	Annual Science Conference (ICES)	NOAA	National Oceanic and Atmospheric Administration (USA)
ASCOBANS	Agreement on Small Cetaceans of the Baltic and North Seas	NSTF	North Sea Task Force
BEWG	Benthos Ecology Working Group	OSPAR	OSPAR Commission
BMF	bone marrow fat content	PCBs	polychlorinated biphenyls
CORINE	EEA Coordination of Information on the Environment	ROV	remotely operated vehicle
CPUE	catch per unit effort	SACs	Special Areas of Conservation
DDT	dichlorodiphenyltrichloroethane	SGEAM	Study Group on Ecosystem Assessment and Monitoring
ΣDDT	total DDT	SGMHM	Study Group on Marine Habitat Mapping
DG	Directorate General	TMAP	Trilateral Monitoring and Assessment Programme (Wadden Sea)
EC	European Commission	UK	United Kingdom
EcoQ	Ecological Quality	UN	United Nations
EcoQO	ecological quality objective	UNCED	UN Conference on Environment and Development
EEA	European Environment Agency	U.S.	United States
EU	European Union	USA	United States of America
EUNIS	European Nature Information System	WGECO	Working Group on Ecosystem Effects of Fishing Activities
FAO	Food and Agriculture Organization	WGEXT	Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem
GIS	Geographical Information System	WGMHM	Working Group on Marine Habitat Mapping
HCB	hexachlorobenzene	WGMMHA	Working Group on Marine Mammal Habitats
HCH	hexachlorocyclohexane	WGMMPH	Working Group on Marine Mammal Population Dynamics and Habitats
HCI	hydroxyproline-creatinine index	WGSE	Working Group on Seabird Ecology
HELCOM	Helsinki Commission (Baltic Marine Environment Protection Commission)		
IBTS	International Bottom Trawl Survey		
ICES	International Council for the Exploration of the Sea		
IWC	International Whaling Commission		
JAMP	OSPAR Joint Assessment and Monitoring Programme		
JNCC	Joint Nature Conservation Committee (UK)		