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10–14 March 2008

Lisbon, Portugal

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Contents

Executive summary

Highlights:

- WGSE considered further the effects of climate change on seabirds and presents two new case studies using data provided by the Working Group on Oceanic Hydrography, data also provided to other WGs. The data were of some use in highlighting effects of sea surface temperature on black-legged kittiwake populations; the overall importance of choosing appropriate hydrographic data to explore associations between physical and biological components of the ecosystem is stressed.
- In response to a request by the European Commission, the problem of incidental catch of seabirds in longline fisheries in EU waters was reviewed by WGSE. Although there are few data to indicate the true extent of the bycatch problem, enough information exists to recognise that there is indeed a problem, and that the EU should develop and implement a Community Plan of Action aimed at investigating the issue further and at reducing this bycatch.
- An updated review of the ecological role and effects of viral and bacterial parasites in seabird populations is presented.

The Working Group on Seabird Ecology (WGSE) met for five days (10–14 March 2008), and was attended by sixteen persons from eleven countries (Annex 1). Twelve were nominated members of the group and four were invited by the Working Group Chair to attend this year's meeting. During the meeting, WGSE addressed all Terms of Reference with the exception of ToR h (peer reviews of OSPAR nominations for threatened and declining species), which was addressed intersessionally. An enlargement of the ToRs pertaining to longline fishing to include other forms of fishing, made at the intervention of the Vice Chair of the Advisory Committee, was also addressed with a view to future development. The results of the meeting are reported here.

In response to an OSPAR request to ICES, WGSE in 2007 assessed changes in the distribution and abundance of seabirds in the OSPAR maritime area in relation to hydrodynamics and sea temperature. This issue was considered further in 2008 in relation to the framework provided by the *ad hoc* group established to advise on the use of appropriate hydrographic information, and the recommendations made by the *ad hoc* group on working hypotheses regarding the effects of climate change. An updated overview of the topic is presented with two new case studies – the black-legged kittiwake in the North Sea and the Atlantic puffin in north Norway. While demographic parameters of the former were associated with one feature of climate, namely sea surface temperature, they appeared not to be with another, the strength of the North Atlantic Oscillation. Similarly, the hydrographic data provided proved of limited usefulness in analyses involving Atlantic puffin demographic data. The importance of selecting appropriate hydrographic data for use in seabird population analyses is emphasised.

Most of the WGSE Terms of Reference in 2008 pertained to the issue of seabird bycatch in longline fisheries. In response to a request from the European Commission, we were asked to review criteria previously used to assess the need for a plan of action to mitigate bycatch, to address the extent of the problem in EU waters, and to prioritise action for its mitigation here. Although there are too few data to inform the degree to which seabird populations in the EU (and within individual ICES Areas and other seas) are being affected by mortality in longline fisheries, information is provided to indicate that there is indeed a chronic problem. The problem would appear to be especially acute in the Mediterranean. This alone justifies the recommendation of WGSE that the European Union formulates a Plan of Action (POA) to reduce the bycatch. Such a plan should be modelled on the UN Food and Agriculture Organisation International POA-Seabirds, a model adopted, or in the process of being so, by several other countries where longline fisheries operate. Various actions and research are recommended to be included within any Community POA, from quantifying more precisely seabird bycatch to altering the behaviour of fishers.

Seabird bycatch and mortality occurs not only in longline fisheries; it has been recorded from all types of commercial fishery, notably gill net and drift netting. A brief review of this issue is presented with a view to future consideration by WGSE.

An updated review of ecological issues related to the circulation of pathogens and parasites in seabird populations is presented. This chapter mainly addresses viral and bacterial parasites in seabirds and the effects on their populations, as well as relations with humans.

1 Introduction

1.1 Participation

The following members of the Working Group on Seabird Ecology (WGSE) attended and participated in the meeting (see Annex 1 for full details).

Tycho Anker-Nilssen	Norway
Pep (J. M.) Arcos	Spain
Rob Barrett	Norway
Thierry Boulinier*	France
John Chardine	Canada
Euan Dunn	UK
Morten Frederiksen	Denmark
Jakob Fric	Greece
Bob Furness	UK
Arnthor Gardarsson	Iceland
Ommo Hüppop	Germany
Leif Nilsson	Sweden
Manuela Nuñes	Portugal
Iván Ramírez	Portugal
Jim Reid (Chair)	UK
Mark Tasker	UK
Richard Veit	USA

*contribution by correspondence

Twelve persons were nominated members of the group and four persons were invited by the WG Chair to attend this year's meeting. The authority to nominate persons not yet nominated by national delegates was again considered by the group to be an extremely useful tool.

1.2 Terms of Reference

The 2007 Statutory meeting of ICES gave the Working Group on Seabird Ecology [WGSE] the following Terms of Reference:

a) consider the reports of the Ad Hoc Groups on;

Hydrographic Attributes

Trend Analyses and Quantifying Relationships

Formulating Hypotheses and Predictions about Mechanisms

Selecting Species for More Intensive Investigations

and use their recommendations concerning (1) recommended time series, (2) analytical methods and suitable software, (3) hypotheses and guidance for their use, and (4) a suggested list of species for intensive study, to complete the assessment of changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature.

b) review criteria used elsewhere to assess the need for national plans of action for seabirds (FAO NPOA-Seabirds) and recommend one set of criteria for use by the European Commission;

c) establish a list of seabirds known or likely to caught in longline fisheries in EU waters and as far as possible describe the status of the populations of these seabirds in each of ICES Areas [III, IV, VI, VII, VIII, IX and X, the western Mediterranean, Tyrrhenian Sea, Ionian Sea, Aegean Sea and eastern Mediterranean] and the status of any seabird populations that migrate into these areas from elsewhere in the world;

d) review information on the bycatch in longline fisheries in the above sea areas and where possible estimate a total annual catch of seabirds (numbers per 1000 hooks set/species/longline fishery);

e) evaluate mitigation measures in use to reduce this bycatch;

f) based on the above analyses, prioritise research and monitoring needs for longline fisheries in EU waters;

g) finalize the consideration of ecological issues linked to the circulation of parasites and pathogens within seabird populations;

h) peer review revised OSPAR nominations of Balearic shearwater, European shag, greater scaup and white-winged scoter for the OSPAR list of threatened and declining species.

1.3 Note on bird names

Throughout the text we use official English names for bird species; scientific and English names are listed in Annex 2.

1.4 Acknowledgements

The Working Group on Seabird Ecology wishes to thank SPEA/BirdLife for organising the meeting logistics in Lisbon, especially Vanessa Oliveira, and to the Fundação Calouste Gulbenkian for providing us with meeting rooms and other facilities. The following persons and organisations provided information for the meeting: Andy Black, Cleo Small, and others from BirdLife International's Global Seabird Programme, the Hellenic Society for the Study and Protection of the Monk Seal (data on seabird bycatch collected in EU funded LIFE-Nature project Monk Seal and Fisheries: Mitigating the Conflict in Greek Seas, LIFE05 NAT/GR/000083), Sarah Wanless (Centre for Hydrology and Ecology), Stefan Garthe (FTZ, University of Kiel), Maite Louzao and Karina Laneri (IMEDEA), Roddy Mavor and Ian Mitchell (Joint Nature Conservation Committee), and Debra Palka, J. Warden and Kim Rivera (National Marine Fisheries Service, NOAA), SEO/BirdLife, Jacob González-Solís, José Luis Roscales and Joan Navarro (University of Barcelona). We also thank Enric Badosa, Oscar Macián, José Torrent, and Alberto Velando. Karen McCoy (Génétique et Evolution des Maladies Infectieuses, CNRS/IRD, Montpellier) also contributed to Chapter 4 of the report.

2 Climate change and seabirds in the OSPAR Maritime Region

OSPAR has requested ICES to assess the changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to hydrodynamics and sea temperature. WGSE has worked on this request, considering primarily how much evidence of climate-related changes exists for seabirds in the OSPAR Maritime Region. The following text relies heavily on chapter 7 in the 2007 WGSE report, with additional text and new analyses.

2.1 Overview

Seabirds are almost without exception colonial breeders, which means that it is reasonably easy to collect data on a wide variety of aspects of their biology. The population size and demography of many seabird species are monitored in detail at several colonies throughout the OSPAR maritime area, although these colonies constitute a small fraction of the total population. Lower intensity monitoring of population size occurs at a larger number of colonies. It is important to note that generally only the size of the actively breeding segment of the population can be monitored accurately, and that the size of the non-breeding segment is poorly known. This has important implications for the detection of effects of environmental change. At-sea surveys can also be used to monitor trends in abundance for entire populations, but need to be standardised, sustained and of sufficient spatial coverage.

Several aspects of seabird ecology make the detection of climate-related changes in abundance and distribution difficult. Seabirds have long generation times (usually 10-20 years); raise few young per year, which recruit to the breeding population after several years, but adults can live for many years (Ashmole 1971, Jouventin and Mougin 1981). This life history strategy implies that population growth rate is most sensitive to changes in year-to-year survival of adults, and consequently that natural selection will tend to make this demographic rate relatively insensitive to environmental variation (‘environmental canalization’, Gaillard and Yoccoz 2003). This means that breeding populations are able to ‘integrate’ environmental variation over many consecutive years, so that years in which resources are scarce may take some time to become evident in population trajectories, because resource scarcity mainly results in reduced production and survival of juveniles. Also, many seabirds seem to be able to sustain episodic, disastrous years, such as occur during El Niño conditions, but be more susceptible to longer-term trends in unfavourable conditions (Schreiber 2002, Veit and Montevecchi 2006). It is thus in general much easier to detect environmental effects on demographic rates (fecundity and survival) than on abundance *per* se. When searching for responses by seabirds to climate change, it is important to include changes that occur as monotonic long-term trends as well as those that seem to cycle. In the sections that follow, we show how seabirds are impacted by changes in the North Atlantic Oscillation (NAO) index, which fluctuates periodically, and also how seabirds have responded to more monotonic long-term change.

In addition, seabirds are well-insulated, homoeothermic animals, and in most species individuals spend only a small fraction of their time immersed in seawater. Furthermore, climate-related changes in sea temperature are small relative to seasonal changes in the OSPAR maritime area, and the breeding range of many species spans a wide temperature interval. Seabirds are therefore usually unlikely to be directly (physiologically) affected by changes in sea temperatures or salinity. However, most species rely completely on marine prey resources, and if key prey species are negatively affected by changes in ocean climate, this is likely to have serious implications. Bottom-up trophic effects are thus expected to be more important than direct physiological ones, and in many cases these effects may be lagged by several years because seabirds often depend on specific age classes of their fish prey. In accordance with this, most observed changes in seabird populations that have been linked to climate are thought to be mediated through seabird prey. Declines (or increases) are due to changing abundance of prey (Thompson and Ollason 2001, Veit *et al.* 1996, Montevecchi and Myers 1997, Frederiksen *et al.* 2006), which in turn are driven by environmental change, such as changes in sea temperature. Usually, it has been difficult to establish the full chain of cause and effect from physical climate forcing through phytoplankton, zooplankton and fish to bird abundance. In the sections that follow we review published evidence from the OSPAR maritime area and draw the appropriate conclusions.

The breeding distribution of seabirds is also likely to change very slowly in response to environmental change. This is because seabirds are both long-lived and strongly site-faithful. Once established as breeders at a colony, adults of most species will only very rarely shift to a different location. In contrast, immature birds are much more likely to settle at a different location from their natal colony. This means that seabirds are more likely to occupy newly suitable areas more quickly than they are to leave areas that have newly become unsuitable. Non-breeding distributions are likely to change much more quickly than breeding distributions, but unfortunately extensive long-term data on non-breeding distributions are rare and difficult to collect.

2.2 Changes in breeding distribution

Few seabirds in the OSPAR region have changed their overall breeding range in the past 50 years, and for those that have, the role of climate change in such changes is tenuous. Great skuas have increased in abundance within their traditional breeding range in Scotland, the Faeroes and Iceland, and have extended their breeding range north to northern Russia and Svalbard during the last 30 years (Mitchell *et al.* 2004). Northern gannets have increased steadily on both sides of the North Atlantic from the late 19th century to the present, and during the last 20 years they have extended their breeding north along the Norwegian coast. Population increase along the Norwegian coast has levelled off recently, probably due to other factors. In Newfoundland, the major increase during the mid 20th century was related to a shift in diet to mackerel *Scomber scombrus*, which moved back into the region when surface waters warmed (Montevecchi and Myers 1997). Nevertheless, around the North Sea, the largest increase in gannet numbers, during the mid 20th century, did not correspond to the period of greatest temperature change, which is occurring now. Two species of gulls, lesser black-backed gull and Mediterranean gull have expanded their breeding range north during the past 30 years, so in theory these expansions could reflect changing climate. The expansion of lesser black-backed gulls incorporates colonization of, and population growth within, Iceland and greatly increased presence (but not breeding) in North America (Nisbet *et al.* in press). The expansion of Mediterranean gulls to Britain is part of a broader scale range expansion from the vicinity of the Black Sea westwards. For each species, there are many factors that are influencing these range expansions and it is not clear that climate change is necessarily among these.

2.3 Changes in non-breeding distribution

Some seabirds in the OSPAR area have shown changes over recent decades in their migrations and winter distributions. As far as we know, most species have shown very little, or no, change in winter distribution or migration routes. A particular case is the distribution of seabirds that specialize in foraging at the ice-edge. Ivory gulls depend on ice edge habitats for foraging, and their recent steep population decline probably reflects diminishing ice coverage in the Arctic Ocean (Gaston *et al*. 2005).

Common guillemots responded to reductions in sandeel *Ammodytes marinus* abundance at Shetland in the late 1980s by moving further east in winter to feed in the Skagerrak (Heubeck *et al.* 1991, Wernham *et al*. 2002).

Northern gannets have increased considerably in breeding numbers in the North Sea, but despite that, the numbers wintering in the North Sea have reduced slightly from the 1980s to 2000s (Garthe *et al.* in prep). Shipboard transects in the North Sea in winter in the 1980s and early 1990s suggest that virtually as many adult gannets were in the North Sea in winter as in summer. Recent studies suggest that at least half of the gannets present in the North Sea in summer now move out of the North Sea to winter from the Celtic Sea to West Africa. These changes are unlikely to be related directly to climate change, but perhaps rather to food availability and in this case possibly to reductions in the amounts of discards from North Sea fisheries (Garthe *et al.* in prep).

Lesser black-backed gulls breeding in the UK have increasingly developed the habit of overwintering in the UK and North Sea rather than migrating to North Africa as they did in previous decades. This progressive change may be linked to milder winter weather and also to available food supplies in the UK (Wernham *et al.* 2002, Mitchell *et al.* 2004).

Data on at-sea distribution in the North Sea provides a quantitative basis from which to assess distributional shifts that might reflect climate. Counts of seabirds at sea have been carried out systematically in the North Sea since 1979. These data show that scavengers have declined while a second group of species that includes many non-scavengers have increased (Table 2.1). Large gulls and northern fulmars declined most strongly, matching what would be expected when fisheries effort and thus the availability of discards and offal decline.

Table 2.1. Overall trends of seabird abundance in the North Sea for the two periods (1979–1991 and 1992–2004) covered in the ESAS (European Seabirds at Sea) database 4.1 (Garthe *et al.* in prep.).

Overall North Sea trend	
Summer/breeding period	**Species**
>50% increase	Northern gannet, lesser black-backed gull, Atlantic puffin
20-50% increase	no species
<20% changes	European shag, greater black-backed gull, black-legged kittiwake, common guillemot
20-50% decrease	Northern fulmar, common gull, herring gull
>50% decrease	no species
Winter	**Species**
>50% increase	Atlantic puffin
20-50% increase	no species
<20% changes	European shag, northern gannet, common gull, common guillemot
20-50% decrease	Northern fulmar
>50% decrease	Herring gull, greater black-backed gull, black-legged kittiwake

Trends for the northern and southern North Sea were different. Fulmar, kittiwake and large gull declines were most obvious in the northern half of the North Sea, coinciding with a trend of declining fisheries in that area, while numbers in the southern North Sea did not decline. It thus seems that fisheries effects may have overridden any climatic effects on the at-sea distribution and abundance patterns of seabirds in the North Sea. More detailed investigations are under way to assess these phenomena (Garthe *et al.* in prep).

2.4 Changes in reproductive success

One of the best examples of climate-induced changes in reproductive success to date from the OSPAR region comes from the North Sea. Black-legged kittiwakes have declined by 50% since 1990 (Frederiksen *et al.* 2004b) and several species experienced breeding failure and/or late breeding in 2004 and 2005 (Wanless *et al.* 2005, ICES 2006). The decline in numbers was associated with poor breeding success and lower adult survival over several years (Frederiksen *et al.* 2004b). The increasing trend in the NAO index to the mid-1990s and the associated warming of the Northeast Atlantic and the North Sea has caused major changes in plankton communities, in particular, a decline in the copepod *Calanus finmarchicus* (Fromentin and Planque 1996, Planque and Fromentin 1996). This copepod is often eaten by sandeels, which are in turn a major source of food for several seabird species in the eastern North Atlantic and North Sea (Frederiksen *et al.* 2006). It is now thought that the bottom-up effect of changing ocean climate conditions causing reductions in forage fish food is a controlling factor in sandeel abundance and quality (Frederiksen *et al.* 2004b, Wanless *et al.* 2004, see also Wanless *et al.* 2005, Frederiksen *et al.* 2007.

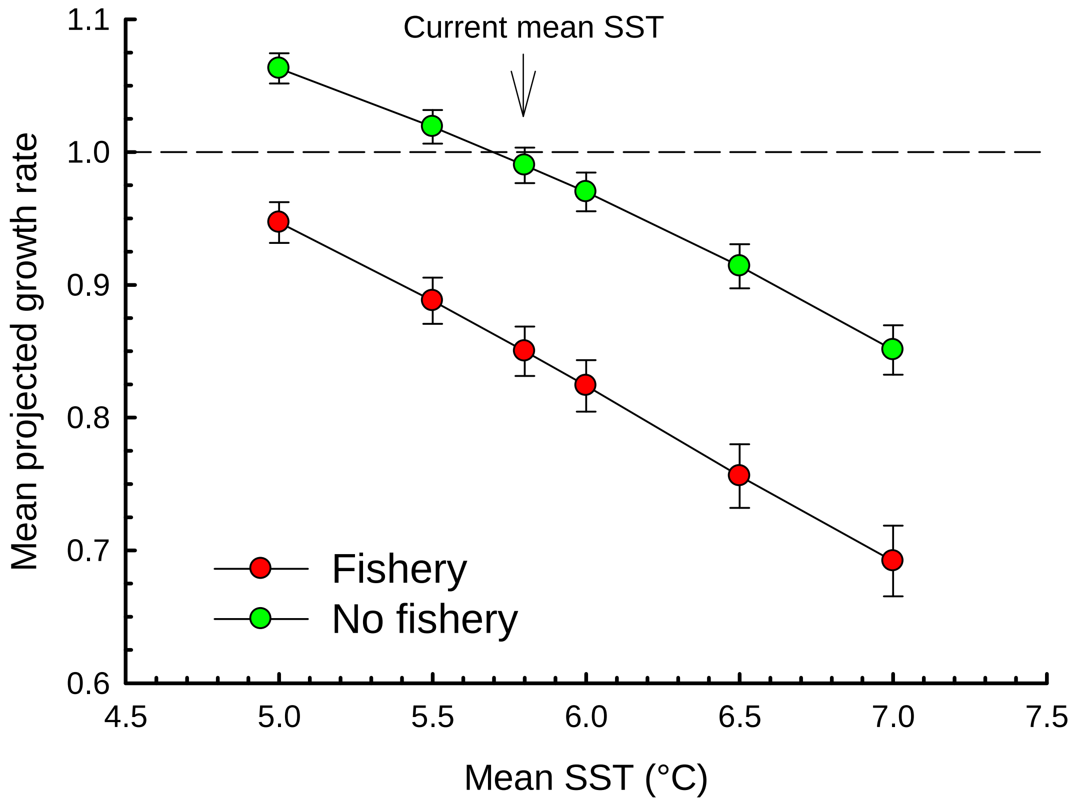


Figure 2.1: Figure adapted from Frederiksen *et al.* (2004b) showing additive effects of the local fishery for sandeels and climate change on kittiwake breeding success on the Isle of May, Firth of Forth, Scotland 1986–2004. Red symbols indicate years when the fishery was active, green symbols years when it was closed or inactive.

2.5 Changes in annual survival

The survival of northern fulmars breeding on Eynhallow, Orkney, and common guillemots on Skomer, Wales, was negatively correlated with the winter North Atlantic Oscillation index one year previously (Grosbois and Thompson 2005, Votier *et al.* 2005). The survival of black-legged kittiwakes on the Isle of May, Scotland, declined with winter SST one year previously (Frederiksen *et al.* 2004b). The survival of Atlantic puffins at three colonies in the UK was negatively correlated with summer sea surface temperatures (SST), but at Røst, Norway, the relationship was positive (Harris *et al.* 2005). At all these colonies, summer SST one year previously affected survival to the following year, except for the Isle of May where it was influenced by SST in the current year (Harris *et al.* 2005). On Hornøya, Norway, the correlation between survival of four auk species and winter/autumn SST was negative, while that of black-legged kittiwake was positive (Sandvik *et al.* 2005).

In all of these studies, the authors concluded that climate most likely affected seabird survival via indirect effects on prey availability. For Brünnich's guillemots on Hornøya this was established quantitatively, with survival increasing with the combined abundance of herring *Clupea harengus* and capelin *Mallotus villosus* prey which, in turn, declined with SST (Sandvik *et al.* 2005). For the remainder of studies cited, indirect effects were inferred qualitatively from published literature on relationships between key prey species and climate. Such reasoning explains the contrasting trends of survival with SST for Atlantic puffins in the UK and Røst, since those in the UK feed on sandeels and those in Røst feed on herring, and abundance of these are negatively and positively affected by SST respectively (Toresen and Østvedt 2000, Arnott and Ruxton 2002).

The corollary of this conclusion is that links between climate and survival may be inferred from studies where seabird survival has been related to abundance of a prey species known to be sensitive to environmental change. For example, the survival of great skuas, Arctic skuas and black-legged kittiwakes on Shetland varied with the availability of sandeels (Oro and Furness 2002, Ratcliffe *et al.* 2002, Davis *et al.* 2005) and, since sandeel stocks are related to ocean currents and SST (Wright 1996, Arnott and Ruxton 2002), variability in their survival could ultimately be caused by climatic fluctuations.

2.6 Changes in abundance

Common and Brünnich's guillemots provide a good example of global-scale population growth in response to climate change (Irons *et al.* in press). The two species reacted somewhat differently to SST shifts. The Arctic-adapted Brünnich's guillemot performed best when the SST increased slightly, whereas the more temperate common guillemot did best when the SST decreased slightly. Both species reacted negatively following the stronger changes in SST (mean SST differing more than 0.5°C from that in the previous regime), regardless of whether the temperatures changes were positive or negative. This response, with the magnitude of the shift being more important than its direction, suggests that the largest shifts were causing the most severe and long-lasting changes to the food webs these birds rely on. This illustrates the complexity of how climate change will impact seabird populations, and emphasizes that extreme care is needed when projecting an observed, short-term trends to the longer-term climate change scenario.

Few other studies have analysed changes in abundance of seabirds in relation to climate change, largely because the lags inherent in seabird life histories necessitate the use of mathematical population models based on detailed demographic information. For black-legged kittiwakes, Frederiksen *et al.* (2004b) showed that if mean sea surface temperatures in the North Sea were to increase further, this would lead to population declines whether the sandeel fishery was reopened or not (Figure 2.2). In section 2.9 below, relationships between changes in seabird abundance and climate are explored further.

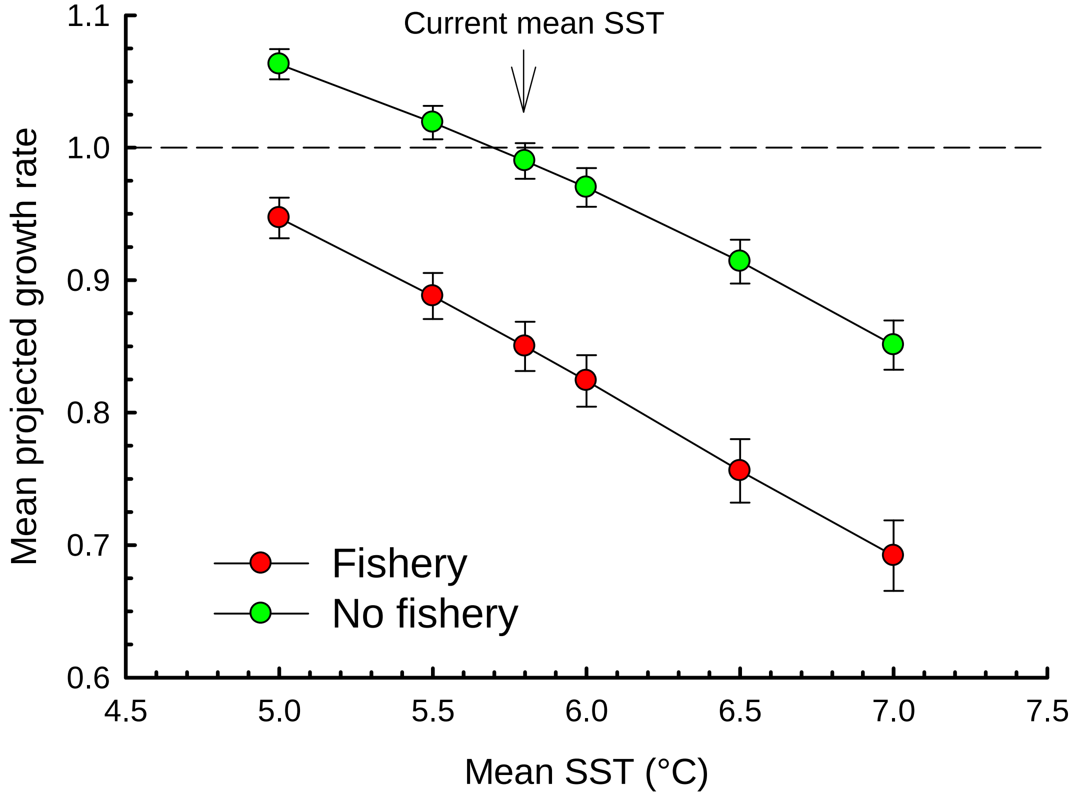


Figure 2.2: Figure adapted from Frederiksen *et al.* (2004b) showing additive effects of the local fishery for sandeels and climate change on projected kittiwake population growth on the Isle of May, Firth of Forth, Scotland.

2.7 Changes in migratory schedule

Among seabirds, few examples of changes in migration phenology are available. Data from a Dutch seawatching project showed that little gulls along the Dutch mainland coast passed continuously earlier in spring over the last three decades (Figure 2.3). Nowadays, the median numbers are counted almost three weeks earlier than in the 1970s. Surprisingly, there is no evidence of a similar pattern with tern species (NZG/Club van Zeetrekwaarnemers unpublished data; C.J. Camphuysen, pers. comm.).

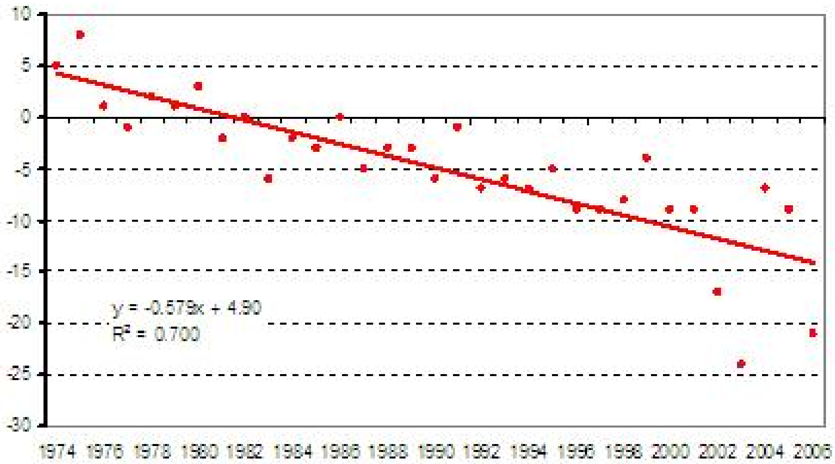


Figure 2.3: Annual median spring passage times of little gulls at the Dutch mainland coast relative to 30. April (=0). n = 484,385 individuals and 24,734 hours of observation (NZG/Club van Zeetrekwaarnemers unpublished data).

2.8 Other phenological changes: laying dates, nest dates, fledging dates

In general, seabirds commence breeding as early as conditions allow, which for most species in the northern hemisphere is in April–June. This is driven by a variety of ultimate and proximate factors. It is well known that for their size, seabirds exhibit protracted incubation and chick development periods (Lack 1968). Thus, an early start to breeding is essential so that chicks are fledged before conditions deteriorate. This adaptation is particularly important in the highly seasonal environments within the northern portions of the OSPAR region, as the summer season is relatively short and winter conditions harsh. Spring is also the time of year when phytoplankton react to high levels of nutrients and increasing amounts of sunlight, and reproduce, creating a rapid increase in primary productivity which eventually results in increased availability of organisms that form the basis of seabird diets (i.e., crustacea, small fishes and squid; Ashmole 1971). It is generally accepted that birds adjust their timing of breeding such that the chick rearing period, a time of maximal food and energy requirements for parents, coincides with the seasonal peak in food availability (Lack 1968).

An ever increasing number of avian studies show that as average temperature increases as a result of climate change, so migration and timing of breeding advance (e.g. Crick 2004). Among seabirds, there are relatively few studies and the results are equivocal in that timing of breeding is advanced in some cases and retarded in others as a result of changes in climate (Durant *et al.* 2004a,b; Barbraud and Weimerskirch 2006). In the North Sea, sea surface temperatures were positively related to egg laying date for Atlantic puffin (Harris *et al.* 1998) and common guillemot (Harris and Wanless 1988), but negatively related in razorbills (Harris and Wanless 1989). Late breeding in the face of warmer conditions (the opposite of the general trend in birds) can result from movement or overall decline, in forage species, which have relatively narrow tolerances to temperature due to poikilothermy. This is a frequent occurrence in the Pacific Ocean where thermal perturbations are often forced by ENSOs.

Frederiksen *et al.* (2004a) showed that the state of the North Atlantic Oscillation (NAO) index was correlated with timing of breeding for common guillemots and black-legged kittiwakes, both of which disperse in the winter over large spatial scales and thus are in a position to sample large-scale ocean climate variation as indicated by the NAO. Although the NAO is a natural mode of variation in the North Atlantic, it has been suggested by general circulation models of climate that forcing due to human-induced greenhouse gas increases (specifically CO_2) may cause the NAO index to increase over the next 100 years (Gillet *et al.* 2003).

In an interesting paper on Atlantic puffins nesting in Røst in the Norwegian Sea, Durant *et al.* (2004b) showed that timing of breeding was negatively related to the NAO index in two periods and not related (or slightly positively related) in an intervening period. They suggested that this was an indication of a regime shift possibly driven by food availability in the year preceding breeding. In a long-term study of Atlantic puffins in the Barents Sea, Barrett (2001) showed that timing of breeding was later in cooler years, with the suggestion that access to nest sites might have been hampered due to ice and snow in years with lower spring temperatures.

In summary, seabirds appear to react to climate change and variability in a variety of ways. In some circumstances, a warming trend advances timing of breeding and in others breeding is retarded. Seabirds show some flexibility in dealing with climate change in this regard but are ultimately constrained because of the finite (and often lengthy) time required to complete the breeding cycle. Because they are long-lived, seabirds are often able to "buffer" short term (< 10 years) environmental variability, especially at the population level. Seabirds are vulnerable to both spatial and temporal mismatches in prey availability, especially when breeding a fixed colony sites with the foraging constraints that these entail (e.g. Weimerskirch *et al.* 1993).

Table 2.2. Links between climate change and seabirds.

Seabird parameter	Species	Region	Climate variable	Sign of correlation with warming	Sources
Breeding range	Lesser black-backed gull	U.K.	Sea temperature	Positive	Mitchell *et al.* 2004
	Northern gannet	U.K.	Sea temperature	Positive	Mitchell *et al.* 2004
Non-breeding range	Lesser black-backed gull	U.K.		Positive	Wernham *et al.* 2002, Mitchell *et al.* 2004
	Common guillemot	Shetland	Sea temperature, sandeels		Heubeck *et al.* 1991
Reproductive success	Northern fulmar	Orkney (North Sea)	NAO index	Negative (hatching); positive (fledging)	Thompson and Ollason 2001
	Atlantic puffin	Røst Norwegian Sea	Sea temperature	Positive	Durant *et al.* 2003
	Atlantic puffin	Røst Norwegian Sea	Salinity	Negative	Durant *et al.* 2006
	Greater black-backed gull	Newfoundland	Sea temperature	Positive	Regehr and Rodway 1999
	Herring gull	Newfoundland	Sea temperature	Positive	Regehr and Rodway 1999
	Black-legged kittiwake	Newfoundland	Sea temperature	Positive	Regehr and Rodway 1999
	Leach's storm-petrel	Newfoundland	Sea temperature	Positive	Regehr and Rodway 1999
	Black-legged kittiwake	Isle of May (North Sea)	Sea temperature	Negative	Frederiksen *et al.* 2004b
Annual survival	Northern fulmar	Orkney (North Sea)	NAO index	Negative	Grosbois and Thompson 2005
	Black-legged kittiwake	Isle of May (North Sea)	Sea temperature	Negative	Frederiksen *et al.* 2004b, 2006
	Atlantic puffin	North Sea, Irish Sea	Sea temperature	Negative	Harris *et al.* 2005
	Atlantic puffin	Røst Norwegian Sea	Sea temperature	Positive	Harris *et al.* 2005
	Atlantic puffin	Norway (Barents Sea)	Sea temperature	Negative	Sandvik *et al.* 2005

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

2.9 Seabird demography and population dynamics in relation to ocean climate: new analyses

To investigate the utility of the data sets provided by the Working Group on Oceanic Hydrography (WGOH), and to illustrate the generic points about how seabirds are expected to be affected by environmental change, two sets of new analyses have been carried out. Each of these uses highly detailed seabird data-sets, which have previously been used in many published studies:

a) data on black-legged kittiwake breeding success and abundance from the Isle of May in southeast Scotland, provided by the UK Centre for Ecology and Hydrology and the Joint Nature Conservation Committee; and b) data on Atlantic puffin breeding success and abundance provided by the Norwegian Institute for Nature Research. Similar analyses could potentially be carried out for several other long-term seabird data-sets, including both detailed studies at breeding colonies and at-sea surveys of abundance and distribution.

2.9.1 Black-legged kittiwakes in the North Sea

Frederiksen *et al.* (2004b) demonstrated negative effects of high sea surface temperature on breeding success, adult survival and projected population growth for black-legged kittiwakes at the Isle of May colony in the North Sea (see previous sections). For breeding success, there was a 1 year lag, consistent with kittiwake dependence on 1-group sandeel, their main prey during the breeding season. New analyses showed that this pattern was found both for local SST and for the SE North Sea SST data provided by WGOH, whereas no relationship was found for the NAO (Figure 2.4). For year-to-year population growth, defined here as the log-transformed ratio of successive annual counts of breeders, there was an almost significant negative correlation with a 1 year lag, consistent with a negative effect of SST on survival of adult breeders. Again, this pattern was apparent for both SST data sets, whereas no effect of NAO was apparent (Figure 2.4). These results demonstrate that lagged (i.e. indirect) effects of ocean climate on seabirds cannot be ignored, and that hydrographic variables must be selected carefully based on a good understanding of the local ecosystem in order to provide meaningful results.

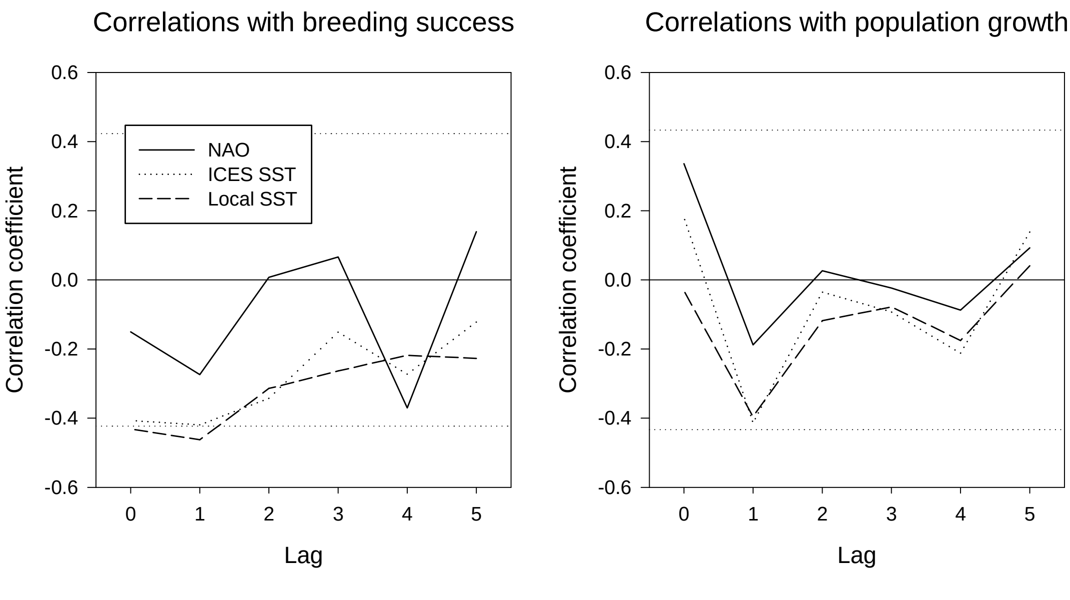
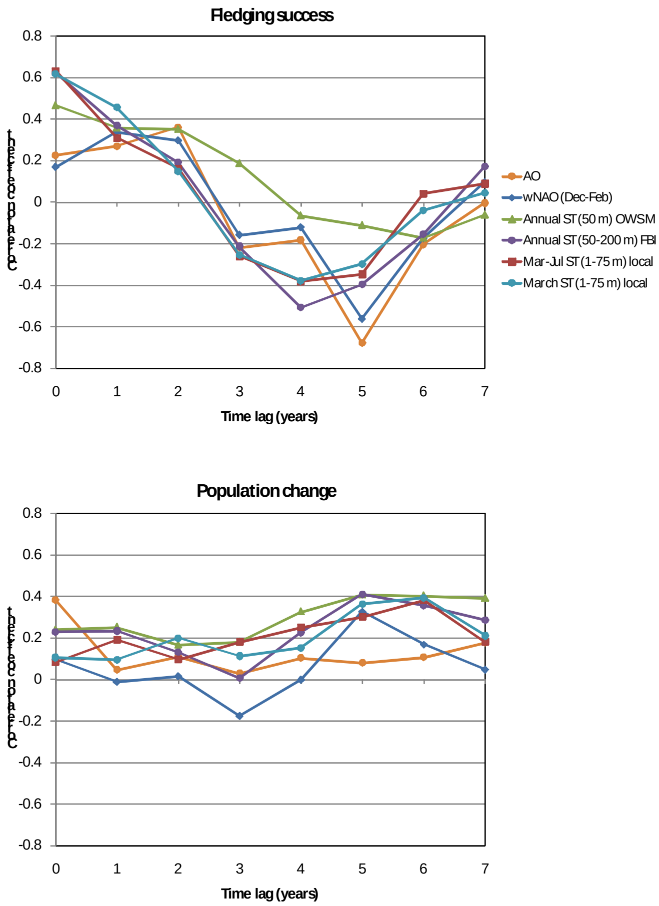


Figure 2.4: Magnitude of correlation coefficients between three hydrographic variables and two aspects of black-legged kittiwake population dynamics at the Isle of May in the North Sea. Horizontal dotted lines indicate conventional levels of significance ($\alpha = 0.05$). Data provided by ICES WGOH, British Atmospheric Data Centre, Centre for Ecology and Hydrology and Joint Nature Conservation Committee.

2.9.2 Atlantic puffins in North Norway

Durant *et al.* (2003) have demonstrated that the breeding success of the Atlantic puffin in Røst, North Norway, is largely explained by the combined effect of local sea temperatures (i.e. within the Norwegian coastal current) in March–July and the size of first-year (0-group) herring they provide for their chicks in the same year. The repeated breeding failures have caused a severe decline in population size over several decades (Anker-Nilssen 1992). In a more recent paper Durant *et al.* (2006) showed that the nestling period of these chicks, and hence the quality of the reproductive output of the population, can be equally well predicted by only using local data for sea temperatures and salinity in March, which is the period of first growth for larval herring drifting northwards along this coastline. Simple correlations between different time series for sea temperatures and an updated version of the data set on breeding success for the Røst puffins (Anker-Nilssen and Aarvak, 2006 and unpublished data) suggest that temperatures sampled further away from the breeding site, at different depths, in different water masses and/or at different times of year are less able to uncover such relationships (Figure 2.5a). This highlights the importance of selecting the most relevant descriptors of environmental change, i.e. those that are expected to be most closely linked to the underlying ecological processes (in this case the growth and survival of young herring). Usually, this will demand a closer cooperation between oceanographers and seabird ecologists than merely selecting information from a (restricted) list of available data-sets.

When repeating the analysis with the same set of environmental data series, but substituting fledging success with the rate of population change from year to year in the same colony (Anker-Nilssen and Aarvak 2006), all significant relationships disappear (Figure 2.5b). This emphasizes the unsuitability of breeding numbers as an indicator of the effect of climate change on this population. Not only are puffin numbers monitored early in the egg-laying period when herring is expected to be a less important prey, but as the age at first breeding in this population is 5-7 years (Anker-Nilssen and Aarvak, 2006), these analyses are also biased by probably great variation in immature survival of different cohorts.



Figures 2.5a (top) and 2.5b (bottom): Degree of correlation between a selection of climatic variables and (a) the fledging success and (b) the ln-transformed change in annual breeding numbers of Atlantic puffins at Røst, northern Norway in 1979-2007. To test for indirect effects of trophic relationships and demographic processes, the data for puffin performance were also lagged by 1-7 years. Data provided by ICES WGOH, Svein Østerhus (for Ocean Weather Station Mike, OWS M), Harald Loeng (for Fugløya-Bear Island FBI), and Anker-Nilssen and Aarvak (2006, and unpubl. data).

2.10 Conclusions

There is a substantial body of evidence linking changes in seabird demography and population dynamics to changes in ocean climate. Most of these studies assume that climatic effects are indirect, i.e. mediated through the prey base. This assumption is strongly based on theoretical consideration, although it is rarely possible to elucidate all steps of the causal chain. For example, changes in abundance and distribution of *Calanus* copepods in the North Sea have been clearly linked to climate (e.g. Beaugrand *et al.* 2003). Sandeels are known to eat mainly copepods, but there are no published studies showing exactly how the marked change in copepod community composition in the North Sea has affected sandeels. The documented low recruitment of sandeels in the North Sea in recent years is almost certainly the main direct reason for low reproductive success in several seabird species, but in the absence of spatially explicit estimates of sandeel recruitment this hypothesis cannot be tested directly. Thus, although a coherent mechanistic hypothesis for how climate change affects North Sea seabirds can be constructed, it is not possible to test all elements of the hypothesis with existing data. Research is therefore often limited to analyses of the relationships between climatic variables and seabird demography, sometimes skipping several trophic levels.

Analytical problems are likely to be encountered when restricting exploratory analyses of climate change effects to be based on a small selection of pre-defined data sets for sea temperature, salinity or other key oceanographic variables. Such data series are rarely the most optimal descriptors of abiotic influence on the biological processes in question, because they are unlikely to match these events in terms of spatial and vertical distribution and/or seasonal timing. Naturally, such problems are more likely to arise within the largest OSPAR regions, which cover a wide diversity of ecosystems and biological communities. OSPAR Region I is a very good example of this, with great differences in the composition of seabird communities and key prey species for seabirds between sub-regions. From a functional point-of-view, even a relatively simple sub-divisioning would have to distinguish between areas such as the northern Barents Sea (Svalbard, Franz Josef Land and Novaya Zemlya), the southern Barents Sea (Russian mainland coast and northernmost parts of Norway), the White Sea, the Norwegian Sea, the Greenland Sea (including Jan Mayen) and the Faroese and Icelandic shelf areas. Some of these areas also need to be analysed on a finer scale, for instance the contrasting oceanographic regimes of northwest and south-east Iceland.

The variation in adult survival rates of Atlantic puffins illustrates this point. Even though mean survival has not been found to differ much between colonies located far apart, it reacts clearly differently to sea temperature changes in different sea areas (Harris *et al.* 2005). The positive effect on puffin survival with a temperature increase in the Norwegian Sea most likely reflects the parallel positive effect of temperature on the survival of young herring of the Norwegian spring-spawning stock (Toresen and Østvedt 2000), which are the staple food for puffins in that area (e.g. Anker-Nilssen 1992). On the other hand, the negative effects of a temperature increase on puffin survival in the shallower North and Barents Seas are likely to reflect the parallel negative effects of temperature on the reproduction of the Barents Sea capelin and North Sea sandeel populations, respectively (Arnott and Ruxton, 2002; Hjermann *et al.* 2004).

In conclusion, while a unified approach across taxonomic groups for investigating climatic effects on abundance and distribution of organisms would in principle be desirable, the nature of the available data combined with fundamental differences in basic ecology and life history strategies make this aim unrealistic. Limiting analytical approaches and explanatory variables according to a pre-defined list would unnecessarily restrict the strength of inference possible with the existing data. In contrast, using analytical approaches and explanatory variables, which have been optimized with respect to the available data (and thus differ among taxonomic groups), will allow stronger inference and more general conclusions to be reached. Also, for groups such as seabirds where detailed demographic data exist and where long generation times make direct links between climate and abundance more obscure, it is straightforward to integrate demographic effects in a population model, which then can be used to predict changes in abundance in response to environmental change.

2.11 References

Aebischer, N.J., Coulson, J.C., and Colebrook, J.M. 1990. Parallel long-term trends across four marine trophic levels and weather. Nature, 347: 753–755.

Aebischer, N., and Wanless, S. 1992. Relationships between colony size, adult non-breeding and environmental conditions for Shags *Phalacrocorax aristotelis* on the Isle of May, Scotland. Bird Study, 32: 43–52.

Ainley, D.G., Sydeman, W.J., and Norton, J. 1995. Upper trophic level predators indicate interannual negative and positive anomalies in the California Current food web. Marine Ecology Progress Series, 118: 69–79.

Ainley, D.G., Spear, L.B., Allen, S.G., and Ribic, C.A. 1996. Temporal and spatial patterns in the diet of the common murre in California waters. Condor, 98: 691–705.

Anderson, P.J., and Piatt, J.F. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Marine Ecology Progress Series, 189: 117–123.

Anker-Nilssen, T. 1992. Food supply as a determinant of reproduction and population development in Norwegian Puffins *Fratercula arctica*. PhD thesis, University of Trondheim.

Anker-Nilssen, T., and Aarvak, T. 2006. Long-term studies of seabirds in the municipality of Røst, Nordland. Results with focus on 2004 and 2005. Norwegian Institute for Nature research, NINA Report 133.

Arnott, S.A., and Ruxton, G.D. 2002. Sandeel recruitment in the North Sea: demographic, climatic and trophic effects. Marine Ecology Progress Series, 238: 199–210.

Ashmole, N.P. 1971. Sea bird ecology and the marine environment. In: Avian Biology, 1. Farner, D., King, J., and Parkes, K. eds. New York, Academic Press. 1: 224–286.

Barber, R.T., and Chavez, F.P. 1983. Biological consequences of El Nino. Science, 222: 1203–1210.

Barber, R.T., and Chavez, F.P. 1986. Ocean variability in relation to living resources during the 1982–1983 El Nino. Nature, 319: 279–285.

Barbraud, C., and Weimerskirch, H. 2006. Antarctic birds breed later in response to climate change. Proceedings of the National Academy of Science of the U.S., 103: 6248–6251.

Barrett, R.T. 2001. The breeding demography and egg size of Norwegian Atlantic Puffins *Fratercula arctica* and Razorbills *Alca torda* during 20 years of climatic variability. Atlantic Seabirds, 3: 97–112.

Barry, J.P., Baxter, C.H., Sagarin, R.D., and Gilman, S.E. 1995. Climate-related, long-term, faunal changes in a California rocky intertidal community. Science, 267: 672–675.

Beaugrand, G., Brander, K.M., Lindley, A., Souissi, S., and Reid, P.C. 2003. Plankton effect on cod recruitment in the North Sea. Nature, 426: 661–664.

Boersma, P.D. 1977. Breeding patterns of galapagos penguins as an indicator of oceanographic conditions. Science, 200: 1481–1483.

Boersma, P.D. 1998. Population trends of the Galapagos Penguin: impacts of El Nino and La Nina. Condor, 100: 245–253.

Chastel, O., Weimerskirch, H., and Jouventin, P. 1993. High annual variability in reproductive success and survival of an Antarctic seabird, the snow petrel *Pagodroma nivea*. Oecologia, 94: 278–285.

Chelton, D.B., Bernal, P.A., and McGowan, J.A. 1982. Large-scale interannual physical and biological interaction in the California Current. Journal of Marine Research, 40: 1095–1124.

Christensen, J.H., and Christensen, O.B. 2003. Severe summer flooding in Europe. Nature, 421: 805.

Clark, R.A., Fox, C.J., Viner, D., and Livermore, M. 2003. North Sea cod and climate change – modelling the effects of temperature on population dynamics. Global Change Biology, 9: 1669–1680.

Crick, H.Q.P. 2004. The impact of climate change on birds. Ibis 146, Supplement 1: 48–56.

Croxall, J.P. 1992. Southern ocean environmental changes: effects on seabird, seal and whale populations. Philosophical Transactions of the Royal Society of London B, 338: 319–328.

Croxall, J.P., Trathan, P.N., and Murphy, E.J. 2002. Environmental change and Antarctic seabird populations. Science, 297: 1510–1514.

Cushing, D.H. 1982. Fisheries and Climate. Academic Press, London.

Davis, S.E., Nager, R.G., and Furness, R.W. 2005. Food availability affects adult survival as well as breeding success of parasitic jaegers. Ecology, 86: 1047–1056.

Divoky, G. 1998. Factors âffecting the growth of a Black Guillemot colony in northern Alaska. PhD Thesis. Alaska: University of Alaska, Fairbanks, Alaska.

Durant, J.M., Anker-Nilssen, T., and Stenseth, N.C. 2003. Trophic interactions under climate fluctuations: the Atlantic puffin as an example. Proceedings of the Royal Society of London B, 270. 1461–1466.

Durant, J.M., Stenseth, N.C., Anker-Nilssen, T., Harris, M.P., Thompson, P.M., and Wanless, S. 2004a. Marine birds and climate fluctuation in the North Atlantic. *In* Marine ecosystems and climate variation - The North Atlantic. A comparative perspective. Pages 95-105. Ed. By N.C. Stenseth, G. Ottersen, J.W. Hurrell, and A. Belgrano. Oxford Univ. Press, New York.

Durant, J.M., Anker-Nilssen, T., Hjermann, D.Ø., and Stenseth, N.C. 2004b. Regime shifts in the breeding of an Atlantic puffin population. Ecology Letters, 7: 388–394.

Durant, J.M., Anker-Nilssen, T., and Stenseth, N.C. 2006. Ocean climate prior to breeding affects the duration of the nestling period in the Atlantic puffin. Biology Letters, 2: 628–631.

Fiedler, W., Bairlein, F., and Köppen, U. 2004: Using large-scale data from ringed birds fort the investigation of effects of climate change on migrating birds: pitfalls and prospects. In: Advances in Ecological Research 35: Birds and Climate Change. Pages 49–67. Ed. by A.P. Møller, W. Fiedler and P. Berthold. Elsevier Science, London.

Erikstad, K., Fauchald, P., Tveraa, T., and Steen, H. 1998. On the cost of reproduction in long-lived birds: the influence of environmental variability. Ecology, 79: 1781–88.

Finney, S., Wanless, S., and Harris, M. 1999. The effect of weather conditions on the feeding behaviour of a diving bird, the Common Guillemot *Uria aalge*. Journal of Avian Biology, 30: 23–30.

Francis, R.C., and Hare, S.R. 1994. Decadal-scale regime shifts in the large marine ecosystems of the northeast Pacific: a case for historical science. Fisheries Oceanography, 3: 279–291.

Francis, R.C., Hare, S.R., Hollowed, A.B., and Wooster, W.S. 1998. Effects of interdecadal climate variability on the oceanic ecosystems ofthe northeast Pacific Ocean. Fisheries Oceanography, 7: 1–21.

Fraser, W.R., Trivelpiece, W.Z., Ainley, D.G., and Trivelpiece, S.G. 1992. Increases in Antarctic penguin populations: reduced competition with whales or a loss of sea ice due to environmental warming? Polar Biology, 11: 525–531.

Frederiksen, M., Harris, M.P., Daunt, F., Rothery, P., and Wanless, S. 2004a. Scale-dependent climate signals drive breeding phenology of three seabird species. Global Change Biology, 10: 1214–1221.

Frederiksen, M., Wanless, S., Harris, M.P., Rothery, P., and Wilson, L.J. 2004b. The role of industrial fishery and oceanographic changes in the decline of the North Sea black-legged kittiwakes. Journal of Applied Ecology, 41: 1129–1139.

Frederiksen, M., Wright, P.J., Harris, M.P., Mavor, R.A., Heubeck, M., and Wanless, S. 2006. Regional patterns of kittiwake *Rissa tridactyla* breeding success are related to variability in sandeel recruitment. Marine Ecology Progress Series, 300: 201–211.

Frederiksen, M., Furness, R.W., and Wanless, S. 2007. Regional variation in the role of bottom-up and top-down processes in controlling sandeel abundance in the North Sea. Marine Ecology Progress Series, 337: 279–286.

Fromentin, B., and Planque, J.-M. 1996. *Calanus* and environment in the eastern North Atlantic. II. Influence of the North Atlantic Oscillation on *C. finmarchicus* and *C. helgolandicus*. Marine Ecology Progress Series, 134: 111–118.

Furness, R., and Bryant, D. 1996. Effect of wind on field metabolic rates of breeding Northern Fulmars. Ecology, 77: 1181–1188.

Gaillard, J.-M., and Yoccoz, N.G. 2003. Temporal variation in survival of mammals: a case of environmental canalization? Ecology, 84: 3294–3306.

Gaston A.J., Gilchrist, H.G., and Hipfner, J.M. 2005. Climate change, ice conditions and reproduction in an Arctic nesting marine bird: Brunnich's guillemot (*Uria lomvia* L.). Journal of Animal Ecology, 74: 832–841.

Gillett, N.P., Graf, H.F., and Osborn, T.J. 2003. Climate change and the North Atlantic Oscillation. Geophysical Monographs, 134: 193–209.

Grosbois, V., and Thompson, P.M. 2005. North Atlantic Climate variation influences survival in adult fulmars. Oikos, 109: 273–290.

Guinet, C., Chastel, O., Koudil, M., Durbec, J.P., and Jouventin, P. 1998. Effects of warm sea-surface temperature anomalies on the blue petrel at the Kerguelen Islands. Proceedings of the Royal Society of London B, 265: 1001–1006.

Hamre, J. 1988. Some aspects of the interrelation between the herring in the Norwegian Sea and the stocks of capelin and cod in the Barents Sea. ICES Doc. C.M. 1988/H: 42, 15 pp.

Harris, M.P., Murray, S., and Wanless, S. 1998. Long-term changes in breeding performance of Puffins *Fraturcula arctica* on St. Kilda. Bird Study, 45: 371–374.

Harris, M.P., and Wanless, S. 1988. The breeding biology of guillemots *Uria aalge* on the Isle of May over a six year period. Ibis, 130: 172–192.

Harris, M.P., and Wanless, S. 1989. The breeding biology of Razorbills (*Alca torda*) on the Isle of May. Bird Study, 36: 105–114.

Harris, M.P. and Wanless, S. 1996. Differential responses of Guillemot *Uria aalge* and Shag *Phalacrocorax aristotelis* to a late winter wreck. Bird Study, 43: 220–230.

Harris, M.P., Wanless, S., Murray, S., and Mackley, E. 2005. Isle of May seabird studies in 2004. JNCC Report No.375, Joint Nature Conservation Committee, Peterborough, UK.

Harris, M.P., Anker-Nilssen, T., McCleery, R.H., Erikstad, K.E., Shaw, D.N., and Grosbois, V. 2005. Effects of wintering area and climate on the survival of adult Atlantic puffins *Fratercula arctica* in the eastern Atlantic. Marine Ecology Progress Series, 297: 283–296.

Hayward, T.L. 1997. Pacific Ocean climate change: atmospheric forcing, ocean circulation and ecosystem response. Trends in Ecology and Evolution, 12: 150–154.

Hedgren, S. 1979. Seasonal variation in fledging weight of Guillemots, *Uria aalge*. Ibis, 121: 356–361.

Heubeck, M., Harvey, P.V., and Okill, J.D. 1991. Changes in the Shetland guillemot *Uria aalge* population and the pattern of recoveries of ringed birds, 1959-1990. Seabird, 21: 3–21.

Hughes, L. 2000. Biological consequences of global warming: is the signal already apparent? Trends in Ecology and Evolution, 15: 56–61.

Hüppop, O. 2000. Zum Einfluß von Sturm auf Anzahl, Körperkondition, Sterblichkeit und Ernährung auf Helgoland überwinternder Kormorane (*Phalacrocorax carbo*). Jahrensbericht des Instituts für Vogelforschung, 4: 14.

Hurrell, J.W. 1995. Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. Science, 269: 676–678.

Hyrenbach, K.D., and Veit, R.R. 2003. Ocean warming and seabird communities of the southern California Current System (1987–1998): response at multiple temporal scales. Deep-Sea Research II, 50: 2537–2566.

ICES. 2006. Report of the Working Group on Seabird Ecology (WGSE) 2006. ICES CM 2006/LRC:08, Ref. ACE, ACME. 86 pp.

Irons, D., Anker-Nilssen, T., Gaston, A.J., Byrd, G.V., Falk, K., Gilchrist, G., Hario, M., Hjernquist, M., Krasnov, Y.V., Mosbech, A., Olsen, B., Petersen, A., Reid, J.B., Robertson, G., Strøm, H., and Wohl, K.D. in press. Fluctuations in circumpolar seabird populations linked to climate oscillations. Global Change Biology.

Jakobsson, J. 1985. Monitoring and Management of the Northeast Atlantic Herring Stocks. Canadian Journal of Fisheries and Aquatic Sciences, 12, Supplement l: 201–221.

Jouventin, P., and Mougin, J. 1981. Les stratégies adaptatives des oiseaux de mer. Revue Ecologie, Terre et Vie, 35: 217–272.

Lack, D. 1968. Ecological adaptations for breeding in birds. Methuen and Co., London.

Lambrechts, M.M., Blondel, J., Maistre, M., and Perret, P. 1997. A single response mechanism is responsible for evolutionary adaptive variation in a bird's laying time. Proceedings of the National Academy of Science of the U.S.A., 94: 5153–5155.

Lehikoinen, E., Sparks, T.H., and Zalakevicius, M. 2004. Arrival and departure dates. In: Advances in Ecological Research 35: In: Advances in Ecological Research 35: Birds and Climate Change. Pages 1-31. Ed. by A.P. Møller, W. Fiedler and P. Berthold. Elsevier Science, London.

Loeb, V., Siegel, V., Holm-Hansen, O., Hewitt, R., Fraser, W., Trivelpiece, W., and Trivelpiece, S. 1997. Effects of sea-ice extent and krill or salp dominance on the Antarctic food web. Nature, 387: 897–900.

Lyver, P.O.B., Moller, H., and Thompson, C. 1999. Changes in Sooty Shearwater *Puffinus griseus* chick production and harvest precede ENSO events. Marine Ecology Progress Series, 188: 237–248.

Marchant, S., and Higgins, P.J. 1990. Handbook of Australian, New Zealand and Antarctic birds. Oxford University Press, Melbourne, Australia.

Mavor, R.A., Pickerell, G., Heubeck, M., and Mitchell, P.I. 2002. Seabird numbers and breeding success in Britain and Ireland, 2001. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No.26.)

Mavor, R.A., Parsons, M., Heubeck, M., Pickerell, G., and Schmitt, S. 2003. Seabird numbers and breeding success in Britain and Ireland, 2002. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No.27.)

Mavor, R.A., Parsons, M., Heubeck, H., and Schmitt, S. 2004. Seabird numbers and breeding success in Britain and Ireland, 2003. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No.28.)

Mavor, R.A., Parsons, M., Heubeck, M., and Schmitt, S. 2005. Seabird numbers and breeding success in Britain and Ireland, 2004. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No.29)

Mavor, R.A., Parsons, M., Heubeck, M., and Schmitt, S. 2006. Seabird numbers and breeding success in Britain and Ireland, 2004. Peterborough, Joint Nature Conservation Committee. (UK Nature Conservation, No.30)

McGowan, J.A., Cayan, D.R., and Dorman, L.M. 1998. Climate-ocean variability and ecosystem response in the northeast Pacific. Science, 281: 210–217.

Mitchell, J.K., and Ericksen, N.J. 1992. Effects of climate change on weather-related disasters. *In* Confronting Climate Change; risks, implications and responses. Pages 141-151. Cambridge University Press, Cambridge.

Mitchell, P.I., Newton, S.F., Ratcliffe, N., and Dunn, T.E. 2004. Seabird populations of Britain and Ireland. T and A.D. Poyser; London.

Monaghan, P., Uttley, J.D., and Okill, J.D. 1989. Terns and sandeels: seabirds as indicators of changes in marine fish populations. Journal of Fish Biology 35, 339–340.

Montevecchi, W.A., Garthe, S., and Davoren, G.K. 2006. Biophysical influences on seabird trophic assessments. *In* Top predators in marine ecosystems. Pages 118-130. Ed. by I.L. Boyd, S. Wanless, and C.J. Camphuysen. Cambridge University Press, Cambridge.

Montevecchi, W.A., and Tuck, L.M. 1987. Newfoundland Birds: Exploitation, Study, Conservation. Nuttall Ornithological Club, Cambridge, U.S.A.

Montevecchi, W.A., and Myers, R.A. 1997. Centurial and decadal oceanographic influences on changes in northern gannet populations and diets in the north-west Atlantic: implications for climate change. ICES Journal of Marine Science, 54: 608–614.

Montevecchi, W.A., and Berruti, A. 1991. Avian indication of pelagic fishery conditions in the Southeast and Northwest Atlantic. Acta XX Congressus Internationalis Ornithologici: 2246–2256.

Morrison, M.L. 1986. Bird populations as indicators of environmental change. *In* Current Ornithology.Pages 429-451. Ed. by R.F. Johnston. Plenum Press, New York.

Newton, S. 2004. Roseate Tern *Sterna dougallii*. *In* Seabird Populations of Britain and Ireland. Pages 302-314. Ed. by P.I. Mitchell, S.F. Newton, N. Ratcliffe, and T.E. Dunn. T. & A.D. Poyser, London.

Nisbet, I.C.T., Veit, R.R., and Auer, S.A. in press. Marine birds of the eastern USA and the Bay of Fundy: distribution, numbers, trends, threats and management. Nuttall Ornithological Monographs, Cambridge, USA.

Oro, D., and Furness, R.W. 2002. Influences of food availability and predation on survival of Kittiwakes. Ecology, 83: 2516–2528.

Pedersen, S.A., Lewy, P., and Wright, P. 1999. Assessments of the lesser sandeel (*Ammodytes marinus*) in the North Sea based on revised stock divisions. Fisheries Research, 41: 221–241.

Piatt, J.F., and Anderson, P. 1996. Response of common murres to the Exxon Valdez oil spill and long-term changes in the Gulf of Alaska marine ecosystem. American Fisheries Society Symposium, 18: 720–737.

Pickerell, G. 2004. Little Tern *Sterna albifrons*. *In* Seabird Populations of Britain and Ireland. Pages 339-349. Ed. by P.I. Mitchell, S.F. Newton, N. Ratcliffe, and T.E. Dunn. T. & A.D. Poyser, London.

Planque, J.-M., and Fromentin, B. 1996. *Calanus* and environment in the eastern North Atlantic. I. Spatial and temporal patterns of *C. finmarchicus* and *C. helgolandicus*. Marine Ecology Progress Series, 134: 101–109.

Proctor, R., Wright, P.J., and Everitt, A. 1998. Modelling the transport of larval sandeels on the north west European shelf. Fisheries Oceanography, 7: 347–354.

Ratcliffe, N., Catry, P., Hamer, K.C., Klomp, N.I., and Furness, R.W. 2002. The effects of age and year on the survival of breeding great skuas *Catharacta skua* in Shetland. Ibis, 144: 384–392.

Regehr, H.M., and Montevecchi, W.A. 1997. Interactive effects of food shortage and predation on breeding failure of black-legged kittiwakes: indirect effects of fisheries activities and implications for indicator species. Marine Ecology Progress Series, 155: 249–260.

Regehr, H., and Rodway, M. 1999. Seabird breeding performance during two years of delayed Capelin arrival in the Northwest Atlantic: a multi-species comparison. Waterbirds, 22: 60–67.

Rindorf, A., Wanless, S., and Harris, M.P. 2000. Effects of changes in sandeel availability on the reproductive output of seabirds. Marine Ecology Progress Series, 202: 241–252.

Roemmich, D. 1992. Ocean warming and sea level rise along the southwest U.S. coast. Science, 257: 373–375.

Roemmich, D., and McGowan, J.A. 1995. Climatic warming and the decline of zooplankton in the California Current. Science, 267: 1324–1326.

Sandvik, H., Erikstad, K.E., Barrett, R.T., and Yoccoz, N.G. 2005. The effect of climate on adult survival in five species of North Atlantic seabirds. Journal of Animal Ecology, 74: 817–831.

Scheffer, M., Carpenter, S., Foley, J.A., Folke, C., and Walker, B. 2001. Catastrophic shifts in ecosystems. Nature, 413: 591–596.

Schreiber, R.W., and Schreiber, E.A. 1984. Central pacific seabirds and the El Nino-Southern Oscillation: 1982–1983 perspectives. Science, 225: 713–716.

Schreiber, E.A. 2002. Climate and weather effects on seabirds. *In* Biology of Marine Birds. Pages 179-215. Ed. by E.A. Schreiber and J. Burger. CRC Press Boca Raton, Louisiana.

Siriwardena, G.M., and Wernham, C.V. 2002. Synthesis of the migration patterns of British and Irish birds. *In* The Migration Atlas: movements of the birds of Britain and Ireland. Pages 70-102. Ed. by C.V. Wernham, M.P. Toms, J.H. Marchant, J.H. Clark, G.M. Siriwardena, and S.R. Baillie. T. and A.D. Poyser, London.

Smith, R.C., Ainley, D., Baker, K., Domack, E., Emslie, S., Fraser, B., Kennett, J., Leventer, A., Mosley-Thompson, E., Stammerjohn, S,, and Vernet, M. 1999. Marine ecosystem sensitivity to climate change. BioScience, 49: 393–404.

Springer, A.M. 1998. Is it all climate change? Why marine bird and mammal populations fluctuate in the North Pacific. *In* Biotic Impacts of Extratropical Climate Variability in the Pacific. Ed. by G. Holloway, P. Muller and D. Henderson. SOEST Special Publication, NOAA Award No. NA67RJ0154.

Springer, A.M., Roseneau, D.G., Murphy, E.C., and Springer, M.I. 1984. Environmental controls of marine food webs: food habits of seabirds in the eastern Chukchi Sea. Canadian Journal of Fisheries and Aquatic Sciences, 41: 1202–1215.

Springer, A.M., Roseneau, D.G., Lloyd, D.S., McRoy, C.P., and Murphy, E.C. 1986. Seabird responses to fluctuating prey availability in the eastern Bering Sea. Marine Ecology Progress Series, 32: 1–12.

Springer, A.M., Murphy, E.C., Roseneau, D.G., McRoy, C.P., and Cooper, B.A. 1987. The paradox of pelagic food webs in the northern Bering Sea — I. Seabird food habits. Continental Shelf Research, 7: 895–911.

Steele, J.H. 1998. Regime shifts in marine ecosystems. Ecological Applications, 8: S33–S36.

Thompson, P.M., and Ollason, J.C. 2001. Lagged effects of ocean climate change on fulmar population dynamics. Nature, 413: 417–420.

Thompson, P.M., and Grosbois, V. 2002. Effects of climate variation on seabird population dynamics. Directions in Science, 1: 50–52.

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

Uttley,J., Monaghan, P., and White, S. 1989. Differential effects of reduced sandeel availability on two sympatrically breeding species of tern. Ornis Scandinavica, 20: 273–277.

Veit, R.R., Pyle, P., and McGowan, J.A. 1996. Ocean warming and long-term change in pelagic bird abundance within the California Current System. Marine Ecology Progress Series, 139: 11–18.

Veit, R.R., McGowan, J.A., Ainley, D.G., Wahl, T.R., and Pyle, P. 1997. Apex marine predator declines 90% in association with changing oceanic climate. Global Change Biology, 3: 23–28.

Veit, R.R., and Montevecchi, W.A. 2006. The influences of climate change on marine birds. Acta Zoologica Sinica 52, Supplement: 165–168.

Votier, S.C., Hatchwell, B.J., Beckerman, A., McCleery, R.H., Hunter, F.M., Pellatt, J., Trinder, M., and Birkhead, T.R. 2005. Oil pollution and climate effects have wide-scale impacts on seabird demographics. Ecology Letters, 8: 1157–1164.

Wanless, S., Wright, P.J., Harris, M.P., and Elston, D.A. 2004. Evidence for decrease in size of lesser sandeels *Ammodytes marinus* in a North Sea aggregation over a 30-yr period. Marine Ecology Progress Series, 279: 237–246.

Wanless, S., Harris, M.P., Redman, P., and Speakman, J.R. 2005. Low energy values of fish as a probable cause of a major seabird breeding failure in the North Sea. Marine Ecology Progress Series, 294: 1–8.

Weimerskirch, H. 2001. Seabird demography and its relationship with the marine environment. *In* Biology of Marine Birds. Pages 115-135. Ed. by E.A. Schreiber and J. Burger. CRC Press, Boca Raton, Louisiana.

Weimerskirch H, Salamolard, M., Sarrazin, F., and Jouventin, P. 1993. Foraging strategy of wandering albatrosses through the breeding season: A study using satellite telemetry. Auk, 110: 325–342.

Weimerskirch, H., Barbraud, C., and Lys, P. 2000. Sex differences in parental investment and chick growth in Wandering Albatrosses: fitness consequences. Ecology, 81: 309–318.

Wernham, C.V., Toms, P.M., Marchant, J.H., Clark, J.A., Siriwardena, G.M., and Baillie, S.R. eds. 2002. The Migration Atlas: Movements of the Birds of Britain and Ireland. T and A.D. Poyser, London.

Williams, G. 1966. Natural selection, the costs of reproduction, and a refinement of Lack's principle. American Naturalist, 100: 687–690.

Wiltshire, K.H., and Manly, B.F.J. 2004. The warming trend at Helgoland Roads, North Sea: phytoplankton response. Helgoland Marine Research, 58: 269–273.

Wright, P.J. 1996. Is there a conflict between sandeel fisheries and seabirds? A case study at Shetland. *In* Aquatic predators and their prey. Pages 154-165. Ed. by S.P.R. Greenstreet and M.L. Tasker. Fishing News Books, Oxford.

Wright, P.J., Jensen, H., and Tuck, I. 2000. The influence of sediment type on the distribution of the lesser sandeel, *Ammodytes marinus*. Journal of Sea Research, 44: 243–256.

3 Seabird bycatch in longline fishing and its future mitigation in European Union waters

Longline fishing is a technique in which a line with a large number (thousands) of baited hooks, each attached to a branchline, is deployed ('set') from the stern of a vessel. Pelagic longlines target species in the water column, notably tuna and swordfish, whereas demersal longlines target fish on the sea-bed including cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, hake *Merluccius merluccius*, halibut *Hippoglossus hippoglossus* and toothfish *Dissostichus eleginoides*. Longlines are often set in the evening and hauled back in the morning. Individual boats usually organize their daily schedule such that a complete cycle of fishing lasts less than 24 hours. Incidental catch of seabirds (bycatch) occurs because birds wait for the baited hooks to be deployed, and then attempt to capture the bait (usually fish or squid) from the hooks before they are dragged underwater by the deploying longline. Birds become hooked and are then drowned as the lines sink. Birds are often attracted to the boat in the first place because offal from processed fish is continually pumped overboard.

The problem of seabird bycatch in commercial longline fisheries has been particularly acute in the southern oceans and has mainly affected various species of albatrosses and petrels (e.g. Brothers *et al*. 1999, Weimerskirch *et al*. 1997). However, the incidental take of seabirds is not confined to large Procellariiformes nor to regions of the world's seas where these species occur. There is certainly a significant, though largely unquantified, degree of bycatch in commercial longline fisheries in European Union waters (e.g. Belda and Sanchez 2001).

Mitigation measures have been successful in substantially lowering the mortality of seabirds caused by longlining (Løkkeborg 2003, Klaer and Polachek 1998). A significant reason for compliance with mitigation measures is that fishermen benefit financially from preventing birds from taking baits that would otherwise be available to fish. There are, however, other benefits for fishers. While bait retention might be of considerable economic benefit in specific examples where very high bait loss occurs, e.g. Norway, it is likely to be insignificant in fisheries with lower seabird bycatch rates, where the bycatch might well impact highly threatened species, such as the Balearic shearwater. Fishers in Malta, for example, are not concerned about bait loss but do want to reduce seabird bycatch because they use aggregations of birds to detect fish. This is likely to be powerful argument in artisanal fisheries, such as those in the Mediterranean (A. Black, pers. comm.). Therefore, there is strong argument from the fishers' point of view for identifying fisheries in the ICES region where mortality may be occurring, and for proposing mitigation for those fisheries where such mortality occurs.

Data on bycatch rates are extremely sparse and patchy, so identifying problem areas is difficult. Where observers have been placed on fishing vessels, such as in Canada, the USA, the southern oceans, and the Mediterranean, substantial seabird mortality has been recorded (e.g. Dunn and Steel 2001; Hata 2006; Soczek 2006). Therefore, there is a strong justification for implementing additional observer programmes in ICES regions and EU waters where longlining takes place. Such a programme would contribute to the assessment of any bycatch problem, placed within the context of Community plan of action aimed at its mitigation; the United Nations Food and Agriculture Organisation (FAO) has established a model for such a plan of action (FAO 1999).

(It is not only in longline fisheries that seabirds suffer incidental mortality. Other types of fishing gear also cause mortality through entanglement - which may also occur in longlines. This issue is addressed further in Chapter 5 below.)

3.1 Criteria used to assess the need for national plans of action for seabirds

In the context of assessing the need for a national plan of action for seabirds (NPOA-Seabirds) for EU waters, ICES WGSE recommends using those criteria set out in the FAO International Plan of Action (IPOA-Seabirds) adopted by the 23rd Session of the FAO Committee on Fisheries (COFI) in February 1999 and endorsed by the FAO Council in June 1999 (FAO 1999). The FAO IPOA-Seabirds is a voluntary undertaking by member states of the FAO.

According to the IPOA-Seabirds (and as itemised in the letter, 9 July 2007, from the Commission to ICES requesting scientific advice), the assessment may include, but is not limited to, the collection and analysis of the following:

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

Although the FAO guidance invites elements additional to this list to be invoked, as required, WGSE is not aware that other contracting parties to FAO have invoked any additional criteria in assessing the need for developing a NPOA-Seabirds. WGSE therefore finds the stated list to be necessary and sufficient for the EU's assessment purposes.

The first-listed element, *Criteria used to evaluate the need for NPOA-Seabirds* is, in effect, defined by some (but not necessarily all) of the other metrics in the list, and especially by *Total annual catch of seabirds* and the *Status of seabird populations in the fishing areas*. Together, these two criteria enable a determination of the significance of the impact of longline fishing on the seabird populations that use EU waters, whether for the whole or just part of the year.

In assessing the need for a NPOA-Seabirds, it is important to note that it is not strictly necessary to link these two elements (total bycatch and population status) to invoke the degree of threat to any particular seabird species in order to justify the need for a NPOA-Seabirds. The IPOA-Seabirds does not recommend making the need to develop a NPOA-Seabirds conditional on the population status of the affected seabird species. The implication of the IPOA-Seabirds is therefore that if longline fisheries operate in EU waters, then measures should be taken to avoid the bycatch of all seabird species, irrespective of the degree of threat posed to their populations.

This is in keeping with the FAO Code of Conduct for Responsible Fisheries (FAO 1995, Art 6.6), which calls for best practice to avoid unnecessary mortality of non-target species, irrespective of whether or not this mortality threatens the overall status of the impacted species. Nevertheless, the need for a NPOA-Seabirds will be greater if any of the species incurring mortality from longline fishing are listed as threatened or in need of protection according to IUCN criteria, or are listed on Annex I of the EU Birds Directive (EEC 1979; 3.11 Appendix); it is certainly the case in EU waters that longline fisheries are impacting such seabird species.

Among the other criteria used to assess the need for national plans of action for seabirds, two are particularly relevant to evaluating the need for a NPOA-Seabirds in EU waters. These are *Systems for monitoring seabird bycatch* and *Use/effectiveness of mitigating measures*. The *Total annual catch of seabirds* cannot be assessed without adequate monitoring systems (especially on-board observer programmes). Nor can bycatch be prevented without routine application of effective mitigation measures. As there is *a priori* reason to consider that neither monitoring nor mitigation are adequately developed in longline fisheries in EU waters, both of these criteria are highly relevant to evaluating the need for the EU to develop a NPOA-Seabirds.

Most of the other criteria on the FAO list are more relevant to how and where the NPOA-Seabirds should be implemented than to evaluating the need to have a NPOA in the first place.

The key criteria recommended here for evaluating the need for a NPOA-Seabirds are consistent with the draft framework objectives developed for assessing seabird mortality in the International Commission for the Conservation of Atlantic Tunas (ICCAT) longline fisheries (Phillips *et al*. 2007):

1) Identify seabird species most at risk from fishing in the ICCAT Convention Area.
2) Collate available data on at-sea distribution of these species.
3) Analyse the spatial and temporal overlap between species distribution and ICCAT longline fishing effort.
4) Review existing bycatch rate estimates for ICCAT longline fisheries.
5) Estimate total annual seabird bycatch (number of birds) in the ICCAT Convention Area.
6) Assess the likely impact of this bycatch on seabird populations.

Particularly as the ICCAT region covers longline fisheries for tuna and swordfish in the Mediterranean, WGSE considers that these ICCAT criteria should be regarded as supportive of the case for using the FAO criteria for assessing the need for a NPOA-Seabirds in EU waters, and should help to create synergy with developing action plans for these two overlapping regions of fisheries governance.

3.2 Species of seabird known or likely to be caught in longline fisheries in EU waters

A review of published literature, and other data sources, concerning the recent bycatch of seabirds on longlines in European waters generated a list of 20 species known to have been caught, albeit in very low numbers for some taxa (Table 3.1). In addition, large numbers of auks (mostly common guillemots) used to be caught on salmon *Salmo salar* surface-set longlines in northern Norway and the Faroe Islands, but these fisheries had ceased by the early 1990s. Six species have been reported as bycaught from the Northeast Atlantic alone, nine from the Mediterranean, and five from both.

Table 3.1. List of seabird species known to be caught in longline fisheries in EU waters. Of these 20 species, six are notable for their high conservation concern (emboldened; see 3.11 Appendix) and moderate to high frequency of capture (sooty shearwater, Balearic shearwater, Yelkouan shearwater, Cory's shearwater, Audouin's gull and black-legged kittiwake), and two (emboldened) for the high numbers of casualties reported (northern fulmar and great shearwater). The remaining species are either caught in very low numbers or, despite being regularly caught, are of lower conservation concern.

SPECIES	WATERS	REFERENCES
Northern fulmar	NE Atlantic	1,3
Great shearwater	NE Atlantic	2,3
Sooty shearwater	NE Atlantic	2,3,4
Balearic shearwater	Mediterranean	2,5
Yelkouan shearwater	Mediterranean	2,5,
Cory's shearwater (subspp. *diomedea*)	Mediterranean	2,5
Cory's shearwater – (subspp. *borealis*)	NE Atlantic	6
European shag	Mediterranean	2,5
Great cormorant	Mediterranean	5
Northern gannet	NE Atlantic, Mediterranean	2,3,5
Great skua	NE Atlantic, Mediterranean	1,2,5
Lesser black-backed gull	NE Atlantic	1,6
Great black-backed gull	NE Atlantic	1,3
Audouin's gull	Mediterranean	2,5
Mediterranean gull	Mediterranean	2,5
Black-headed gull	Mediterranean	5
Yellow-legged gull	Mediterranean, NE Atlantic	2,5,6
Black-legged kittiwake	NE Atlantic	3,7
Sandwich tern	Mediterranean	5
Black tern	Mediterranean	5
Razorbill	NE Atlantic	6,8

References: 1. Dunn and Steel 2001; 2. Dunn 2007 and references therein; 3. Barros 2007; 4. SEO/Birdlife unpublished data; 5. Cooper *et al*. 2003 and references therein; 6. C. Santos pers comm.; 7. González-Solís and Roscales (UB), unpublished data; 8. Arcos *et al*. 1996.

3.3 Population status and trends of seabirds caught on longlines in EU waters

In order to assess the potential effects of longline fishing on seabirds in European waters, the population status and trends of those species known or likely to be caught in each of ICES Areas III–X, and the western, central and eastern Mediterranean Sea, are summarized here. The breeding populations of the species caught on longlines and breeding in ICES Areas III–X and in the Mediterranean are summarised in Tables 3.2 and 3.3 respectively. Table 3.4 presents numbers of breeding and wintering seabirds in the Mediterranean and Black Sea, country by country.

Table 3.2. Breeding population estimates of seabird species breeding in Europe and known to be caught on longlines in ICES Areas III-X. Data sources: Barrett *et al.* 2006a (areas III-VIII) and Catry 2002, Bermejo and Mouriño 2003, Morais *et al.* 2003, Mouriño and Bermejo 2003, Mouriño and Alcalde 2003, Leal and Lecoq 2005, Neves *et al.* 2006a, Morais 2007, M. Lecoq, pers. comm. (areas IX-X).

	ICES AREA							
	III	IV	V	VI	VII	VIII	IX	X
	Baltic, Skagerrak, Kattegat	North Sea including Shetland	Iceland, Faeroes	Western Scotland	Irish Sea, English Channel	Biscay	Portugal, Western Galicia	Azores
Northern fulmar	2	300 000	2 000 000	165 000	45 000	5		
Cory's shearwater							1 000	189 000
Great cormorant	75 000	12 500	4 000	2 100	8 500			
Northern gannet			34 000	110 000	77 500			
Great skua		11 000	6 000	500				
Lesser black-backed gull	30 000	105 000	39 000	0	86 000	11 000	300	
Great black-backed gull	18 000	14 000	20 000	5 500	8 000	1 000	<5	
Audouin's gull							40	
Mediterranean gull					75	25		
Yellow-legged gull						30 000	50 000	4 150
Black-legged kittiwake	650	250 000	900 000	72 000	46 000	250	50	
Sandwich tern	2 000	32 000			4 000	4 600		

Table 3.3. Breeding population estimates (pairs) of seabird species known to be caught in significant numbers on longlines in the three FAO fisheries sub-areas of the Mediterranean Sea (FAO 37; http://www.fao.org/fishery/area/Area37). The sizes of populations in many Mediterranean countries are not known.

	Total	Western Mediterranean FAO 1	Central Mediterranean FAO 2	Eastern Mediterranean FAO 3
Balearic shearwater	2000-2400+	2000-2400+	not present	not present
Cory's shearwater[1]	30 000-43 000+	11 000-20 000+	14 000-17 000+	5000+
Yelkouan shearwater	14 000-34 000+	4900-8900+	5000-8700+	4000-17 000
European shag[2]	8900-13100+	3700-4000+	3300-6100+	1900-3000+
Audouin's gull	23 000+	21 000+	300-600+	800-1000+
Mediterranean gull	11 000-12 000+	4000+	1000	6000-7000+
Yellow-legged gull	220 000-310 000+	95 000-105 000+	50 000-85 000+	75 000-120 000+

[1]subspp. diomedea; [2]subspecies desmarestii

There are too few available data to accurately estimate population trends for all the species of concern in each of the ICES or Mediterranean fishing areas. Data for only a few species, such as northern fulmar and black-legged kittiwake in ICES Areas IV and VI, allow accurate trends to be estimated, and only between 1997 and 2007.

3.3.1 Northern fulmar

About 2.5 million pairs of northern fulmar breed within the area of concern (ICES III-X, Table 3.1) and up to 1 million pairs in the Barents Sea. In ICES Areas IV and VI, the population of northern fulmar has declined at annual rates of 2.5% and 2.4% respectively. The reasons for these declines are not known. Although the species is of some conservation concern in the UK, the European and world populations are of little concern.

3.3.2 Great Shearwater

Of the eight species highlighted in Table 3.1, the great shearwater is one of two that breeds outside European waters. It breeds on islands in the South Atlantic, and migrates into the North Atlantic during the northern summer. It is most common in European waters in summer–autumn (peaking in August–September) when hundreds to thousands may pass through on their way south. The global population is somewhere between 5 and 10 million pairs, and population trends have not been quantified. It is classified as being a species of least concern on the IUCN Red List (IUCN 2007).

3.3.3 Sooty shearwater

The sooty shearwater is the other species that breeds outside the immediate area of longlining interest. It breeds in the Southeast Pacific (New Zealand and Australia, more than 5 million pairs), and the Southwest Pacific and Southeast Atlantic (southern Chile, 200 000 pairs and Falkland Islands, 10–20 000 pairs) (IUCN 2007). In common with the great shearwater, it undergoes long migrations to the North Atlantic outside the breeding season (although most stay in the Pacific), and occurs in large numbers off the European coast during the northern summer and early autumn, peaking in late August–September. It is classified as Near Threatened by IUCN because of large declines in the New Zealand populations; the reasons for these declines are probably various, including bycatch in drift nets (formerly) and gill nets, depredation by alien predators, and climate change.

3.3.4 Balearic shearwater

This species breeds almost exclusively in the Balearic Islands; about 2000 pairs breed on islets and coastal cliffs of the main islands, between March and early July (Arcos and Oro 2004; Ruiz and Marti 2004). Some remain in the western Mediterranean all year, but most enter the Atlantic for a post-breeding moult in the Bay of Biscay in summer. Many fly north to the English Channel and the Irish Sea. The population is currently exhibiting a severe decreasing trend, with an extinction risk of more than 50% within three generations (Oro *et al*. 2004). Consequently, the species has been classified as Critically Endangered (IUCN 2007). The main threats reported at colonies are predation by feral cats and rodents. However, the declining trend is not explained by those threats alone, and significant mortality at sea seems to be responsible. Longlining bycatch is suspected to be the main cause of mortality at sea – the species is highly gregarious and shows close associations with fishing boats (Oro *et al*. 2004, Arcos *et al*. 2008).

3.3.5 Cory's shearwater

There are two subspecies of the Cory's shearwater - *Calonectris d. diomedea* breeds in the Mediterranean and *C. d. borealis* breeds in the Atlantic. The global population of the species is 280 000–420 000 pairs, and it is classified as a species of Least Concern (IUCN 2007). The Atlantic population shows a stable trend and bycatch of the species at sea has not been intensively researched. Nevertheless, there have been some studies carried out in the Azores (an observers programme - Programa de Observãçao para as Pescas dos Açores, longline experiment, and fish-size observer programme) that do not identify bycatch as a main threat for this subspecies in the Atlantic. However, the population of the Mediterranean subspecies numbers fewer than 50 000 pairs (Tables 3.3, 3.4), is subject to high mortality on longlines (Belda and Sanchez 2001), and is considered vulnerable because of continuous decline during recent decades, especially in the extreme western Mediterranean.

3.3.6 Yelkouan shearwater

The Yelkouan shearwater is endemic to the Mediterranean, where it breeds on islets and coastal cliffs primarily in the eastern and central regions. Most individuals spend the winter in the Mediterranean, although very small numbers enter the Atlantic in late summer. The global population has been estimated at 14 750–52 300 pairs (IUCN 2007), with 14 000-34 000 in Europe (Tables 3.3, 3.4), although these figures could be overestimates (BirdLife International 2007). There have also been recent downward population trends, with the extirpation of several colonies due to threats both on land (disturbance and habitat destruction by tourists and introduced cats and/or rats) and at sea (bycatch, algal blooms). For these reasons, it has been proposed that the species be upgraded from Least Concern (IUCN 2007) to Near Threatened (BirdLife International 2007a). The species is also included in Annex I of the EU Birds Directive (EEC 1979).

3.3.7 Audouin's gull

The global population of this species is estimated at slightly more than 23 000 pairs, all in the Mediterranean except for 40 pairs in southern Portugal. (Tables 3.2-3.4). There has been a steady increase in population size since the mid-1970s, when the world population was estimated at only 1000 pairs. However, the species is still a scarce and localised seabird, and is regarded as Near Threatened (IUCN 2007, 3.11 Appendix).

3.3.8 Black-legged kittiwake

Approximately 1.25 million pairs of black-legged kittiwake breed in the ICES Areas of interest, and none in the Mediterranean. Although the population is large, severe declines have occurred over the last decade throughout Europe (at annual rates of 5.0% and 1.1% in ICES IV and VI respectively, and 6-8 % in Norway; Barrett *et al*. 2006b) and the black-legged kittiwake is now a species of European Conservation Concern (see 3.11 Appendix). It is categorised as Vulnerable in the Norwegian Red List; declines have also been recorded throughout the circumpolar Arctic. The reasons for population declines are not known for certain but are likely to be related to poor breeding success caused by reduced availability of staple prey such as sandeels *Ammodytes* spp., in turn possibly caused by climate-induced changes in the marine ecosystem and exarcebated by industrial fishing.

Table 3.4. Numbers of seabirds breeding (in pairs) and wintering (individuals) in the FAO subdivisions 1-3 of the Mediterranean and Black Sea Fishing area 37 (i.e. Western, Central and Eastern Mediterranean Sea; http://www.fao.org/fishery/area/Area37), country by country. Seabird population size estimates for the Eastern Mediterranean also include birds in the Turkish Black Sea.

		Western Mediterranean							Central Mediterranean						Eastern Mediterranean						
		Algeria[1]	Gibraltar[1]	Morroco[1]	Tunisia[1]	Spain	France	Italy[2]	Slovenia[2]	Croatia[2]	Montenegro[2]	Albania[2]	Malta[2]	Libya[1]	Greece[2]	Turkey[2]	Cyprus[2]	Syria[1]	Lebanon[1]	Israel[1]	Egypt[1]
Balearic shearwater	**BPS**	*	*			**1650-2050+ [2]**															
	PT					-3															
	WPS	*	*			**10000-20000+ [3]**															
	PT					?															
Cory's shearwater	**BPS**	*	*			**2500-10000+[2]**	**1000-1300[10]**	**15000-18000**		**800-1000**			**6090-7130**		**5000-5000**	**0-200**				*	
	PT					(-2)	0	0		(-4)			0		0	?					
Yelkouan shearwater	**BPS**		*		*	**50-250[2]**	**1350-1650[12]**	**7000-14000**		**50-100**		*	**1400-1560**	*	**4000-7000**	**0-10000**					
	PT					?	0	0		(-5)			0		0	?					
Mediterranean shag	**BPS**					**2100-2100[4]**	**800[13]**	**1600-2200**		**2500-5000**		*			**1000-1200**	**900-1800**	**80-120**				
	PT	*	*			(+)	?	0		(+2)				*	0	0	0			*	
	WPS							**500-1000**	*	**2500-5000**	*				**1500-3000**	**3000-6000**					
	PT							0		(+2)					0	0					
Audouin's gull	**BPS**					**20315-20315[5]**	**56-92[2]**	**510-982**		**65-70**					**750-900**	**60-70**	**15-30**				
	PT	*	*	*	*	+3	F	F		(+)				*	0	F	0		*	*	
	WPS					**1000-3000[6]**		**500-1000**							**200-1000**	**61-584**	**40-80**				
	PT							0							0	F	0				

		Western Mediterranean							Central Mediterranean							Eastern Mediterranean					
Mediterranean gull	**BPS**	*	*	*	*	2-3	3000[11]	1980-1980			*			*	1000-1350	4900-5500			*	*	*
	PT					0	+5	0							-1	0					
	PT						+3	+1					0		F	0					
Yellow-legged gull	**BPS**	*	*	*	*	33566-33566[7]	40000-45000[2]	40000-50000	*	25000-50000	*	*	150-180	*	60000-100000[9]	20000-30000	100-200	*	*	*	*
	PT					(+1)	+4	+3		(-1)			(+1)		+1	+2	-1				
	WPS					7600-55000+[3]		84 280													
	PT					?															

*** - present, but no population data available**

BPS - breeding population size per country (breeding pairs); + = possible underestimation

PT - population trend per country (over the period 1990–2000): 0 = stable; -1 = decreasing (change 0-19%); -2 = decreasing (overall 20-29%) -3 = decreasing (change 30-49%); -4 = decreasing (change 50-79%); -5 = descreasing (change >80%) +1 = increasing (change 0-19%); +2 = increasing (change 20-29%); +3 = increasing (change 30-49%); +4 = increasing (change 50-79%); +5 = increasing (change >80%); ? = no data

WPS – winter population size per country (individuals)

Sources: [1] BirdLife International (2007b); [2] Birdlife International (2004a); [3] Arcos (2005); [4] Álvarez and Velando (2007); [5] Oro, D., pers. comm.; [6] Anonymous (2004); [7] Martí and del Moral (2003); [8] Birdlife International (2001); [9] Hellenic Ornithological Society, unpublished data; [10] Vidal and Fernandez (2004); [11] Sadoul and Pin (2007); [12] Institut Méditerranée Méditerranéen d'Ecologie et de Paléoécologie/Université Paul Cézanne, IMEP IMEP-CNRS, unpublished data; [13] Ligue pour la Protection des Oiseaux Provence Provence-Alpes Alpes-Côte d'Azur d'Azur, France, LPO PACA, unpublished data; [14] Nidal ISSA, Les oiseaux marins en Méditerranée française, unpublished data.

3.4 Longlining bycatch of seabirds in EU waters

3.4.1 Overview of seabird bycatch on longlines

Large numbers of seabirds have been killed as bycatch in longline fisheries (Birdlife International 2004b; Dunn and Steel 2001; Lewison and Crowder 2003; Phillips *et al*. 2006). The most serious population level impacts have been upon albatrosses and other petrels in the southern hemisphere (Birdlife International 2004b), where 17 species are in danger of extinction due largely to this one factor. Albatrosses and other petrels are especially vulnerable because they habitually attend fishing vessels to scavenge, and they are large enough to be able to capture and swallow the baited hooks used to catch Patagonian toothfish, tunas, and swordfish. Bycatch of smaller species, often due to entanglement, is also possible.

Several mitigation measures designed to reduce seabird mortality have been effective (Løkkeborg 2003, Gilman *et al*. 2005), and are relatively easy to implement because fishermen benefit financially by preventing birds from eating their baits, thereby improving fishing efficiency. As a result of reduced bycatch mortality, some populations of endangered albatrosses have slowed their rate of decline (Brothers 1999); nevertheless, other populations affected by bycatch are declining rapidly. Fisheries management can have direct conservation benefits, but there are few examples of fisheries where a high proportion of fishermen have voluntarily adopted mitigation measures.

While longline fisheries occur in all the world's oceans, few conservation issues as pressing as that of southern hemisphere albatrosses have yet been identified. Yet data on bycatch are sparse and it is possible that serious problems have gone undetected. There has been no compilation of data on demersal and pelagic longline bycatch mortality for the North Atlantic, although such mortality has been documented (Dunn and Steel 2001, Hata 2006, Soczek 2006).

We aim here to compile data on bycatch mortality for ICES Regions III–X and the Mediterranean, in order to estimate as far as is possible annual rates of mortality for seabirds known to be caught on longlines, and to suggest mitigation measures where needed.

3.4.2 Seabird bycatch in longline fisheries in European Union waters (ICES Area III–X and the Mediterranean)

In compiling data on seabird bycatch in the Northeast Atlantic generally it has become clear that very few data exist and that there is a large information gap in our knowledge of the extent of the problem; this is readily apparent from Table 3.5. For ICES Regions III through X, the only data available on seabird bycatch from longline fishing are:

1) Data from three cruises (2006-2007) on Spanish hake longliners (*c*. 20 vessels fleet) fishing the Gran Sol (ICES Regions VI and VII);

2) Data from a single vessel fishing in the vicinity of Iceland and the Faeroes in 1996-1998 (ICES Regions V and II), which were extrapolated to a total fleet of about 2000 vessels. These are supplemented by some bird ring recoveries;

3) Limited data from the Azores in 2000-2005; and

4) Occasional events reported elsewhere.

From the Mediterranean, there are more data available (though still few in absolute terms), but these have not been collected systematically and uncertainty remains about seabird mortality levels.

3.4.2.1 Western Europe

In general, data on longline bycatch have been collected on an experimental basis outside the Mediterranean and Azorean waters. There are some detailed data available for Spanish demersal longliners targeting hake in the Gran Sol area (whose fishing fleet numbers about 20 vessels) off western Ireland (ICES Region VII; Barros 2007, SEO/BirdLife unpublished data). In addition, some detailed data have been collected on longliners operating off Iceland, the Faroe Islands and Norway (ICES Region V). Arcos *et al*. (1996) also reported estimates of bycatch from demersal longlining from northwest Iberia (ICES Region VIII), based on questionnaires completed by fishermen. For the rest of Western Europe outside the Mediterranean, there are almost no data on seabird bycatch.

3.4.2.2 Mediterranean

Patchy data on longline bycatch is readily available for all three fishing areas of the Mediterranean (Western, Central and Eastern). Cooper *et al*. (2003) compiled an exhaustive review of the existing information, and more recent information supplements this. The most extensive information on bycatch in longlines is available for Spain (Belda and Sánchez 2001; Sánchez and Belda 2003; Valeiras 2003; Laneri *et al*. 2007), but there are significant data and information gaps for several Mediterranean countries in North Africa, the Middle East and the Balkans (Table 3.5). The available data, however, were sufficient to enable identification of the main species threatened by longlines, as well as for qualitative and approximate estimations of mortality for seabird species present. Notably, shearwater species such as Balearic, Yelkouan and Cory's are recorded in the seabird bycatch of the Spanish longlining fleet (Table 3.6).

The data refer primarily to bycatch incidents during the last decade on a small proportion of the total fishing fleet in the Mediterranean. The sources of information were on-board observations, fishermen questionnaires, individual reports, and information from research, conservation, management and wildlife rehabilitation institutions. Bycatch has been reported for both pelagic and demersal longlining, although the latter seems to be the main threat to seabirds.

The true situation in the Mediterranean is complicated by the activities of longline vessels that are not part of the European Community fleet. For example, Cooper *et al.* (2003) noted that of 12 Mediterranean countries known to undertake longline fishing, seabird mortality from longlining had been reported only for six - France, Greece, Italy, Malta, Spain and Tunisia. However, even those data were (and remain) very sparse and not systematically collected, with only Spain furnishing quantitative data. To highlight the scale of the data gaps, Italy had, at the time of the Cooper *et al*. (2003) study, 700 longline vessels based in Sicily alone.

Cooper *et al*. (2003) found no data for longline vessels from Cyprus, far less from non-EU countries known to practise longline fishing in the Mediterranean, namely Turkey, Israel, Tunisia, Libya, Morocco, or for pelagic longline vessels from Japan, Korea and Taiwan. There is a clear need to work collaboratively with all non-EU nations fishing in the Mediterranean to assess the size of their fleets, their associated fishing operations, and interations with seabirds.

3.4.2.3 Azorean waters

In recent years, some observer programmes have been implemented at the Azores archipelago (ICES Area X), such as the Programa de Observãçao para as Pescas dos Açores. These have mostly targeted longline fisheries and fisheries discards.

In 2005, the so-called "Minimum Programme" was implemented for monitoring demersal longline fisheries discards by DOP-Azores University (developed after Reg. (EC) no. 1543/2000). The programme placed three observers on board from between 6 and 9 months between 2005 and 2007, who monitored bycatch of non target fish species. Although not directly focused on monitoring seabird bycatch, those observers did not record any seabirds caught on hooks during the fishing events (A. Canha pers. comm.).

Another bycatch project, "Longline Experiment", was conducted by DOP-Azores University and ACCSTR- University of Florida to determine the effects of pelagic longline gear modification on sea turtle bycatch rates. Data from 343 longline sets, collected during five longline fishing experiments (2000-2004), showed that only one yellow-legged gull was caught on the lines (M. Aurélio pers. comm.).

The above mentioned surveys might suggest that bycatch caused by longlining (both demersal and pelagic) is not a major threat to seabird species in the Azores. However, these are very small-scale studies that addressed a small part of the Azorean fleet. It is clear that larger scale studies are required covering both a larger proportion of the Portuguese national fleet and also other foreign vessels present in the Azorean EEZ.

Table 3.5. Estimated annual seabird bycatch by longline vessels in ICES Areass III-X and in the Mediterranean. These figures are based on very limited information, and should be regarded as conservative estimates.

	ICES REGION								MEDITERRANEAN		
	III	IV	V	VI	VII	VIII	IX	X	I	II	III
	Skagerrak	North Sea	Iceland	NW UK	W Ireland	Cantabrian sea	W Iberia	Azores	W Med	C Med	E Med
Northern fulmar			43000	12000							
Great shearwater					48000						
Sooty shearwater				1600							
Balearic shearwater									100s +		
Cory's shearwater									1000s	1000s	1000s
Yelkouan shearwater									100s +	100s +	100s +
Shearwaters spp							>4000				
European shag									10s		
Great cormorant										10s	
Northern gannet				4500		moderate-high	>3000		10s - 100s	10s	
Great skua									<10s		
Lesser black-backed gull											
Great black-backed gull				1200							
Audouin's gull									10s - 100s	10s	10s
Mediterranean gull									10s +	10s +	
Black-headed gull									10s		
Yellow-legged gull									100s +	100s +	100s +
Black-legged kittiwake				5000					10s +		
Gull spp.						low-moderate	200-250				
Sandwich tern										10s	
Black tern										10s	
Tern spp.						low	750				
Auks						low	130				

Sources: ICES V - Dunn and Steel (2001); ICES VI and VII – SEO/BirdLife unpublished data; ICES IX – Arcos *et al*. (1996); Mediterranean - SEO/BirdLife unpublished data.

Table 3.6. Reported bycatch of three species of shearwater (the significant species most likely to be bycaught) in the Spanish longline fleet in the Mediterranean.

Pelagic effort	72 vessels
Demersal effort	High (*c.* 100, but 1000s including artisanal vessels)
Bird Information	low-moderate
Balearic shearwater	Some reported
	3/46 - 237sets (demersal); Valencia-Balearics[1]
	>10% of bycatch in the Balearics (120 questionnaires) [2]
	c. 50 birds beached winter 1999-2000[3]
	30 birds/set in 2 sets, winter 2000-2001 (?), Barcelona, (demersal)[4]
	27/229 birds in 25 visits to port 2003-2007; up to 7/vesselandday (demersal)[5]
	c. 100 birds/set off Barcelona, May 2007 (demersal)[6]. Yelkouan shearwater could be involved.
	12 birds found dead and hooked at sea (4 miles transect), off Ebro Delta, June 2007[7]
Yelkouan shearwater	60/229 birds in 25 visits to port 2003-2007; up to 15/vesselandday (demersal)[5]
Cory's shearwater	34/46 - 237sets (demersal); Valencia-Balearics[1]
	9/554 sets (pelagic)
	38 ringed birds caught 1992-98, Columbretes area
	Around 437-1867 in Columbretes area + 1300/year in the Balearic Islands area
	113/229 birds in 25 visits to port 2003-2007; up to 29/vessel and day (demersal)[5]

Sources: [1]Laneri *et al.* (2007), [2]Louzao and Oro (2004), [3]Arcos and Oro (2004), [4]E. Badosa, unpublished data, [5]J. González-Solís and J.L. Roscales, University of Barcelona, unpublished data, [6]O. Macián, unpublished data, [7]J. Torrent, SEO/BirdLife, unpublished data. Other data from Cooper *et al.* (2003).

3.4.2.4 Data Quality

Whether data on bycatch have been collected by paid observers, or reported voluntarily by fishermen on their own boats, or have been reported by other means (e.g. recovery centres, beached surveys, etc.), clearly there is a need for more systematic data collection. Similarly, data have variously been reported as number of birds killed per hook, number killed per haul, or number killed per boat, and this number extrapolated to an estimated total number killed per year by the entire fishery, so there is also a need for standardized recording of seabird bycatch.

In assessing seabird bycatch rates in various fisheries there have been varying degrees of sampling coverage. In the southern hemisphere, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) has dictated 100% coverage by the observer programme (i.e. every fishing vessel has one or more observers). By contrast, observer coverage in North Atlantic domestic fleets (Canada and USA) has been closer to 5%, or even lower (see Table 3.7 for species that occur also in EU waters). Since statistical distributions of bycatch are often extremely skewed (a few very large catches and many zeroes - Perkins and Edwards 1996, Hilborn and Mangel 1997), this low proportion of vessels sampled may lead to gross underestimates of mortality.

Table 3.7. Seabirds caught on longline hooks in the northwest Atlantic 1986–2006. Observer coverage of fishing vessels varied from 5% on American and Canadian vessels to 100% for foreign vessels operating in Canadian waters. Data were presented as sums over the years listed; in this table, data are corrected for differing degrees of effort and divided by the number of years over which they were collected. Therefore, all results are of estimated number of birds killed per year. Data from Fisheries and Oceans Canada 2007, Hata 1986, Soczek 2006 and Palka and Warden 2007.

	North Atlantic Fisheries Organisation subregion			Total
	Newfoundland 1989–2001	Scotia Shelf 1986–2001	New England and Mid Atlantic 1986–2006	
Northern Fulmar	129	72	20	221
Great Shearwater	15	57	540	612
Sooty Shearwater	32	5	100	137
Great Black-backed Gull	0.4	29	640	670
Herring Gull	13	0	640	653

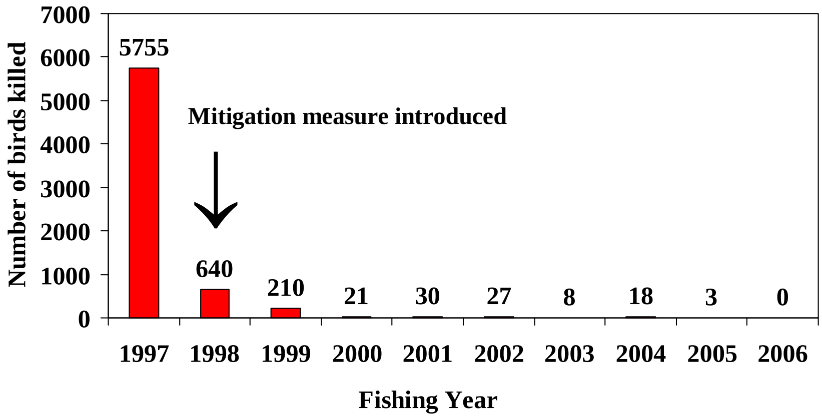
The combined results from the data presented here, allied to low monitoring and surveillance rates, as well as the likely high underestimation of actual bycatch rates, indicate that there is significant seabird mortality in the North Atlantic and the Mediterranean from longline fisheries.

3.5 Mitigation measures in use to reduce seabird bycatch on longlines worldwide

Many effective methods have been developed to reduce seabird bycatch in fishing gear (Gilman *et al*. 2005, Bull 2007). The motivation for this has come not just from conservation agencies and governments concerned about these unnecessary losses, but also from the fishing industry itself. Bait loss and associated reduction in catch caused by seabirds feeding off the stern of the vessel as a longline is set can present a significant cost to the industry (Sánchez and Belda 2003). The development of methods to mitigate seabird bycatch has partly relied on the expertise of fishers themselves through consultation and even competitions to decide the best method. This goes some way to ensure that the mitigation is cost-effective, practicable, and has minimal impacts on fishing efficiency, all attributes important to fishers. However, efficacy in reducing seabird bycatch itself needs to be, and indeed has been, tested scientifically in a number of situations.

Seabird bycatch on longlines seems to be particularly amenable to mitigation, judging by the wide array of methods that have been shown to be effective (see Table 3.8 and Figure 3.1). However, one should not underestimate the challenge of reducing seabird bycatch in this type of fishery. Scavenging seabirds, such as petrels and gulls, are adapted to scour the ocean surface for food, and when encountered, to quickly capture the items, sometimes in the face of fierce competition from other seabirds feeding in the same place. From the fishers' point of view, there is obviously a cost, sometimes significant, to obtaining and fitting equipment designed to reduce bycatch, and an added burden of learning how to operate and fine-tune devices while at the same time fishing in the frequently challenging conditions encountered at sea.

Figure 3.1. Seabird bycatch in the South Georgia Patagonian toothfish longline fishery in relation to the introduction of mitigation measures.



Gilman *et al*. (2005) list six general methods to reduce seabird mortality rates in longline fisheries:

1) avoiding peak areas and periods of seabird feeding;
2) reducing detection of baited hooks;
3) limiting bird access to baited hooks;
4) deterring birds from approaching hooks;
5) use of deterrents to make hooks less attractive; and
6) improving bird handling when removing live birds from hooks.

The first method is a general one that could work in other kinds of fisheries where bycatch is a problem such as trawling and gillnetting. Another generally applicable method, and one mentioned by Bull (2007), is to modify the discharge operations of offal and discarded fish so that fewer birds are attracted to the vicinity of the longliner in the first place.

Below, we briefly describe methods currently is use to reduce bycatch in longline fisheries. Many of these will have general applicability in EU waters. Headings are taken from Bull (2007) with the addition of comment on management of offal and discarded fish. Of course, as Bull (2007) has pointed out, a suite of mitigation measures is likely to be more successful in reducing or eliminating bycatch rather than one single measure. The nature of such a suite will be determined by various factors (see section 3.9).

3.5.1 General methods: offal and discard management

There is evidence that the practice of discharging offal or discarded fish increases the overall numbers of scavenging seabirds around fishing vessels (e.g., Weimerskirch *et al*. 2000; Melvin *et al*. 2001; Neves *et al*. 2006). It is easy to see how this could lead to higher levels of bycatch. Several methods to manage offal and discarded fish discharge may be effective in reducing numbers of scavenging seabirds around a fishing vessel including:

1) discharge from the side of the vessel rather than over the stern where the longline is shot, or from the opposite side if the longline is deployed from

one side of the vessel (this may attract birds away from the area where the baited hooks are sinking);

2) retaining offal and discards temporarily when shooting the longline and then discharging once the longline is set;

3) dumping homogenised or frozen blocks of offal and discards; and

4) processing of offal and discards on-board to produce fish meal. Methods vary in their practicality and costs but it seems clear that managing offal and discarded fish discharge from longliners is an important component of any plan to reduce seabird bycatch (see Bull 2007).

3.5.2 General methods: area/seasonal closures

Seabirds can only be caught incidentally in fishing gear if their distribution overlaps that of fisheries in space and time. Therefore an obvious method to reduce bycatch is to reduce this overlap by closing areas to fishing at certain times of year when bycatch is known to be a problem. This is done for example in Southern Ocean CCAMLR waters where fishing is restricted to the winter only. This has produced an almost ten-fold reduction of seabird bycatch (SC-CAMLR 1995, 1998). It may be possible in specific fisheries to fine-tune the opening and closing dates to avoid major seabird bycatch while at the same time not unduly affecting the fishery (although better information on seabird distributions at sea would be required in some areas). Ultimately, fisheries closures could cost a great deal of money to the industry and be unpalatable to it and to agencies and politicians responsible for fisheries management.

3.5.3 Underwater setting devices

These devices (USDs) guide and cover the baited hooks from deck level to where they are delivered underwater, 1 to several metres below the surface. In this way, they are not exposed above the surface and accessible to scavenging seabirds. There are three general types of USD: funnel, chute and capsule. The funnel is a commercially available device designed to work with autoline demersal gear: the mainline and branchlines with baited hooks run through the device. Because all the longline gear is running through the funnel, the chances are much greater that gear can become tangled and bait lost from hooks. The chute differs from the funnel in that only the branchlines and baited hooks are fed underwater, thus allowing use in pelagic longlines, which have floatation devices attached. Hook baiting and setting rates are slower with the chute than with the funnel. The capsule device delivers each baited hook underwater before returning for another. This results in slow hook setting rates gear entanglement and bait loss is low. Theoretically the concept of underwater setting is appealing but in practice, success in reducing bycatch has been mixed (Table 3.8). Factors such as sea conditions and weight distribution in the vessel can result in the end of the setting device remaining above the surface of the water, thus failing to protect the baited hooks (e.g., Løkkeborg 1998). Some other problems with these types of devices include their high cost to purchase and fit, and spatial clutter produced at the stern of the vessel.

3.5.4 Bait-casting/throwing machines

These devices are used in pelagic longline fisheries to project the baited branchlines some distance from the longline, thus reducing the chance of gear entanglement and allowing more rapid sinking rates because the lines are not continuously under tension. Although not specifically designed to reduce seabird bycatch, studies have reported lower bycatch rates when these devices are used (Klaer and Polacheck 1998).

3.5.5 Blue-dyed bait

Dying bait blue is hypothesized to reduce its visibility to seabirds. Results of testing this method have been mixed so it is not generally considered efficacious, but it may be useful in pelagic longline fisheries. The method is inconvenient because bait has to be thawed and dyed on the vessel and not commercially available (Gilman *et al*. 2007). Also, demersal longline fisheries use many more hooks and thus bait, so the problem of on-board dying is exacerbated (Bull 2007).

3.5.6 Side-setting

The idea of this fishing modification is that by setting the longline from the side of the vessel, baited hooks have sunk to such a depth by the time they reach the stern, so that fewer seabirds are able to access the hooks. Gilman *et al*. (2007) found that this method reduced bycatch in a pelagic longline fishery to a greater extent that bait-dying or underwater setting. Advantages of the method include the relatively small costs of refitting deck gear, practicability of use, and efficacy in reducing bycatch (Bull 2007). Problems with this method include safety issues with fishing crew, and the limited applicability to larger vessels on which the longline can be set sufficiently far forward.

3.5.7 Night-setting

Night-setting of longlines may reduce the visibility of baited hooks to seabirds or offset fishing activity to a time when seabirds are relatively inactive. Belda and Sánchez (2001) and Weimerskirch *et al*. (2000) and others (see Table 3.8) report significantly reduced bycatch during night setting. Barnes *et al*. (1997) and Brothers and Foster (1997) suggest that it is also important to reduce lighting on the fishing vessel when night-setting. Advantages of night-setting include little if any addition costs for equipment, applicability to both pelagic and demersal longline fisheries, and its efficacy. Disadvantages include increased safety issues for fishers working at night, possible increase of night-feeding seabirds, possible negative effects on target fish catches, and limited effectiveness in higher latitudes during the summer and/or when the moon is full (Bull 2007).

Barros (2007) noted that switching off deck lights during night setting substantially reduced seabird mortality (two birds killed in four settings without lighting whereas 119 birds killed in six settings with lighting).

3.5.8 Bird-scaring lines

A streamer line, also called a bird-scaring line or tori line, is a long (ca. 90 m) line that extends from a high point near the stern of the vessel to a weighted buoy floating in the water behind the vessel, and is deployed when setting the longline. Forward vessel movement tenses the streamer line from which hangs streamers made of UV protected, brightly colored tubing spaced every ca. 5 m. Streamers must be heavy enough to maintain a near-vertical fence in moderate to high winds. Individual streamers should extend to the water, to prevent aggressive birds from getting to the baited hooks. When deployed in pairs – one from each side of the stern – streamer lines create a moving fence around the sinking longline, which very effectively deters the scavenging seabirds. Various other specifications exist for the deployment of tori lines and the efficacy of these needs to be addfressed further in order to assess which might be the most appropriate for use in EU waters.

The efficacy of streamer lines has been tested in diverse longline fisheries and has been found to be almost universally effective at reducing bycatch (Table 3.8). Other advantages are the relatively low cost to make and fit the streamers, ease of deployment, and general applicability to various longline fisheries. Disadvantages include the need to refine the design and use of the streamer for each individual vessel so that efficacy is optimised (Brothers 1995 referred to in Bull 2007).

3.5.9 Brickle curtain

Uneaten bait can present a problem for seabird bycatch when the longline is being hauled back into the vessel. In this case a barrier to the seabirds in the form of a curtain of lines hanging from a rope strung around the hauling bay of the vessel can be used to prevent birds from approaching (see Sullivan 2004). Advantages of this method include applicability to various types of longline fishery and low cost of production and fitment (Bull 2007). Disadvantages include the possibility that some species of seabird may habituate to the curtain (Sullivan 2004).

3.5.10 Fish oil

Oil extracted on board from bycatch shark and applied over the stern of the vessel can deter seabirds, especially shearwaters and other burrow-nesting petrels, from entering the area in which they could gain access to baited hooks. This method won a SEO/BirdLife prize enhancing the proposal of mitigation measures, and was later studied in detail by Pierre and Norden (2006). The deterrent effect was associated with the smell of the oil rather than the oil itself, as the shark oil performed better than canola oil controls. However, although these initial trials were encouraging, further trials proved that the oily slick did not deter albatrosses and large petrels (Norden and Pierre 2007). It may be an effective technique when specific seabird assemblages are present but further trials are needed.

Advantages of this method include its efficacy in reducing numbers of seabirds and number of dives for submerged bait, the fact that bycatch fish products are used in the production of the oil, and that there was no observed reduction in target catches of fish species. Disadvantages include possible negative effects of oiling if seabirds come into contact with the oil, and possible habituation (where birds cease to respond to the smell over time).

3.5.11 Integrated and external line weights

Increasing the weight on lines increases their sink rate during line setting, and hence decreases the time that baited hooks remain available to seabirds. Lines can be weighted externally with attached weights or weights can be built-in or integrated into the longline gear. Research has addressed the effect of line weights on sinking rates to attempt to determine an optimum beyond which no further gain in efficacy is achieved. Generally the efficacy of this method is good (Table 3.8) although in one study, no benefit in addition to that attributed to a streamer line was seen (Melvin *et al*. 2001). Advantages of this method include its applicability to various longline fisheries and increased fish catches resulting from the weights keeping the line at an appropriate depth for longer. Disadvantages include costs of added weights or weighted line, practical difficulties of using weighted lines, lead entering the marine environment, and fisher safety due to risks of entanglement in attached weights (Bull 2007).

3.5.12 Line shooter

This device delivers the baited hooks into the water on a slack line, thus potentially increasing the rate at which lines sink. The results of tests of this method have been equivocal, with some studies showing a decrease in seabird bycatch rates but at least one showing an increase. At the present time, the disadvantages of using this method outweigh the advantages (Bull 2007).

3.5.13 Bait condition and species

Either frozen or thawed bait can be used on longline hooks, and bait fish can have their swim bladders inflated or deflated. These factors and the bait species can affect sinking rates and thus the risk that baited hooks are taken by seabirds. Although there is general agreement that frozen baits will sink more slowly than thawed baits, research into this has not produced very clear results, with one research study suggesting the opposite in the case of frozen squid (Table 3.8). Nevertheless, use of fully thawed baits is included in mitigation requirements in legislation for many fisheries (see Table 3.9).

Table 3.8. Results of trials to test the efficacy of methods to mitigate seabird bycatch in longline fisheries.

	Mitigation measure	Location tested	Metric	Outcome	Reference
General	Offal and discard not discharged	Shetland	numbers of birds attending at vessels	numbers reduced by 70 to 95%	Hudson 1986
	Offal and discard not discharged	North Sea	numbers of birds attending at vessels	numbers reduced by 50 to 90%	Camphuysen *et al*. 1993
	Offal and discard not discharged	New Zealand	seabird bycatch	most important single factor reducing bycatch rate in squid fishery	Bull 2007
	Observer coverage	various	compliance of fishermen with regulations	difficult to assess, but likely to increase	Bull 2007
	Area/seasonal closures	various	bycatch rate	probably reduced where 'hot spots' can be avoided	Bull 2007
Long-lining	Underwater setting devices; Funnel (lining tube)	Norway	birds caught per 1000 hooks	somewhat reduced	Løkkeborg 1998, 2001
	Underwater setting devices; Funnel (lining tube)	Alaska	birds caught per 1000 hooks	somewhat reduced	Melvin *et al*. 2001
	Underwater setting devices; Funnel (lining tube)	S Africa	birds caught per 1000 hooks	somewhat reduced	Ryan and Watkins 2002
	Underwater setting devices; Chute	Hawaii	albatross bycatch rate	reduced by 95%	Gilman *et al*. 2003, 2007
	Underwater setting devices; Chute	Australia	bird bycatch rate	high, despite use of tube	Baker and Robertson 2004
	Underwater setting devices; Capsule	New Zealand	bird activity at vessel	greatly reduced	Smith and Bentley 1997
	Underwater setting devices; Capsule	Australia	bird activity at vessel	greatly reduced	Brothers *et al*. 1999, 2000
	Bait-casting/throwing machine	New Zealand	bird bycatch rate	reduced	Duckworth 1995
	Bait-casting/throwing machine	Australia	bird bycatch rate	reduced	Klaer and Polacheck 1998
	Blue-dyed bait	Hawaii	albatross contact rate	significantly reduced	Boggs 2001
	Blue-dyed bait	S Africa	seabird bycatch	reduced	Minami and Kiyota 2004
	Blue-dyed bait	New Zealand	seabird bycatch	no clear effect	Lydon and Starr 2005
	Blue-dyed bait	Hawaii	bycatch rate	less reduction than from other mitigation measures tested	Gilman *et al*. 2007
	Side-setting	Hawaii	bycatch rate	strongly reduced	Gilman *et al*. 2007
	Night-setting	Mediterranean	bycatch rate	peak at sunrise and before sunset	Belda and Sanchez 2001

Mitigation measure	Location tested	Metric	Outcome	Reference
Night-setting	Kerguelen	birds caught per 1000 hooks	reduced from 0.91 to 0.17	Weimerskirch *et al*. 2000
Night-setting	Falklands	birds caught per 1000 hooks	reduced to 0.00	Sullivan *et al*. 2004
Night-setting	New Zealand	birds caught per 1000 hooks	reduced	Duckworth 1995
Night-setting	Australia	birds caught per 1000 hooks	reduced from 0.25 to 0.02	Klaer and Polacheck 1998
Bird-scaring lines	Chile	birds caught per 1000 hooks	significantly reduced	Ashford and Croxall 1998
Bird-scaring lines	New Zealand	birds caught per 1000 hooks	significantly reduced	Imber 1994, Smith 2001
Bird-scaring lines	Hawaii	birds caught per 1000 hooks	significantly reduced	Boggs 2001
Bird-scaring lines	Australia	birds caught per 1000 hooks	reduced from ca 1.5 to 0.1 in daytime	http://www.afma.gov.au/fisheries/tuna/etbf/publications/observer/aug03/chute040803.pdf
Bird-scaring lines	Australia	birds caught per 1000 hooks	reduced from ca 0.4 to 0.03 at night	http://www.afma.gov.au/fisheries/tuna/etbf/publications/observer/aug03/chute040803.pdf
Bird-scaring lines	Norway	bird behaviour	mostly deterred from area where hooks were within reach	Dunn and Steel 2001
Bird-scaring lines	Norway	birds caught per 1000 hooks	reduced from 1.06 to 0.03	Løkkeborg 2001
Bird-scaring lines (paired lines)	Alaska	birds caught per 1000 hooks	reduced by 88-100%	Melvin 2000
Bird-scaring lines (single line)	Alaska	birds caught per 1000 hooks	reduced by 71-91%	Melvin 2000
Brickle curtain	various	bait stealing by birds	reduced	Brothers *et al*. 1999
Brickle curtain	Falklands	bait stealing by birds	reduced, but birds can habituate	Sullivan 2004
Fish oil	New Zealand	number of dives for bait by seabirds	reduced	Pierre and Norden 2006
Integrated and external line weights	Falklands	line sink rate	increased with weight	Robertson 2000
Integrated and external line weights	New Zealand	line sink rate	increased with weight	Smith 2001
Integrated and external line weights	Hawaii	bird contact rate	reduced by 91-93% with weighted lines	Boggs 2001
Integrated and external line weights	S Georgia	bird bycatch rate	reduced with weight use, but not as a linear function of mass added	Agnew *et al*. 2000
Integrated and external line weights	Alaska	bird bycatch rate	reduced bycatch, relative to no deterrent, but no added effect when bird scaring line used	Melvin *et al*. 2001

Mitigation measure	Location tested	Metric	Outcome	Reference
Integrated and external line weights	New Zealand	bird bycatch rate	reduced by 60-100%	Robertson *et al*. 2006
Line shooter	Norway	bird bycatch rate	reduced, but not statistically significantly	Løkkeborg and Robertson 2002
Line shooter	Alaska	bird bycatch rate	increased significantly, by about 50%	Melvin *et al*. 2001
Bait condition	lab tests	sink rate of fish baits	faster when baits fully thawed	Brothers *et al*. 1995
Bait condition	New Zealand	bird bycatch rate	reduced when baits fully thawed	Brothers *et al*. 1995, Duckworth 1995
Bait condition	New Zealand	sink rate of squid baits	slower when baits fully thawed	Anderson and McArdle 2002
No offal discharge during setting	Hawaii	bait stealing attempts in swordfish fishery	reduced from 76.6 to 29.4 per 1000 hooks	McNamara *et al*. 1999
No offal discharge during setting	Hawaii	bait stealing attempts in tuna fishery	reduced from 10.7 to 4.3 per 1000 hooks	McNamara *et al*. 1999
No offal discharge during setting	Kerguelen	numbers of birds at vessels	numbers reduced by 60 to 90%	Weimerskirch *et al*. 2000
Offal deployed to lure birds from setting side	Kerguelen	bycatch rate	attracting birds to other side of vessel reduced bycatch rate	Cherel *et al*. 1996
Shooting (with shotgun or rifle)	Norway	bird behaviour	some short-term deterrent effect	Dunn and Steel 2001
Water cannon	various	bird activity at vessel	can be reduced slightly and temporarily	reports from fishermen
Deterrent noise generator	various	bird activity at vessel	little or no effect on birds	reports from fishermen

3.6 Regulations covering mitigation of seabird bycatch on longlines

Regulations to reduce seabird bycatch in longline fisheries have been in place for some years in many of the major longline fisheries around the world. In Table 3.9 we briefly outline the key mitigation measures that are mandatory in a variety of fisheries. The examples presented are listed in chronological sequence, starting with the fisheries where bycatch mitigation regulations were first introduced, but giving current details of the required mitigation measures where these have changed over time. Many of these fisheries have modified the mitigation measures in the light of experience and research findings from their own and other fisheries (such as data presented in Table 3.8). Note that most fisheries require a combination of mitigation measures, but especially the use of bird scaring lines when setting baited hooks, which is one of the most consistent and powerful of the many mitigation methods tested (Table 3.8). Note also that the requirement for fully thawed baits, which is mandated in many of the regulations listed in Table 3.9, is based on a clear and widespread understanding that thawed baits sink faster than frozen or partially frozen baits, although research data testing this are in fact rather limited (see above and Table 3.8).

There are a number of fisheries not included in Table 3.9, where new regulations are currently being adopted or have very recently been adopted (e.g. the Falkland

Islands, New Zealand demersal longlines), and also in fisheries where there are as yet no statutory requirements to deploy specific mitigation measures, but where the voluntary use of appropriate mitigation measures by fishermen is encouraged (Norway).

Table 3.9. Details of regulations in place to reduce seabird bycatch in longline fisheries around the world.

Country/Region	Year regulations first established	Fishery	Fishing method	Mitigations required	References
CCAMLR	1992	Patagonian toothfish	Demersal longline	Thawed bait only, weights exceeding 8.5 kg no more than 40 m apart, setting at night only, minimal lighting on vessels, no discharge of offal during setting, offal discharge during haul only from opposite side of vessel, bird scaring line to approved specification, fishing season specified in relation to bird activities, seabird bycatch monitored by observers.	Measures adopted at CCAMLR XIX
New Zealand	1993	Tuna	Pelagic longline	Bird scaring line to CCAMLR standard, scaring line made available to inspection by scientific observers	NZ-MAFF-Commercial Fishing Regulations amended 1993
Australia	1995 (amended 2001)	Tuna	Pelagic longline	Bird scaring line, setting at night, baits must be thawed, no discharge of offal during setting, observer monitoring of bycatch.	Australian Fisheries Management Amendment Regulations 2001
Japan	1997	Tuna	Pelagic longline	Bird scaring line, efforts to be made to release hooked birds unharmed, two or more of (night setting, weighted branch lines, bait casting machines, properly thawed baits) as appropriate in prevailing conditions	NPA Seabird submitted by Japan to FAO - COFI in February 2001
South Africa	1998	Hake	Demersal longline	Bycatch observer must be taken when mandated (15% coverage), bird scaring line to be used during setting, record of seabird bycatch must be kept, setting only at night, lines must be properly weighted, no dumping of offal during setting, no dumping of hooks, lines or plastic except where crew safety is affected, deck lighting minimised consistent with safety.	Marine Living Resources Act 1998 (Act No. 18)
South Africa	1998	Tuna	Pelagic longline	Bycatch observer must be taken when mandated (20% coverage), bird scaring line to be used during setting, record of seabird bycatch must be kept and birds or bird heads returned to shore for inspection and data on bird bands reported, setting only at night, no dumping of offal during setting, no dumping of hooks.	Marine Living Resources Act 1998 (Act No. 18)
USA Alaska	1997, revised 2001	Pacific cod *Gadus macrocephalus*	Demersal longline	Bycatch observers at frequency depending on vessel size (30% of fishing days medium sized vessels, 100% coverage for large vessels), bird scaring line to NOAA Fisheries standard must be deployed during setting, or deploy line underwater through a lining tube, deploy gear at specified hours (based on nautical twilight) with minimal deck lighting consistent with safety.	Federal Register 66: 31561-31565.

Country/Region	Year regulations first established	Fishery	Fishing method	Mitigations required	References
USA Alaska	1998, revised 2001	Pacific halibut *Hippoglossus stenolepis*	Demersal longline	Bird scaring line to NOAA Fisheries standard must be deployed during setting, or deploy line underwater through a lining tube, deploy gear at specified hours (based on nautical twilight) with minimal deck lighting consistent with safety.	Federal Register 66: 31561-31565.
USA Hawaii	2001	Swordfish and Tuna	Pelagic longline	Fishing for swordfish prohibited north of equator (to reduce bycatch of sea turtles), use thawed blue-dyed bait only, discharge offal from opposite side of vessel to where line is set and hauled to attract scavenging seabirds away from line, remove all hooks from offal before discarding, when making shallow sets for swordfish north of 23N set only at night, when making deep sets for tuna north of 23N employ a line setting machine with weighted branch lines (at least 45g on each line within 1 m of the hook).	Federal Register 66: 31561-31565.
				Recommended regulations (not officially implemented)	
ICCAT	2007	Atlantic Tuna	Demersal and pelagic longline	Applies to vessels fishing S to 20°S. All vessels shall carry and use bird-scaring lines (tori poles). Details on the proposed tori-lines and setting are available at Annex I of ICCAT resolution.Vessels are encouraged to use a second tori pole and bird-scaring line at times of high bird abundance or activity; Longline vessels targeting swordfish using monofilament longline gear may be exempted on condition that these vessels set their longlines during the night, with night being defined as the period between nautical dusk/dawn as referenced in the nautical dusk/dawn almanac for the geographical position fished. In addition, these vessels are required to use a minimum swivel weight of 60g placed not more than 3m from the hook to achieve optimum sink rates.	Measures adopted the 2007 ICCAT Commission Meeting (http://www.iccat.int/)
Spain/Med	2002-2006	Tuna, swordfish and related species	Pelagic longline	Applies to vessels operating south of 30ºS, all Spanish vessels at all seas. Setting shall be done preferably between dusk and dawn; vessel external lights must be reduced to those strictly necessary for navigation and fishing purposes. If offal discharge is unavoidable during setting and hauling, it shall be done on opposite side of vessel to that from where setting is done. If seabirds/turtles are caught, they should be freed alive with minimal damage. The use of devices to reduce bycatch will be favoured.	Orden APA/1127/2002, de 13 de mayo. BOE núm. 124, de 23 de mayo de 2002, pág 18429. Orden APA/2521/2006, de 27 de julio, BOE núm. 183, de 2 de agosto de 2006, págs. 28896-28901.

3.7 Measures adopted by CCAMLR as a model of best practice

CCAMLR established the Ad hoc Working Group on Incidental Mortality Arising from Longline Fishing (WG-IMALF) in 1992, and has since then published several regulations and communication materials that aim to eliminate the seabird mortality associated with fishing. The CCAMLR system uses a system of risk assessment for seabirds based on assessing the relative risk of seabird bycatch within sub-areas of the Convention Area (see Table 3.10), and uses information on:

- taxa breeding ranges;
- foraging distributions;
- the number of taxa breeding in the area;
- the proportion of the global population of each taxa breeding in the area;
- the number of taxa foraging in the area;
- at sea sightings data;
- the proportion of each taxon's foraging time in the area (CCAMLR 2005a);
- the IUCN threat status of those taxa;
- qualitative information about bycatch (e.g whether birds of a species are known to be caught in that area, rather than catch-rate information); and
- information adequacy.

Risk ratings under the CCAMLR system of management of fisheries derive from this method are used to define the mitigation requirements for fisheries in each CCAMLR statistical area, via a series of Conservation Measures (CCAMLR 2005b, Appendix 6). Areas with higher risk ratings (levels 4-5) are subject to a broader suite of Conservation Measures than those with lower ratings (levels 1-2).

Table 3.10. Summary data from risk-assessment ratings for the CCAMLR statistical sub-areas in 2005 in relation to numbers of bird breeding taxa, percentages of global breeding numbers, and foraging usage (From CCAMLR 2005a, and BirdLife International 2005).

Area rating	Number of breeding taxa	Proportion world population (max)	Number of taxa foraging	Single taxon foraging time (max)	Multi-taxa average foraging time	Number of sub-areas with this rating
5 (highest)	7 - 11	19 – 80%	3 - 7	11 - 51%	3 – 29%	4
4	1-3	7 - 26%	2 - 7	0.3 – 51%	0.2 – 20%	2
3	0 - 1	0 – 20%	3-6	0 – 16 %	0 – 7%	5
2	0 - 1	Not estimated	2-8	0.3 – 12%	2.4 – 3.8%	4
1(lowest)	0	n.a.	1	0.3 – 5.2%	0.3 – 5.2%	2

The CCAMLR model (CCAMLR 2005a) is still being refined, but it can be seen as a good example on how to indicate high risk areas for seabirds.

3.8 Mitigation measures in use in EU waters

Currently, there is little knowledge of EU countries implementing mitigation measures of seabird bycatch in longline fisheries, either officially or voluntarily. Some sparse information is available.

There is some evidence that fishers in the area around Columbretes Islands, Mediterranean Sea, may be setting lines at night to avoid peak periods of seabird abundance and activity at dawn and dusk (E. Belda, pers. comm.; Dunn 2007). They are apparently doing this voluntarily, after finding that 80% of bait loss due to seabirds occurred at these times (Sánchez and Belda 2003). In another example of attempted bycatch mitigation, some fishers in the same area use a single line without streamers towed behind the vessel to deter birds from taking baited hooks as the longline is set. However, this is considered very ineffective in reducing seabird bycatch (Dunn 2007).

In the North Atlantic (Norway), streamer lines have proven to be an effective measure to reduce accidental catch of seabirds, namely northern fulmars (Løkkeborg 1998; Dunn and Steel 2001). These lines have been in voluntary use in Norwegian fishing grounds since 1992 (Løkkeborg 1998), when the first experiment was conducted, and it seems to be still in use in some Norwegian longline fisheries (Løkkeborg, pers. comm.). Traditionally, Norwegian longliners also used a rudimentary line with no streamers, and some might still do so, even though this is considered to be ineffective. Some Icelandic longline vessels are also believed to use a streamer line (E. Dunn, pers. comm.).

In the Gran Sol area, significant reductions of bycatch were observed when fishermen set lines with the stern lights switched off, an easy measure to apply (Barros 2007, Dunn 2007).

3.9 Seabird bycatch mitigation - concluding remarks

Although there is an abundance of methods to mitigate seabird bycatch on longline fisheries, their utility ultimately relies on their widespread adoption and use. Gilman *et al*. (2005) make the point that few longline fisheries employ mitigation methods; part of this problem must originate from the many unregulated, "pirate" fishers around the world (see Sumalia *et al*. 2006). Factors that affect rates of adoption of bycatch mitigation methods by the fishing industry include the costs and practicability of use, efficacy of the method, which is positively related to fishing efficiency through reduction in bait loss, enforcement and penalties.

Both Bull (2007) and Gilman *et al*. (2005) make the point that no one mitigation method is likely to be successful on its own, but that a combination of methods used simultaneously will be most efficacious. The specific combination that is most effective will depend on factors such as the target fishery, gear used, location and suite of seabird species encountered, and sea conditions, and may need to be fine-tuned on a vessel by vessel basis in order to optimise performance (Bull 2007). Trials of methods and this fine-tuning process will necessarily involve direct participation by the fishers themselves.

In conclusion, the effective mitigation of seabird bycatch needs to be more focused, and founded upon a clear, objective assessment of seabird interactions with various types of fishing activity. Such fishing activity needs to be better characterised within the EU, both through the release and collation of existing data, and the collection of new information where necessary.

3.10 References

Agnew, D. J., Black, A. D., Croxall, J. P. and Parkes, G. B. 2000. Experimental evaluation of the effectiveness of weighting regimes in reducing seabird by-catch in the longline toothfish fishery around South Georgia. CCA-MLR Science, 7: 119–131.

Anderson, S. and McArdle, B. 2002. Sink rate of baited hooks during deployment of a pelagic longline from a New Zealand fishing vessel. New Zealand Journal of Marine and Freshwater Research, 36: 185–195.

Anonymous. 2004. Preliminary results from cruises ECOMED 2003 and ECOMED 2004. Spanish Institute of Oceanography IEO. Internal Report.

Arcos,F., Velando, A. and Moriño, J. 1996. Seabird mortality in fishing gear in Galicia (NW Spain). Poster - Seabird Group Conference, Glasgow.

Arcos, J.M. 2005. Seabird distribution along the Mediterranean Iberian coast in autumn/winter: preliminary results from cruises ECOMED 2003 and ECOMED 2004. Spanish Institute of Oceanography IEO. Internal Report.

Arcos, J.M., Louzao, M. and Oro, D. 2008. Fishery Ecosystem Impacts and Management in the Mediterranean: Seabirds Point of View. pp. 1471-1479. *In*: Reconciling Fisheries with Conservation: Proceedings of the Fourth World Fisheries Congress. American Fisheries Society, Symposium 49. Pages 1471-1479. Ed. by J.L. Nielsen, J.J. Dodson, K. Friedland, T.R. Hamon, N. Hughes, J. Musick, and E. Verspoor. American Fisheries Society, Bethesda, Maryland.

Arcos, J.M. and Oro, D. 2004. Pardela balear, *Puffinus mauretanicus*. *In* Libro Rojo de las Aves de España. Dirección General para la Biodiversidad. Pages 46-50. Ed. by A. Madroño, C. González, and J.C. Atienza. SEO/BirdLife, Madrid.

Álvarez, D. and Velando, A. 2007. El Cormorán moñudo en España y Gibraltar. Población en 2006-2007 y método de censo. SEO/Birdlife, Madrid.

Ashford, J.R. and Croxall, J.P. 1998. An assessment of CCAMLR measures employed to mitigate seabird mortality in longlining operations for *Dissostichus eleginoides* around South Georgia. CCAMLR Science, 5: 217–230.

Baker, B. and Robertson, G. 2004. Negotiating the chicanes on the road to eliminating seabird bycatch: lessons learnt in an Australian pelagic fishery. *In* Abstract Volume, Oral and Poster Presentations from the Third International Albatross and Petrel Conference (IAPC) (Proceedings of the Third International Albatross and Petrel Conference). Pages 59-60. Montevideo, Uruguay.

Barnes, K. N., Ryan, R. G., and Boix-Hinzen, C. 1997. The impact of the hake *Merluccius* spp. longline fishery off South Africa on Procellariiform seabirds. Biological Conservation, 82: 227-234.

Barrett, R.T., Chapdelaine, G., Anker-Nilssen, T., Mosbech, A., Montevecchi, W.A., Reid, J.B., and Veit, R.R. 2006a. Seabird numbers and prey consumption in the North Atlantic. ICES Journal of Marine Science, 63: 1145-1158.

Barrett, R.T., Lorentsen, S.-H. and Anker-Nilssen, T. 2006b. The status of breeding seabirds in mainland Norway. Atlantic Seabirds, 8: 97-126.

Barros, A. 2007. Embarcados en Gran Sol. La Garcilla, 130: 15-17

Belda, E.J. and Sanchez, A. 2001. Seabird mortality on longline fisheries in the Western Mediterranean: factors affecting bycatch and proposed mitigation measures. Biological Conservation, 98: 357-363.

Bermejo, A. and Mouriño, J. 2003. Gaviota Patiamarilla *Larus cachinnans. In* Atlas de las aves reproductoras de España. Pages 272-273. Ed. by R. Martí and J.C. del Moral. DGCN-SEO.

Birdlife International. 2001. Action Plan for the conservation of Mediterranean Shag (*Phalacrocorax aristotelis desmarestii*). Unpublished report.

Birdlife International. 2004a. Birds in Europe; Population estimates, trends and conservation status. Birdlife International, 2004.

BirdLife International. 2004b. Tracking ocean wanderers: the global distribution of albatrosses and petrels. Results from the Global Procellariiform Tracking Workshop, 1–5 September, 2003, Gordon's Bay, South Africa. BirdLife International, Cambridge, UK.

BirdLife International. 2007a. Species factsheets. http://www.birdlife.org.

BirdLife International. 2007b. http://www.birdlifeforums.org/WebX/.2cba5a77.

Boggs, C.H. 2001. Deterring albatrosses from contacting baits during swordfish longline sets. *In* Seabird Bycatch: Trends, Roadblocks and Solutions. Pages 79-94. Ed. by E. Melvin and J.K. Parrish. University of Alaska Sea Grant, Fairbanks, Alaska.

Brothers, N. 1995. Principles of Birdline Construction and Use to Reduce Bait Loss and Bird Deaths During Longline Setting. CCAMLR Working Paper WG-IMALF-94. CCAMLR, Hobart, Australia, 19 pp.

Brothers, N., Foster, A. B. and Robertson, G. 1995. The influence of bait quality on the sink rate of bait used in the Japanese longline tuna fishing industry: an experimental approach. CCAMLR Science, 2: 123–129.

Brothers, N, and Foster, A. 1997. Seabird catch rates: an assessment of causes and solutions in Australia's domestic tuna longline fishery. Marine Ornithology, 25: 37-42.

Brothers, N.P., Cooper, J. and S. Løkkeborg, S. 1999. He incidental catch of seabirds by longline fisheries: worldwide review and technical guidelines for mitigation. FAO Circular 937, FIIT/c937, ISSN 0429-9329.

Brothers, N., Chaffey, D. and Reid, T. 2000. Performance Assessment and Performance Improvement of Two Under- water Line Setting Devices for Avoidance of Seabird Interactions in Pelagic Longline Fisheries. CCAMLR WG-FSA 00/64, Hobart, Australia, 32 pp.

Bull, L. S. 2007. Reducing seabird bycatch in longline, trawl and gillnet fisheries. Fish and Fisheries, 8: 31-56.

Camphuysen, C. J., Ensor, K., Furness, R. W., Garthe, S., Hüppop, O., Leaper, G., Offringa, H. and Tasker, M. L. 1993. Seabirds feeding on discards in winter in the North Sea. NIOZ Rapport 1993-8, Netherlands Institute for Sea Research, Texel. 140pp.

Catry, I. 2002. Distribuição e efectivo das populações reprodutoras de Gaivota-de-patas-amarelas (*Larus cachinnans*) e Corvo-marinho-de-crista (*Phalacrocorax aristotelis*) na costa rochosa continental. Instituto da Conservação da Natureza. Unpublished report.

CCAMLR 2005a. SC-CAMLR XXIV/BG/26. IMAF Risk Assessment of Fisheries by Statistical Area. Ad Hoc Working Group on Incidental Mortality Associated with Fishing.

CCAMLR 2005b. CCAMLR Conservation Measures CM24-02, CM25-02, CM25-03. CCAMLR Secretariat, Hobart.

Cherel, Y., Weimerskirch, H. and Duhamel, G. 1996. Interactions between longline vessels and seabirds in Kerguelen waters and a method to reduce seabird mortality. Biological Conservation, 75: 63–70.

Cooper, J., Baccetti, N., Belda, E.J., Borg, J.J., Oro, D., Papaconstantinou, C. and Sánchez, A. 2003. Seabird mortality from longline fishing in the Mediterranean Sea and Macronesian waters: a review and a way forward. Scientia Marina, 67 (Suppl. 2): 57-64.

Duckworth, K. 1995. Analysis of factors which influence seabird bycatch in the Japanese southern bluefin tuna longline fishery in New Zealand waters, 1989–1993. New Zealand Fisheries Assessment Research Document 95/ 26, 62 pp.

Dunn, E. 2007. The case for a community plan of action for reducing incidental catch of seabirds in longline fisheries. A report from Birdlife International's Global Seabird Programme, Birdlife International, Cambridge, UK. 19 pp.

Dunn, E. and Steel, C. 2001. The impact of longline fishing on seabirds in the north-east Atlantic: recommendations for reducing mortality. Report to RSBP, NOF, JNCC, BirdLife International. 112 pp.

EEC 1979. Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds. Official Journal L103 (25.4.1979).

FAO 1995. Code of conduct for responsible fisheries. FAO, Rome.

FAO 1999. International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries. FAO, Rome.

Fisheries and Oceans Canada 2007. National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries. DFO/2007. ISBN 978-0-662-49883-4

Gilman, E., Boggs, C. and Brothers, N. 2003. Performance assessment of an underwater setting chute to mitigate seabird bycatch in the Hawaii pelagic longline tuna fishery. Ocean and Coastal Management, 46: 985–1010.

Gilman, E., Brothers, N. and Kobayashi, D. 2005. Principles and approaches to abate seabird bycatch in longline fisheries. Fish and Fisheries 6: 35-49.

Gilman, E., Brothers, N. and Kobayash, D.R. 2007. Comparison of three seabird bycatch avoidance methods in Hawaii-based pelagic longline fisheries. Fisheries Science, 73: 208–210

Hata, D.N. 2006. Incidental captures of seabirds in the U.S. Atlantic pelagic longline fishery, 1986-2005. Report to NOAA Fisheries Service, Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, Miami, FL

Hilborn, R. and Mangel, M. 1997. The Ecological Detective, Monographs in Population Biology, Princeton University Press, Princeton.

Hudson, A. V. 1986. The biology of seabirds utilising fishery waste in Shetland. Ph.D. thesis, University of Glasgow.

Imber, M. J. 1994. Report on a Tuna Long-lining Fishing Voyage Aboard Southern Venture to Observe Seabird By- catch Problems. Science and Research Series 65. Department of Conservation, Wellington, 12 pp.

IUCN. 2007. IUCN Red List of Threatened Species. http://www.iucnredlist.org/

Klaer, N. and Polacheck, T. 1998. The influence of environmental factors and mitigation measures on by- catch rates of seabirds by Japanese longline fishing vessels in the Australian region. Emu, 98:305–316.

Laneri K., M. Louzao, M. Martínez-Abraín, A. Arcos, J.M., Guallart, J. Belda, E. Giménez, M., Maestre, R., Sánchez, A. and Oro, D. 2007. Modelling seabird bycatch in the western Mediterranean: implications for their conservation. 6th European Conference on Ecological Modelling, Trieste, Italy, 2007.

Leal, A. and Lecoq, M. 2005. Conservation of the Audouin's Gull in Southern Portugal. SPEA. Unpublished report.

Lewison, R.L. and L.B. Crowder. 2003. Estimating fishery bycatch and effects on a vulnerable seabird population. Ecological Applications, 13: 743-753.

Løkkeborg, S. 1998. Seabird by-catch and bait loss in long-lining using different setting methods. ICES Journal of Marine Science, 55:145–149.

Løkkeborg, S. 2001 Reducing seabird bycatch in longline fisheries by means of bird-scaring lines and underwater setting. *In* Seabird Bycatch: Trends, Roadblocks and Solutions. Pages 33-41. Ed. by E. Melvin and J.K. Parrish. University of Alaska Sea Grant, Fairbanks, Alaska.

Løkkeborg, S. 2003. Review and evaluation of three mitigation measures – bird scaring line, underwater setting, and line shooter – to reduce seabird bycatch in the North Atlantic longline fishery. Fisheries Research, 60: 11-16.

Løkkeborg S. and Robertson, G. 2002. Seabird and longline interactions: effects of a bird scaring streamer line and line shooter on the incidental capture of northern fulmars *Fulmarus glacialis.* Biological Conservation, 106: 359-364.

Louzao, M. and Oro, D. 2004. Resultados preliminares sobre la captura accidental de aves marinas en las Islas Baleares. IMEDEA-Conselleria Medi Ambient (Illes Balears). Technical report.

Lydon, G. and Starr, P. 2005. Effect of Blue Dyed Bait on Incidental Seabird Mortalities and Fish Catch Rates on a Commercial Longliner Fishing Off East Cape, New Zealand. Unpublished Conservation Services Programme Report. Department of Conservation, Wellington, 12 pp.

Martí, R. and del Moral, J.C. (Eds.) 2003. Atlas de las aves reproductoras de España. Ministerio de Medio Ambiente. SEO/BirdLife. Madrid.

McNamara, B., Torre, L. and Kaaialii, G. 1999. Hawaii Longline Seabird Mortality Mitigation Project. U.S. Western Pacific Regional Fishery Management Council, Honolulu, HI, 108 pp.

Melvin, E.F. 2000. Streamer lines to reduce seabird bycatch in longline fisheries. Washington Sea-grant Program. WSG-AS 00-03. Univ. of Washington Board of Regents, Seattle. 2 pp.

Melvin, E., Parrish, J. K., Dietrich, K. S. and Hamel, O. S. 2001. Solutions to Seabird Bycatch in Alaska's Demersal Longline Fisheries. Washington Sea Grant Programme A/ FP7. University of Washington, Seattle, 52 pp.

Minami, H. and Kiyota, M. 2004. Effect of Blue-dyed Bait and Tori-pole Streamer on Reduction of Incidental Take of Seabirds in the Japanese Southern Bluefin Tuna Longline Fisheries. CCSBT-ERS/0402/08 CCSBT, Canberra.

Morais, L., Crisóstomo, P. and Santos, C. 2003. Contagens de aves marinhas nidificantes na Ilha da Berlenga *Larus cachinnans*, *Phalacrocorax aristotelis* e *Uria aalge*. Actualidade e dados históricos. Instituto da Conservação da Natureza, Reserva Natural das Berlengas. Unpublished report.

Morais, L. 2007. Notas sobre a nidificação de *Larus fuscus* na ilha da Berlenga em 1998. Instituto da Conservação da Natureza e da Biodiversidade, Reserva Natural das Berlengas. Unpublished report.

Mouriño, J. and Bermejo, A. 2003. Gaviota Sombría *Larus fuscus. In* Atlas de las aves reproductoras de España. Pages 270-271. Ed. by R. Martí, and J.C. del Moral. DGCN-SEO.

Mouriño, J. and Alcalde, A. 2003. Gaviota tridáctila *Rissa tridactyla. In* Atlas de las aves reproductoras de España. Pages 274-275. Ed. by R. Martí, and J.C. del Moral. DGCN-SEO.

Neves, V.C., Murdoch, N. and Furness, R.W. 2006a. Population Status and Diet of Yellow-legged Gull in the Azores Arquipélago. Life and Marine Sciences, 23A: 59-73.

Norden, W.S. and Pierre, J.P. (2007) Exploiting sensory ecology to reduce seabird bycatch. Emu, 107, 38-43.

Oro D., J.S. Aguilar, J.M. Igual, and M. Louzao. 2003. Modelling demography and extinction risk in the endangered Balearic shearwater. Biological Conservation, 116: 93-102

Palka, D. and Warden, M. 2006. Seabird catch from the NOAA Pelagic Observer Program. Document presented to the Atlantic Marine Bird Conservation Cooperative Workshop. 29 January – 1 February 2006. Northeast Fisheries Science Center, Woods Hole, MA.

Perkins, P.C. and Edwards, E.F. 1996. A mixture model for estimating discarded bycatch from data with many zero observations: tuna discards in the eastern tropical Pacific Ocean. Fishery Bulletin, 94: 330–340

Phillips, R.A., Silk, J.D.R. Croxall, J.P. and Afanasyev, V. 2006. Year-round distribution of white-chinned petrels from South Georgia: Relationships with oceanography and fisheries. Biological Conservation, 129: 336-347.

Phillips, RA, Tuck, G and Small, C. 2007. Assessment of the impact of ICCAT fisheries on seabirds: proposed methodology and framework for discussion. SCRS/2007/030, ICCAT.

Pierre, J. P. and Norden, W. S. 2006. Reducing seabird bycatch in longline fisheries using a natural olfactory deterrent. Biological Conservation, 130: 406–415.

Robertson, G. G. 2000. Effect of line sink rate on albatross mortality in the Patagonian toothfish longline fishery. CCAMLR Science, 7: 133–150.

Robertson, G., McNeill, M., Smith, N., Wienecke, B. C., Candy, S. and Olivier, F. 2006. Fast sinking (integrated weight) longlines reduce mortality of white-chinned petrels (*Procellaria aequinoctialis*) and sooty shearwaters (*Puffinus griseus*) in demersal longline fisheries. Biological Conservation, 132: 458–471.

Ruiz, A. and Martí, R. 2004. La Pardela Balear. SEO/BirdLife-Conselleria de Medi Ambient del Govern de les Illes Balears, Madrid, Spain.

Ryan, P. G. and Watkins, B. P. 2002. Reducing incidental mortality of seabirds with an underwater longline setting funnel. Biological Conservation, 104: 127-131.

Sadoul N. and Pin C. 2007. Mouette mélanocéphale *Larus melanocephalus*. In Riegel J. and les coordinateurs-espèce. Les oiseaux nicheurs rares et menacés en France en 2005 et 2006. Ornithos, 14 (3) : 137-163.

Sánchez, A., Belda, E. J. 2003. Bait loss caused by seabirds on longline fisheries in the northwestern Mediterranean: is night setting an effective mitigation measure? Fisheries Research, 60: 99–106

SC-CAMLR. 1995. Report on the working group on fish stock assessment. In: Report of the Fourteenth Meeting of the Scientific Committee (SC-CAMLR-XIV), Annex 5. CCAMLR, Hobart, Australia, pp. 255–454.

SC-CAMLR. 1998. Report on the working group on fish stock assessment. In: Report of the Seventeenth Meeting of the Scientific Committee (SC-CAMLR-XVII), Annex 5. CCAMLR, Hobart, Australia, pp. 301–495.

Smith, N. W. M. 2001. Longline Sink Rates of an Autoline Vessel, and Notes on Seabird Interactions. Science for Conservation 183. Department of Conservation, Wellington, 32 pp.

Smith, M. and Bentley, N. 1997. Underwater Setting Methods to Minimise the Accidental and Incidental Capture of Seabirds by Surface Longliners: Report on a Prototype Device Developed by MS Engineering. Science for Conservation 67. Department of Conservation, Wellington, 8 pp.

Soczek, M.L. 2006. An analysis of seabird bycatch in New England commercial fisheries. Unpublished MSc Thesis, University of Massachusetts, Boston, MA.

Sullivan, B.J. 2004. Falkland Islands FAO National Plan of Action for reducing incidental catch of seabirds in longline fisheries. Falklands Conservation. 50 pp.

Sullivan, B. J., Reid, T. A., Pompert, J., Enticott, J. W. and Black, A. D. 2004. Seabird mortality associated with Patagonian toothfish (*Dissostichus eleginoides*) longliners in Falkland Island waters. Emu, 104: 317–325.

Sumalia, U.R., Alder, J. and Keith, H. 2006. Global scope and economics of illegal fishing. Marine Policy, 30: 696-703.

Tasker, M.L., Camphuysen, C.J. (Kees), Cooper, J. Garthe, S. Montevecchi, W.A. and Blaber, S.J.M. 2000. The impacts of fishing on marine birds. ICES Journal of Marine Science, 57: 531-547.

Vidal, P. and Fernandez, O. 2004. Puffin cendré *Puffinus diomedea*. *In* Oiseaux marins nicheurs de France métropolitaine (1960-2000). Pages 128-133. Ed. by B. Cadiou, J.-M. Pons and P. Yésou. Editions Biotope, Mèze.

Wetlands International 2006. Waterbird population estimates – Fourth Edition. Wetlands International. Wageningen, The Netherlands, 239 pp.

Weimerskirch, H., Brothers, N. and Jouventin, P. 1997. Population dynamics of Wandering Albatross *Diomedea exulans* and Amsterdam Albatross *D. amsterdamensis* in the Indian Ocean and their relationships with longline fisheries: conservation implications. Biological Conservation, 79: 257-270.

Weimerskirch, H., Capdeville, D. and Duhamel, G. 2000. Factors affecting the number and mortality of seabirds attending trawlers and longliners in the Kerguelen area. Polar Biology, 23: 236-249.

3.11 Appendix: Conservation status of seabird species known to be caught in longline fisheries

	IUCN (GLOBAL)	ETS	SPEC	EU BIRDS DIRECTIVE	OSPAR
Northern fulmar		S	–		
Great shearwater		NE	NE		
Sooty shearwater	NT	NE	1		
Balearic shearwater	CR	CR	1	Annex I	pending inclusion
Cory's shearwater (*Calonectris d. diomedea*)		(VU)	2	Annex I	
Yelkouan shearwater		S	–[E]	Annex I	
European shag (*Phalacrocorax aristotelis desmarestii*)		(S)	–[E]	Annex I	
Great cormorant		S	–		
Northern gannet		S	–[E]		
Great skua		S	–[E]	Annex I	
Lesser black-backed gull		S	–[E]		
Great black-backed gull		S	–[E]		
Audouin's gull	NT	L	1	Annex I	
Black-headed gull		(S)	–[E]		
Mediterranean gull		S	–[E]	Annex I	
Yellow-legged gull		S	–[E]		
Black-legged kittiwake		(S)	–		yes
Sandwich tern		H	2		
Black tern		(H)	3		

Key: IUCN (global): EX – Extinct, CR - Critically Endangered, EN – Endangered, VU – Vulnerable, NT - Near Threatened, LC - Least Concern, DD - Data Deficient, NE - Not Evaluated; European Threat Status (ETS, BirdLife International 2004): CR - Critically Endangered, EN – Endangered, VU – Vulnerable, D – Declining, R – Rare, H - Depleted (recent decline, not recovered), L – Localised, S – Secure, DD - Data Deficient, NE - Not Evaluated; SPEC (Species of European Concern) Category: SPEC 1 (1) - Global conservation concern, SPEC 2 (2) - Global population concentrated in Europe, where it faces unfavourable conservation status, SPEC 3 (3) - Global population not concentrated in Europe, but unfavourable conservation status in Europe, Non-SPEC[E] (–[E]) - Global population concentrated in Europe, where it faces favourable conservation status, Non-SPEC (–) - Global population not concentrated in Europe; favourable conservation status in Europe.

4 Priorities for research on and monitoring in longline fisheries in European Union waters

Notwithstanding the paucity of data on bycatch rates and fishing effort, Chapter 3 of this report clearly indicates that there is an incidental take of seabirds in commercial longline fisheries operating in European Union waters. In some cases, this bycatch may be significant in the context of regional populations, especially in the Mediterranean. However, the FAO criteria for the formulation of NPOA-Seabirds do not make this contingent on quantifiable population effects having been demonstrated; if bycatch occurs then member states of the FAO should establish a NPOA-Seabirds. Moreover, the fact that fishing effort data have not significantly informed the issue of population effects might strengthen the case for urgent establishment of an action plan

Consequently, WGSE recommends that the European Union formulates and implements a Community Plan of Action for the mitigation of seabird bycatch in longline fisheries in its waters.

The following recommendations are informed by consideration of the issues outlined in Chapter 3 of this report, and also by examination of the recently developed draft framework for an assessment of the impact of longline fisheries on seabirds in the ICCAT region, and related papers submitted to the ICCAT Sub-Committee on Ecosystems (Phillips *et al*. 2007a,b; Phillips and Small 2007). These ICCAT approaches have in turn been informed by best practice in, for example, the CCAMLR region, as well as the guidance on assessment in the FAO IPOA-Seabirds. These recommendations should be addressed within the context of a Community POA; that is, they are envisaged to be components of a Community POA and not precursors to the formulation of a Community POA.

4.1 Standardised data collection protocol and modus operandi

The European Commission should give priority to putting in place the means of achieving the objectives outlined herein in a coherent, harmonised and best-practice manner across EU waters and fleets. In this regard, it should develop a standardised procedure for data collection across longline fisheries in EU waters, including observer and other protocols, questionnaires for fishermen, bycatch assessment, and mitigation monitoring. This procedure should recognise the commonalities but also be able to address regional differences in longline fishing patterns, gears, target and species.

Overall, the main priorities, following best practice standards from elsewhere, are to:

- Establish an independent observer programme for longline vessels;
- Complement the observer scheme with interviews of fishermen;
- Implement and test mitigation measures; and
- Assess the actual fishing effort of both EU and non-EU fleet fishing within EU waters.

4.1.1 Observer programme

A priority first step for assessment within a Community POA is to quantify the bycatch problem through independent observers in order to understand how, when and where seabirds are caught. WGSE recommends starting with a broad on-board observer scheme covering a wide range of longline fleets.

The Spanish longline fleets serve to indicate what to take into account in trying to achieve representative deployment of observers across different metiers. Those Spanish vessels targeting smaller fish, particularly demersal species (hake and others) and medium-sized species (especially bonito tuna *Sarda sarda*) seem to pose the greatest risk to seabirds. Longline vessels targeting large pelagic species such as adult tuna and swordfish set lines with relatively large hooks and bait, and appear to cause less seabird bycatch. However, the observer scheme needs to be sufficiently representative of different target fish and gears to establish the nature and extent of such differences.

This, in turn, has important implications for levels of observer coverage. Two criteria are recognised: the percentage of baited hooks observed being set by the vessel, and the percentage of vessels carrying an observer. Experience of regulated longline fisheries in other parts of the world indicates that observing at least 10% of hooks set will enable detection of whether a bycatch problem exists, and also enable detection of sea areas where more data are needed. But once a problem is detected, observers are required on at least 20–30% of vessels in order to monitor seabird bycatch accurately.

Using sampling theory based on tropical pelagic longline fisheries, Lawson (2004, 2006) deduced that in order to obtain a bycatch estimate with a coefficient of variation less than 10% (which is equivalent to estimating a 95% confidence limit +/- 20%), 100% observer coverage is needed for species such as seabirds, turtles and marine mammals. However, if cost is an issue, then there are diminishing returns (in terms of improved accuracy of bycatch estimate) above 20-30% coverage. In CCAMLR, all vessels are required to carry an independent observer, trained to monitor seabird bycatch, as a licence condition for entering the fishery.

Observers need to be trained to collect data in a systematic, statistically robust way - for which there are tried-and-tested, peer-reviewed protocols developed from other studies on seabird bycatch in longline fisheries around the world. Observers need to have expertise in bird identification and seabird behaviour in relation to line-setting - it is not adequate to appoint observers who are principally fish experts with no skills in monitoring seabird bycatch and seabird behaviour around longlines.

Seabird observers must impart the skills of identifying birds to fishermen to enable these to assist in data collection and accurate reporting. This exercise should also incorporate a strong element of awareness-raising about the seriousness of the seabird bycatch problem and the rationale for tackling it on deck.

Where relevant to the fishery, emphasis should be put on conservation-fisheries 'win-win' of implementing mitigation measures, i.e. by highlighting the potential economic gains (in terms of reduced bait loss and increased fish catch).

From their monitoring activity, observers need to gain a greater understanding of the problem, sufficient to lead to the development and implementation of effective mitigation measures. It is important that arrangements are therefore put in place to capture and process this knowledge and its interpretation (see below). It is also important to develop modelling approaches that allow more robust estimates of seabird bycatch, given the highly skewed distributions of bycatch data, with many zeroes (K. Laneri and M. Louzao, pers. comm.).

4.1.2 Outreach to fishermen

In addition to observer data, it is important to systematically engage with fishermen (on land or at sea), for example through interviews, to gain the benefit of their knowledge and ideas about (a) incidental mortality of seabirds in relation to their fishing activities, and (b) how they go about (or might go about) avoiding bycatch. Interviews should be designed very carefully to optimise results. Information should also be sought on any mitigation measures that have been tried, successfully or not, in the past, and the fishermen's attitudes to them.

Interviews can be very useful where bycatch occurs irregularly, ranging often from zero to occasionally large numbers entangled in a single line. For example, SEO/BirdLife has recorded 'one-off' events of up to 100+ Balearic shearwaters caught on longlines of coastal (artisanal) Spanish vessels, probably caused by the line being set close to a flock sitting on the sea surface.

The requirement for active engagement, outreach and education with fishermen is perhaps most acute in artisanal fisheries. Here, the cultural change necessary to effect changes in fishers' behaviour and attitudes must be achieved outside the more rigorous management measures that might be imposed in larger fisheries

4.1.3 Applying appropriate mitigation measures

The actual implementation and field testing of mitigation measures should receive most attention in a later phase, once the problem has been assessed and quantified. Typically, a suite of mitigation measures, tailored to the particular characteristics of the longline fishery in question and the seabird assemblage at risk, is needed to achieve effective reduction of seabird bycatch.

From the outset of the observer scheme, however, observers - in association with the fishermen and their first-hand knowledge at sea - need to feed back into the process of arriving at an appropriate suite of mitigation measures. These need to both address the bycatch problem effectively and be operationally tractable for the fishermen (and thus likely to meet with their compliance, even when no observers are present to monitor their activities). Fishers also need to be offered on-board expert instruction on the practical implementation of mitigation measures to facilitate their routine use at sea.

4.1.4 Assess the actual fishing effort of both EU and non-EU fleet fishing within the EU waters

Information on the actual longline fishing effort is required for both EU and non-EU vessels. In order to relate the fishing effort to the by-catch rate for seabirds, an estimation of the number of sets and hooks per set should be available from each vessel. This should be the major tool that helps determine the level of impact on seabird populations. To date, only vessels targeting some commercial species (such as tuna) are requested to report their fishing effort and to implement some mitigation measures. It is necessary that all vessels comply with these requirements, and that EU Member States collate the data and make it accessible in a systematic, transparent way.

4.1.5 Licensing

WGSE notes that the issuing of licences only to longline fishing vessels that meet minimum standards for seabird bycatch mitigation has been a powerful tool in management of the seabird bycatch problem in a number of fisheries in other parts of the world. Such an approach can ensure that there is a strong incentive to fishermen to comply with seabird bycatch mitigation requirements, from the level of vessel design (e.g. vessel design to provide the ability to deploy lines through the hull) through to behaviour of fishermen, including a requirement to collect appropriate data.

4.2 The Mediterranean – a high-risk, data-poor region for seabird bycatch

In EU waters, the impact of longline fisheries on seabirds in the Mediterranean is of special concern. The need for much better data on the Mediterranean is considered a priority, given:

- the relatively small seabird population numbers in the region compared with those in the NE Atlantic. In many cases, endemic taxa are involved, either species (Balearic and Yelkouan shearwaters, Audouin's gull) or subspecies (Mediterranean/Scopoli's Cory's shearwater, Mediterranean European storm-petrel, Mediterranean shag);
- the demonstrable threat to Cory's, Balearic and Yelkouan shearwaters;
- the complexity of fleet flags operating;
- the mix of target fish species and of demersal, pelagic and surface longline methods;
- the high prevalence of small-scale longline fishing, such that fleet capacity includes numerous artisanal vessels; and
- the paucity of information on the activities of these.

To reiterate, the situation in the Mediterranean gives great cause for concern because of the significant presence of longline vessels belonging to both EU longline fleets and also those from outside the European Union (see section 3.4.2.2 above); little information on fishing effort and seabird bycatch is available from these.

4.2.1 Studies on seabird bycatch rates in the Mediterranean

It is of high priority for the Mediterranean region that more information about the impact of longline fisheries on seabird species is gathered, especially on which species are caught by which fleets/gears, and on bycatch rates in relation to fishing effort.

More work also needs to be done to collate (spatial and temporal) data on at-sea distribution of seabirds. This is a long-term objective and should not be regarded as a *sine qua non* for developing a NPOA-Seabirds in the short term for EU waters, although such information is ultimately necessary to inform analyses of the spatial and temporal overlap between species distribution and the fishing effort of EU longline fleets.

4.2.2 Studies on fishing effort

Resource constraints could mean that derivation of bycatch rates in the Mediterranean (and in other EU waters where data are few) is going to be restricted to few vessels, with further constraints likely on spatial and temporal representativity. Limited as they are, bycatch rates for a given species need to be extrapolated to the total fleet activity in order to assess the likely impact of the bycatch on seabird species and to help establish the overall effect on the status of their populations. In this regard, our knowledge of the fishing activity of EU longline fleet in the Mediterranean is currently wholly inadequate and the sourcing and acquisition of effort data from EU Member States for analysis is a high priority. The need for such proper assessment of fishing operations in the context of seabird bycatch should be regarded as a cost of doing business.

4.3 References

Cooper, J., Baccetti, N., Belda, E.J., Borg, J.J., Oro, D., Papaconstantinou, C. and Sánchez, A. 2003. Seabird mortality from longline fishing in the Mediterranean Sea and Macronesian waters: a review and a way forward. Scientia Marina, 67 (Suppl. 2): 57-64.

Lawson, T 2004. Observer coverage rates and reliability of CPUE estimates for offshore longliners in tropical waters of the western and central Pacific Ocean. SCTB17-SWG-4, Pp 1-13. 17th Meeting of the Standing Committee on Tuna and Billfish.

Lawson, T 2006. Scientific aspects of observer programmes for tuna fisheries in the western and central Pacific. WCPFC-SC2-2006/ST WP-1, Pp 1-28. Western and Central Pacific Fisheries Commission.

Phillips, R.A., Small, C. and Howgate, E. 2007a. Studies of distribution, population dynamics and bycatch rates of seabirds in the Atlantic. SCRS/2007/029/updated, paper to ICCAT Ecosystems Sub-Committee.

Phillips, R.A., Tuck, G. and Small, C. 2007b. Assessment of the impact of ICCAT fisheries on seabirds: proposed methodology and framework for discussion. SCRS/2007/030, paper to ICCAT Ecosystems Sub-Committee.

Phillips, R.A. and Small, C. 2007. Results of the preliminary risk prioritization exercise for the ICCAT seabird assessment: updated. SCRS/2007/129, paper to ICCAT Ecosystems Sub-Committee.

5 Seabird bycatch in fisheries other than longlining

In addition to bycatch in longline fisheries, large numbers of seabirds and other top predators are caught in other types of fisheries where sea areas offer good feeding resources for both humans and seabirds (e.g. Davoren 2007; Karpouzi *et al*. 2007). As Tasker *et al*. (2000) highlight, virtually all types of fishing gear may catch seabirds. Bycatch of birds in trawled, fixed or even lost fishing gear occurs worldwide (Tasker *et al*. 2000; Bull 2007; Žydelis in prep.). However, the effects on bird populations are largely unknown. The scale of the bycatch varies with many factors, including time and location of fishing, fishing method, behaviour of the target species, nature and abundance of seabird prey, and demography of the seabird populations. Only a brief overview of the numbers of birds and the species mainly affected in fisheries other than longlining is presented here.

5.1 Species and numbers of birds caught in non-longline fisheries

5.1.1 Baltic Sea

There are relatively few large boats using gillnets in the Baltic Sea, but there is a large number of small boats fishing shallow, coastal waters of every country in the region, most prominently in the Baltic Sea (Žydelis in prep.).

In the Baltic, seaduck such as common eider, common scoter, divers, grebes, and auks are caught and killed mostly in fixed nets. Also, Steller's eider, classified as Vulnerable in the by IUCN (IUCN 2007) and greatly decreasing in numbers, is affected (Žydelis *et al*. 2006b) Substantial mortality of some species occurs locally; for example, an estimated 16 000 long-tailed duck and velvet scoter die annually in fixed-net fisheries for flatfish and cod in the Gulf of Gdańsk, Poland (about 10–20% of the wintering populations combined). Meissner (2001) noted that drowning in nets was the commonest source of mortality of birds on the Polish coast, and some 14 000 ducks, chiefly common eider and common scoter, were killed annually in the same type of fisheries along the east coast of Schleswig-Holstein, representing up to 17% of the maximum winter population (Žydelis in prep.). In beached bird surveys in Lithuania, Žydelis *et al*. (2006a) recorded a significant increase in the proportion of birds discovered as gillnet victims from the early 1990s onwards (Figure 5.1). Estimates for the annual proportion of greater scaup caught in European gillnets range between 2% and >10% with an overall mean of 5.2% of the flyway population size (Žydelis in prep.).

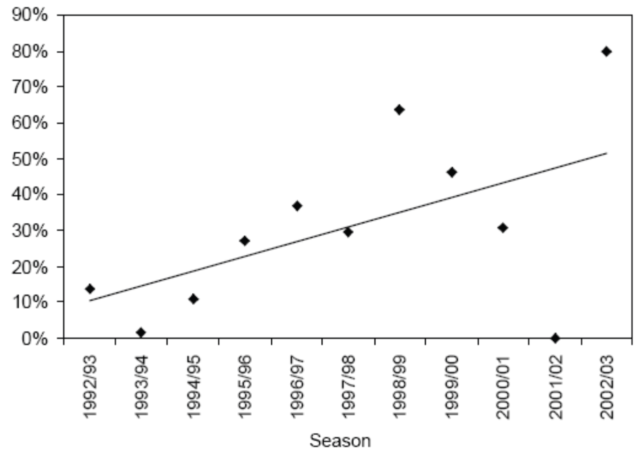


Figure 5.1: The percentage of beached birds identified as bycatch victims of gillnetting on the Lithuanian coast of the Baltic Sea during winters 1992/93–2002/03 (from Žydelis *et al*. 2006a).

5.1.2 North Sea and adjacent waters

There is less information available on bird bycatch in the coastal fisheries in the North Sea compared with the Baltic. Existing studies, however, suggest that the most frequently affected birds are auks, especially the common guillemot. The degree of bycatch in the region varies. It is assumed not to be significant around Britain and Ireland; here, impacts of seabird bycatch tend to be localized. Gillnets set in late winter in Cornwall, have taken an annual bycatch of hundreds of razorbills and common guillemots, possibly reaching 1000, although the birds probably derive from a wide catchment area, diluting any possible population effect. Studies around Wales and Scotland found no evidence of widespread impact, with the exception of sites where nets were set immediately beside colonies (Tasker *et al*. 2000).

An extremely high common guillemot bycatch in Norway is considered to be responsible for large declines in some colonies. Ringed bird recoveries also suggest that fisheries bycatch is a substantial and increasing source of bird mortality in the North Sea (Žydelis in prep.). Gillnets set for cod off northern Norway killed very large numbers of Brunnich's and common guillemots between 1965 and 1985. In early spring 1985, the estimated kill of both species combined exceeded 100 000 birds. In the same area, summer driftnet fisheries for salmon drowned thousands of local breeding birds; numbers of common guillemot in the colony at Hjelmsøy declined from 220 000 in 1965 to 10 000 by 1985, and Brunnich's guillemot declined from >2000 to 220 individuals. The fishery has been closed since 1989 to conserve salmon stocks (Tasker *et al*. 2000).

Bycatch mortality has also been studied in large, artificial coastal lakes in the Netherlands (IJsselmeer and Markermeer): Žydelis (in prep.) quotes an estimate of at least 50 000 waterbirds drowned in gillnets each year during the 1980s and 1990s. Species where more than 5% of their local numbers were annually trapped in the nets were red-breasted merganser, tufted duck, greater scaup, common pochard, common goldeneye, smew, and goosander. A more recent study, conducted using on-board observers in 2002–2003, suggested somewhat lower mortality between 10 000 and 15 000 birds per year; however sampling effort was less intensive than that of earlier study (Žydelis in prep.).

5.1.3 Northwest Spain (ICES Region IX)

Mortality in gillnets has also been reported from northwest Spain. This mainly affects European shags (ca. 3000 birds thought to be caught in Galicia annually) and auks (ca. 2000 birds per year) (Arcos *et al*. 1996). The Iberian population of common guillemot declined from about 20 000 pairs in the first half of the 20th century to fewer than 10 pairs at the end of that century. The main reason for this appears to be mortality caused by synthetic fishing nets when these were introduced in the 1960s (Munilla *et al*. 2007).

5.1.4 Mediterranean Sea

In the Mediterranean, there is very little information about seabird bycatch by fisheries other than longlining. However, the available information available suggests that gillnets and other bottom gear could pose a threat to some specie, particularly the Mediterranean subspecies of the European shag. Louzao and Oro (2004) conducted questionnaire study of seabird bycatch on several fishing gears from the Balearic Islands, based on, and almost 60% of bycatch was due to nets. In Greece, up to 500 Yelkouan shearwaters were recently reported to have been caught in a single drift net (Mom/The Hellenic Society for the Study and Protection of the Monk Seal, 2008 unpublished data), thus highlighting the threat that this type of gear could pose to shearwaters.

5.1.5 Other areas

5.1.5.1 North Atlantic

On the east coast of Canada, gillnets are set in surface waters for salmon and in deeper waters for cod up to 100 km or more from the coast. Pursuit-diving alcids such as common guillemots and Atlantic puffins are the the most vulnerable to entrapment in gillnets and other fixed gear. Brunnich's guillemots, black guillemots, razorbills, great shearwaters, sooty shearwaters, and northern gannets are also drowned. Annual mortality in Witless Bay (Newfoundland) was estimated at 13–20% (around 20 000–30 000 guillemots) of the local breeding population in the early 1970s, falling to about 3–4% by the 1980s. By contrast, only 0.25–1.6% of the much larger local breeding population of Atlantic puffins were caught in fixed gear. Approximately 12% of Newfoundland's razorbill population was killed annually between 1981 and 1984, plus 2% of the western Atlantic gannet population. Offshore gillnets set during summer, autumn, and winter also drowned non-breeding seabirds, including little auks. With the closure of the fisheries and the according complete removal of fixed gears in the 1990s, populations of seabirds have increased (Tasker *et al*. 2000).

Total numbers of incidentally caught seabirds in gillnets in nearshore and offshore Newfoundland waters were estimated for the years 2001, 2002 and 2003 by Benjamin *et al*. (in prep.). The most commonly captured seabirds were guillemots, and shearwaters, although other species were also captured in smaller numbers. As many as 2000–7000 guillemots, more than 2000 shearwaters, and tens to hundreds of northern fulmars, northern gannets, double-crested cormorants, divers, eiders, razorbills, Atlantic puffins, black guillemots, and little auks were estimated to have been captured annually in the area during 2001–2003, although catches varied considerably from year to year. Davoren (2007) estimated that the gillnet fishery for cod on the northeast coast of Newfoundland during July and August 2000–2003 certainly drowns 1936–4973 guillemots annually (0.2-0.6% of the breeding population), but the actual mortality could be as much as 3053–14054 birds per year (0.4–1.7% of the breeding population).

High bycatches of migrant Brunnich's guillemots during autumn were reported from a driftnet fishery for Atlantic salmon off western Greenland during the 1960s and 1970s. Bycatches were shown to be fairly variable over space and time, and exceptionally high catches were considered to result from feeding convergences of guillemots and salmon on capelin (Tasker *et al*. 2000).

Palka and Warden (2007) collated data of bird bycatch for different types of fisheries for US Northwest Atlantic waters (north of South Carolina) for the period 1989–2006. In gillnet fishing, 2715 victims were registered, shearwaters, divers and cormorants being the mostly affected groups (51.3%, .19.2% and 15.2% of all birds, respectively).

5.1.5.2 South Atlantic

Sullivan *et al*. (2006) estimated that more than 1500 seabirds, predominantly black-browed albatross, classified as Endangered (IUCN 2007), 12 southern royal albatross (Vulnerable), and nine white-chinned petrels (Vulnerable), were killed by finfish trawlers operating off the Falkland Islands during 2002/2003. Significant levels of mortality were also recorded on the Patagonian Shelf, north of the islands. Birds were killed after being dragged underwater by the warp cable while feeding on factory discharge at the stern of the vessel. Sullivan *et al*. (2006) conclude that the incidence of mortality caused by the many large trawling fleets around the world that discharge factory waste and attract large bodied seabirds (e.g. albatross and large petrels) requires immediate investigation.

González-Zevallos *et al*. (2007) studied the interaction between seabirds and warp cables in the high-seas Argentine hake *Merluccius hubbsi* trawl fishery operating in Golfo San Jorge, Argentina. Thirteen seabird species exploited food made available by fishing operations. The most frequent seabirds (% occurrence, mean maximum number per haul) were kelp gull (98.1%, 348.5) and black-browed albatross (96.1%, 132.2). A total of 53 individuals of several species were killed through interactions with nets and cables, resulting in a total cable mortality rate of 0.14 birds per haul. Considering the fishery's fishing effort, the estimated total number of birds killed during the study was 2703, of which 306 were killed due to contacts with warp cables (255 kelp gulls and 51 black-browed albatross).

5.1.5.3 North Pacific

Before the 1992 moratorium on high seas drift netting, some 500 000 birds were drowned annually in this type of fishery in the North Pacific. Most of these were sooty shearwaters and short-tailed shearwaters which bred in the southern hemisphere. Two main fisheries were involved, one for salmon (between 60 000 and 137 000 km of net set per year) and one for squid (an estimated 2.85 million km of net set per year). The formerly abundant shearwater populations declined in the early

1990s with significant reductions in numbers recorded at sea off California. Mortality of black-footed albatross amounted to about 2% of the world population *per annum*. Nets killed ca. 8% of marbled murrelet autumn populations in Barkley Sound, British Columbia. Off Japan, 1650 ancient murrelets were found drowned in inshore nets in 1990. Further offshore, bycatch of Japanese murrelets was recorded in the Korean squid fishery, considered to represent 1.5–15.2% of the breeding population of this endangered species. Takekawa *et al*. (1990) noted a decline of more than 50% in common guillemot numbers in central California over 4–6 years in the early 1980s, whereas the adjacent population of northern California remained relatively unchanged. The decline in the former was caused primarily by the rapid growth of an intensive nearshore gillnet fishery, combined with a switch from twine to monofilament nets, and compounded by mortality from oil spills and a severe El Niño event (Tasker *et al*. 2000). In the salmon gillnet fishery in Prince William Sound (Alaska), Wynne *et al*. 1991, cited in Bull 2007) estimated that 1486 seabirds were killed in nets in 1990.

5.2 Mitigation measures to reduce seabird bycatch in fisheries other than longlining

Recently, Bull (2007) assessed mitigation methods to reduce and avoid seabird bycatch in terms of their ability to reduce bycatch rates and their economic viability for longline, trawl and gillnet fisheries worldwide. Factors influencing the appropriateness and effectiveness of a mitigation device include the fishery, vessel, location, seabird assemblage present and season of year. Seabirds interact differently with fisheries depending on the type of fishery and the gear used. As yet, there is no single solution to reduce or eliminate seabird bycatch across all fisheries - a combination of measures is required, and even within a fishery there is likely to be refinement of techniques by individual vessels in order to maximize their effectiveness at reducing seabird bycatch. Urgent investigation is needed into more effective measures at reducing seabird interactions namely with trawl nets and gillnets. Clearly, a mitigation method that reduces bycatch to non-significant levels is of little value if for some reason (e.g. crew safety, unpractical) it is not readily used by fishers. Those mitigation methods that are likely to be adopted by the fishing industry are those which provide operational benefits, do not increase safety hazards to crew, and do not decrease fishing efficiency (e.g. Melvin *et al*. 1999). All these factors must therefore be considered when designing a mitigation protocol (Bull 2007). Besides general considerations such as managing offal and discards through retention or strategic dumping or closing of fishing for a specific season or period, special mitigation measures should be used in trawl and gillnet fisheries.

5.2.1 Trawl fisheries

In trawl fisheries, seabirds often collide with the net monitoring (net sonde) cable and the trawl warps, or birds become tangled in the net (while attempting to feed) when it is at the surface during setting and hauling. Relatively few published studies report on methods to reduce seabird bycatch in trawl fisheries. As such, the recommendations and discussion are based on relatively recent observations (some anecdotal), pilot tests, and trials undertaken in the Falkland Islands, Bering Sea, South Georgia and Australian trawl fisheries (Bull 2007). The results of Bull's (2007) review indicate that a combination of absence of a net monitoring cable (for example by using hull-mounted acoustic net monitors), paired bird-scaring lines (for details see Sullivan *et al*. 2004), retention of offal during fishing operations (especially during setting and hauling), and reducing the time the net is on (or near) the surface, are likely to be the most effective regime at this point in time to mitigate seabird bycatch in trawl fisheries.

González-Zevallos *et al*. (2007) tested a device in the Argentine hake trawl fishery consisting of a plastic cone attached to each warp cable. In hauls with this mitigation device, the number of contacts with warp cables was reduced by 89% and no seabirds were killed. Mean distances between seabirds and cables were significantly greater in hauls with than without a mitigation device (2.6m vs. 0.9m). The proposed device could be easily applied in this and other trawl fisheries.

5.2.2 Gillnet fisheries

In gillnet fisheries, seabirds are most often caught in the nets when diving for prey (Kirchhoff 1982, Melvin *et al*. 1999, Bull 2007). Most studies that have investigated mitigation methods for gillnetting have focused on the impact of this fishery on marine mammals, with little work on seabirds.

Melvin *et al*. (1999) examined several strategies to reduce seabird bycatch, primarily of common guillemots and rhinoceros auklets, in a coastal salmon drift gillnet fishery in Puget Sound, Washington (USA). Their goal was a significant reduction in seabird bycatch without a concomitant reduction in target catch or an increase in the bycatch of any other species. They compared fish catch and seabird bycatch in nets modified to include visual alerts (highly visible netting in the upper net) or acoustic alerts (pingers), with traditional monofilament nets set throughout the normal fishing hours over a 5 week fishing season. Catch and bycatch varied significantly as a function of gear. The results of the study identify three complementary tools to reduce seabird bycatch in the Puget Sound drift gillnet fishery - gear modifications, abundance-based fishery openings, and time of day restrictions - for a possible reduction in seabird bycatch of up to 70–75% with no significant reduction in target fishing efficiency. Although these tools are based on local conditions and will therefore vary among years and locations, all might be exportable to other coastal gillnet fisheries worldwide.

Trippel *et al*. (2003) infused nylon nets with barium sulphate or other metal compounds that have acoustical detection features for reducing small cetacean bycatch. Experimental results show that they can be effective in reducing the bycatch of both, Harbour Porpoise *Phocoena phocoena* and great shearwater, though it has not been ascertained if this is because of their acoustic reflectivity, increased stiffness, or greater visibility over conventional gillnets. Some Newfoundland inshore fishers are of the opinion that white monofilament gillnets do not catch as many guillemots and puffins as those dyed olive green or blue; white nets may increase their visibility to birds. Anecdotal information suggests that white nets do not affect fish catch rates (J.W. Chardine pers. comm.).

Mentjes and Gabriel (1999) conclude for gillnet fishing in the western Baltic Sea that it is obviously impossible to reduce the local and temporal bycatch problem by means of different gillnet constructions or by tactical measurements. Only the temporary avoidance of fishing grounds that host large numbers of ducks, or the change to longlining as the catch method may be an effective solution. Clearly, however, the latter solution might have significant consequences for seabird species that are vulnerable to being caught on longlines.

5.3 References

Arcos,F., Velando, A. and Moriño, J. 1996. Seabird mortality in fishing gear in Galicia (NW Spain). Poster - Seabird Group Conference, Glasgow.

Benjamins, S, Kulka, D.W., and Lawson, J. (in prep.): Incidental catch of seabirds in Newfoundland and Labrador gillnet fisheries, 2001-2003.

Bull, LS .2007. Reducing seabird bycatch in longline, trawl and gillnet fisheries. Fish and Fisherie,s 8: 31–56.

Davoren, G.K. 2007. Effects of gill-net fishing on marine birds in a biological hotspot in the northwest Atlantic. Conservation Biology, 21: 1032-1045.

González-Zevallos, D., Yorio, P. and Caille, G. 2007. Seabird mortality at trawler warp cables and a proposed mitigation measure: A case of study in Golfo San Jorge, Patagonia, Argentina. Biological Conservation, 136: 108-116

IUCN. 2007. IUCN Red List of Threatened Species. http://www.iucnredlist.org/

Karpouzi, V.S., Watson, R., Pauly, D. 2007. Modelling and mapping resource overlap between seabirds and fisheries on a global scale: a preliminary assessment. Marine Ecology Progress Series, 343: 87-99.

Kirchhoff, K. 1982. Wasservogelverluste durch die Fischerei an der schleswig-holsteinischen Ostseeküste. Vogelwelt, 103: 81-89.

Louzao, M. and Oro, D. 2004. Resultados preliminares sobre la captura accidental de aves marinas en las Islas Baleares. IMEDEA-Conselleria Medi Ambient (Illes Balears). Technical report.

Meissner, W., Staszewski, A. and Ziółkowski, M. 2001. Mortality of waterfowl on the Polish Baltic seashore in the 1998/1999 season. Notatki Ornitologiczne, 42:56–62.

Melvin, E.F., Parrish, J.K. and Conquest, L.L. 1999. Novel tools to reduce seabird bycatch in coastal gillnet fisheries. Conservation Biology, 13: 1386–1397.

Mentjes, T. and Gabriel, O. 1999. Fangtechnische Möglichkeiten zur Reduzierung des Beifangs von Meeresenten in der Dorschfischerei mit stationären Fanggeräten (Technical possibilities to reduce duck bycatches in winter cod fishery with static gear). Informationen für die Fischwirtschaft aus der Fischereiforschung 46:36–41.

Munilla, I., Díez, C. and Velando, A. 2007. Are edge bird populations doomed to extinction? A retrospective analysis of the common guillemot collapse in Iberia. Biological Conservation, 137: 359-371.

Palka, D. and Warden, M. 2007. Numbers of seabirds observed interacting with fishing gear in the US Northwest Atlantic waters (north of South Carolina) in the period from the first year gear type was observed throuh Julky 2006. Unpublished Report for Bycatch breakout group of the Atlantic Bird Conservation Cooperative Workshop, 11 pp.

Sullivan, B.J., Brickle, P., Reid, T.A., Bone, D.G., and Middleton, D.A.J. 2004. Trials to test mitigate devices to reduce seabird mortality caused by warp cable strike on factory trawlers. CCAMLR WG-FSA 04/79. CCAMLR, Hobart, Australia, 21 pp.

Sullivan, B.J., Reid, T.A., and Bugoni, L. 2006. Seabird mortality on factory trawlers in the Falkland Islands and beyond. Biological Conservation, 131: 495-504.

Takekawa, J.E., Carter, H.R., and Harvey, T.E. 1990. Decline of the Common Murre in central California, 1980-1986. Studies in Avian Biology, 14: 149–163.

Tasker, M.L., Camphuysen, C.J. (Kees), Cooper, J., Garthe, S., Montevecchi, W. A., and Blaber, S. J. M. 2000. The impacts of fishing on marine birds. ICES Journal of Marine Science, 57: 531–547.

Trippel, E., Holy, N.L., Palka, D.L., Shepherd, T.D., Melvin, G.D. and Terhune, J.M. 2003. Nylon barium sulphate gillnet reduces porpoise and seabird mortality. Marine Mammal Science 19: 240–243.

Žydelis, R. (in prep.) [Review of bird bycatch in fisheries in European waters.]

Žydelis, R., Dagys, M. and Vaitkus, G. 2006a. Beached bird surveys in Lithuania reflect marine oil pollution and bird mortality in fishing nets. Marine Ornithology, 34: 161–166.

Žydelis, R., Lorentsen, S.-H., Fox, A.D., Kuresoo, A., Krasnov, Y., Goryaev, Y., Bustnes, J.O., Hario, M., Nilsson, L., and Stipniece, A. 2006b. Recent changes in the status of Steller's Eider *Polysticta stelleri* wintering in Europe: a decline or redistribution? Bird Conservation International, 16:217-236.

6 Ecological issues related to the circulation of pathogens and parasites in seabird populations

At the 2007 meeting, WGSE presented a review on ecological issues related to the circulation of pathogens and parasites in seabird populations and this topic was listed as a term of reference for the 2008 meeting. This chapter presents an update of this synthesis.

6.1 Introduction

Recent outbreaks of avian influenza (Olsen *et al*. 2006) and West Nile viruses (Rappole and Hubalek 2003, Gerhardt 2006) have highlighted the role that birds can play in the ecology of zoonotic diseases. The large population sizes of seabirds, their high mobility and their wide geographic distribution make them significant potential players in the ecology and epidemiology of zoonotic diseases, and in several instances they have been involved in major outbreaks (e.g., Olsen *et al*. 2006, Herrmann *et al*. 2006). The highly social breeding habits of seabirds and their capacity for long distance movement (Furness and Monaghan 1987) make them unique hosts for micro- and macroparasites. The discrete distribution of seabirds among colonies and the large amount of existing knowledge about their breeding biology and at sea distribution also suggest that they could serve as good models for the study of the dynamics of host-pathogens interactions. Despite the recent active development of work on the ecology and evolution of host-parasite interactions (Grenfell and Dobson 1995, Hudson *et al*. 2002, Frank 2002, Thomas *et al*. 2006), relatively little information is available on seabird-parasite interactions and their epidemiological implications. We present here some elements on ecological issues related to the circulation of pathogens and parasites in seabird populations in order to identify gaps in our knowledge and potential avenues for research of basic and applied interest.

6.2 Seabirds as hosts for pathogens and parasites

Parasites can be defined in an ecological sense as organisms that live at the expense of others (Combes 2001). This definition encompasses both micro- (bacteria, viruses, protozoans etc) and macro-parasites (nematodes, cestodes, insects, mites, ticks etc). Hosts and parasites are involved in intimate relationships that have implications at both ecological and evolutionary scales (Combes 2001). For instance, the costs associated with parasitism can lead to differential survival or breeding success of host individuals living in various ecological conditions on the short-term, but can also lead to the coevolution of host and parasite genomes on the long term (Combes 2001). Hosts are mortal, so parasites face the dilemma of efficiently exploiting their hosts without reducing their probability of transmission. As efficiency at host exploitation is often assumed to be related to virulence, transmission rate and virulence are expected to be positively correlated. This is an important point to consider when investigating implications of the interactions between the life histories of hosts and parasites. Another important issue related to the intimate nature of the relationships between hosts and parasites is the fact that parasites can be more or less specialized in terms of the host species they can exploit. Some generalist parasites can exploit different hosts, which can have key epidemiological implications when some host species play the role of reservoirs for agents that can lead to diseases in others. In terms of ecological implications, generalist parasites could also be involved in apparent competition between seabird species living in sympatry.

As warm-blooded vertebrates, seabirds are hosts of a large suite of pathogens and parasites (Hubalek 1994, 2004). Numerous life history and ecological characteristics of seabirds distinguish them as hosts compared to other vertebrates, especially regarding the probability that parasites are transmitted among host individuals within a given geographic area (Table 6.1).

Table 6.1. Seabirds as hosts for parasites: some implications of their life history and ecology.

LIFE HISTORY PARTICULARITIES	IMPLICATIONS	EXAMPLES
Breeding site fidelity (High probability of returning to the same breeding site between year)	Spatial structure of host-parasite interactions (Holt and Boulinier 2005)	Patterns of infestation by nest dwelling parasites (ticks, fleas) (Rothschild and Clay 1957, Boulinier et al. 1996)
Long-lived	Temporal scale of host-parasite interactions (acquired immunity, maternal effects…)	Interannual persistence and maternal transfer of antibodies against Lyme disease agent Borrelia burgdorferi s.l. (Gasparini et al. 2001, Staszewski et al. 2007)
Colonial breeding	Increased transmission among individuals	Avian influenza in Common terns (Olsen et al. 2006)
Interspecific colony structure (mixed colonies)	Increased potential for host shift and/or host sharing	Evidence of host races for the seabird tick Ixodes uriae (McCoy et al. 2005b, Dunneau et al. 2008)
Migratory and high dispersal capacity	Potential large scale dissemination of parasites	Marine cycle of Lyme disease agent Borrelia burgdorferi (Olsen et al. 1995)
Seasonal reproduction	Seasonality in the interactions with parasites (Altizer et al. 2006),	Seasonal exposure to nest dwelling parasites and associated microparasites (implication for selection on host phenology, time to recovery)
Piscivorous /scavengers	Trophic transmission of micro- and macro-parasites	Salmonella epidemiology (Monaghan et al. 1985)

Detailed reviews of the micro-pathogenic organisms associated with free-living seabirds can be found in Hubalek (1994, 2004) and more specialized papers present reviews for seabird viruses (Chastel 1988) or parasites of auks (Muzaffar and Jones 2004). Here, we do not review this literature *in extenso*, but we highlight some information and references about pathogens and parasites of seabirds to illustrate potentially significant ecological issues. It should be noted that some specific host-parasite systems have been the subject of much work, while very little information is available on others, notably because they have been implicated in dramatic outbreaks. An illustration of this is the large amount of work performed in the 70's and 80's on seabird arboviruses (Nuttal 1984, Chastel *et al*. 1988), while more recent work on seabird microparasites has focused on Lyme disease bacteria *Borrelia burgdorferi sensu lato* since its identification in seabirds in 1993 (Olsen *et al*. 1993). Little is known about the circulation of other pathogens such as avian influenza viruses (Olsen *et al*. 2006). Also, the fact that some detailed studies were performed at a time when genetic approaches were not yet readily available increases the heterogeneity in the quality and quantity of information available on different host-parasite systems. In particular, genetic approaches are increasingly used to infer the evolution of pathogens and parasites, but their use with natural host-parasite systems is still limited (De Meeûs *et al*. 2007).

6.2.1 Viruses

Many viruses are circulating in seabird populations (Hubalek 2004), but we will focus here on two groups: arboviruses (often transmitted among seabirds by nest dwelling parasites such as ticks) and influenza A viruses. Regarding other types of viruses, one of particular interest because of its known pathogenic effects on birds is Newcastle Disease Virus, which is known to circulate in cormorants and shags, but usually in inland areas. It should also be noted that recent investigations on coronaviruses in wild birds clearly stress that little is known about the presence of several viruses in wild populations (Monceyron-Jonassen *et al*. 2005).

Many arboviruses have been identified in seabird species parasitized by soft and hard ticks (Clifford 1979, Nuttal 1984, Chastel 1988, Chastel *et al*. 1990). These arboviruses are circulating at different latitudes, notably due to their associations with different ticks, such as *Ixodes uriae* in the North Atlantic (Main *et al*. 1976, Spence *et al*. 1985, Nunn *et al*. 2006a). Where intensive work has been carried out, as for instance in Brittany, Western France, several of these arboviruses have been isolated in the same ectoparasite species parasitizing the same host species in the same area (e.g., *Ixodes uriae*, *Ornithodoros maritimus*), suggesting the natural exposure of some seabirds to a high diversity of viruses (Chastel *et al*. 1981, 1987, 1990, Quillien *et al*. 1986). In general, not much is known about the pathogenicity of these viruses, although evidence of massive failure of tern colonies have been associated with the detection of some viruses and other viruses have been reported to have pathogenic effects on humans (Converse *et al*. 1975, Feare *et al*. 1976, Clifford *et al*. 1980).

Influenza viruses are circulating in seabird populations although knowledge is still limited. Strains of these viruses have been repeatedly isolated in gulls (*Larus* spp; Krauss *et al*. 2007, Munster *et al*. 2007), but also in a few other seabirds. A recent study showed for instance that three out of 26 common guillemots banded in the Baltic Sea tested positive for influenza A virus using RT-PCR (Wallesten *et al*. 2005). Phylogenetic analyses further showed that five gene segments belonged to the American avian lineage of influenza A viruses, whereas three gene segments belonged to the Eurasian lineage. This indicates that avian influenza viruses may have a taxonomically wider reservoir spectrum than previously known and that naturally occurring chimeric avian influenza A viruses can include genes of American and Eurasian origin in Europe. Influenza A viruses have been known for a long time to circulate in duck populations and the close contact occurring between waterbirds species in some area calls for attention to the potential circulation of such viruses in seabirds (Muzaffar *et al*. 2006).

6.2.2 Bacteria

Many bacteria are circulating in seabird populations (Hubalek 2004). Among them, attention has especially been driven in recent years to Lyme disease agent *Borrelia burgdorferi sensu lato*, which was shown to circulate in seabirds only relatively recently (Olsen 1993). Lyme disease is the main human arthropod borne disease in the northern hemisphere. It is due to various genospecies within the *Borrelia burgdorferi* sensu lato which are transmitted by tick bites to humans, usually by 'terrestrial' ticks such as *Ixodes ricinus* and *Ixodes scapularis*. Pathogenic genospecies of *Borrelia burgdorferi sensu lato* have been identified in seabirds (Olsen *et al*. 1993, 1995, Gylfe *et al*. 1998, Smith *et al*. 2006, McCoy *et al*. unpublished) and some of its epidemiological (Olsen *et al*. 1995, Gylfe *et al*. 1998) and ecological implications have been investigated (Gasparini *et al*. 2001, 2002, Staszewski *et al*., in press).

6.2.3 Other parasites

Several other parasites are of importance for seabirds and they will be briefly reviewed in the next version of this chapter. This is notably the case of Fungi, Protozoa as well as macroparasites such as Ectoparasites (ticks, fleas, feather lice; Rothschild and Clay 1957, Murray and Vestjens 1967, Duffy 1983, Guiguen 1988) and Endoparasites (Trematodes and cestodes notably, Threlfall 1968). Some details about the seabird tick *Ixodes uriae* are provided in the rest of the chapter in relation to its important vector role for viruses and bacteria.

6.3 Factors affecting the circulation of parasites in seabird populations

6.3.1 Seabird population biology and parasites

As summarized in Table 5.1, a series of common characteristics of seabird species are likely to be important for their ecological and evolutionary interactions with parasites. The re-uses of nesting sites year after year and dense aggregations occurring at nesting colonies are obvious characteristics that are favourable for the maintenance of high parasite populations. Large numbers of ectoparasites can in particular be found on most seabird colonies (Guiguen 1988).

Negative effects on reproductive success when parasite loads are high can be significant, with potential consequences for the local dispersal of breeders via mechanisms of differential dispersal and recruitment as a function of local breeding success (Boulinier and Danchin 1996, Boulinier *et al*. 2001, Gauthier-Clerc *et al*. 2003). Currently, there is nevertheless no evidence of negative effects on adult survival, but very few attempts have been made to investigate this issue.

Population genetic investigations using neutral markers (microsatellites) have shown that gene flows between populations of the seabird tick *Ixodes uriae* are much more restricted than gene flows between its host populations at the same geographic scales (McCoy *et al*. 2003, 2005a). An interesting result is also that the ecology and behaviour of the seabird host species may lead to different dispersal rates among colonies of the ticks; for instance, tick populations are much more structured between black-legged kittiwake populations than between Atlantic puffins populations when investigated at the same geographical scale (McCoy *et al*. 2003), which could be due to a higher tendency for prospecting individuals to disperse ticks among colonies in puffins than kittiwakes. Another important finding was that several seabird populations breeding in mixed colonies (i.e., in sympatry) do not appear to share the same *Ixodes uriae* tick populations as revealed by population genetic analyses of the ticks collected on different host (McCoy *et al*. 2001, 2005b). This suggests a specialization of the tick for its hosts, which should have implications for the circulation of microparasites such as *Borrelia* and arboviruses in seabird populations.

6.3.2 Global change and the circulation of pathogens and parasites in seabird populations

Human activities at various spatial scales can have dramatic consequences for the circulation of parasites in seabird populations and between free-ranging birds and humans and domesticated populations. Refuse dumps and fish factories have been identified as foci of bacteria transmission (e.g., *Salmonella*) involving gulls (Monaghan *et al*. 1985, Nesse *et al*. 2005). Concerns of exchange of parasites between intensive animal production facilities (notably of poultry) and free-ranging birds have been raised following the recent outbreaks of avian influenza (Olsen *et al*. 2006). Ecotourism to remote areas hosting large seabird colonies has the potential to lead to exchange of parasites (Wallensten *et al*. 2006).

The effects of climate change on the circulation of parasites, notably via induced changes in the distribution of vectors, could be important. Much work is done on the potential effects of climate change on the distribution of tick species responsible for the terrestrial cycle of Lyme disease, such as *Ixodes scapularis* (Ogden *et al*. 2005), and knowledge of the temperature and humidity tolerance of different ectoparasites could be important in this context. It should nevertheless be noted that species such as *Ixodes uriae* shows clear adaptation to dramatic variations in environmental conditions (Murray and Vestjens 1967, Lee and Baust 1982, Barton *et al*. 1996, Benoit *et al*. 2007).

6.4 Implications of the circulation of pathogens and parasites in seabird populations

6.4.1 Threats to seabird populations and biodiversity

The role of parasitism in the ecology of natural bird populations has attracted much interest in the last two decades, notably in the fields of behavioural and population biology (Lloye and Zuk 1991, Clayton and Moore 1997), but those factors have not often been clearly identified as major threats to seabird populations. This is not to say that parasites do not play a significant role in the ecology of seabirds, as for instance breeding failure and dispersal among sub-colonies have been attributed to high local levels of ectoparasites in various species (Boulinier *et al*. 2001).

As pathogens and parasites have the potential to spread rapidly among dense populations, such as seabird colonies, and as they have the potential to lower dramatically a key demographic parameter such as adult survival (to which seabird populations are highly sensitive), they nevertheless represent a factor that has the potential to be important.

An interesting issue relates to the question of whether the circulation of parasites in seabird populations is more or less independent of the circulation of parasites in other animals and humans. *Borrelia burgdoferi* may have been circulating in seabird populations for thousands of years independently of the terrestrial cycle which involve most human cases (Olsen *et al*. 1995, Gauthier-Clerc *et al*. 1999), but alternatively the development of ecotourism in remote areas with large seabird colonies raised the question of the risk of exposure of seabirds to new parasites, such as in the case of penguins in Antarctica (Wallensten *et al*. 2006). It is nevertheless often hard to know whether parasites were native or introduced (Gauthier-Clerc *et al*. 2002). As we have seen above, global change could lead to increased exposure of individuals and populations to parasites with which they have not evolved, which could have major ecological and epidemiological implications.

6.4.2 Seabird parasites and human disease

Seabirds are carriers of a few diseases that can transmit to humans (zoonoses), but as humans are rarely in close contact with them this poses relatively little health concern. On islands where humans are still exploiting seabirds for food, cases of exposure of humans to zoonotic agents have been reported, such as seropositivity of bird hunters against *Borrelia burgdoferi* in the Faroe Islands (Gylfe *et al*. 1998). Seemingly, biologists handling seabirds and working in areas infested by seabird ectoparasites may be at risk of exposure. The tick *Ixodes uriae* can for instance bite humans, although the fast detection and removal of feeding ticks is likely to often preclude the transmission of bacteria such as *Borrelia burgdoferi* to humans (transmission via a tick bite only occurs after several days of attachment to the host). One other instance that can lead to risks of exposure of humans to parasites carried by seabirds is in the context of rehabilitation programmes associated with the care for e.g. oiled birds (Steele *et al*. 2005).

Due to their high dispersive behaviour and colonial habits, seabirds have the potential to disperse microparasites at large scales. Their role in the epidemiology of zoonoses and notably the emergence of infectious diseases, is nevertheless much constrained by the low contact between seabirds and wild terrestrial vertebrates (e.g., mammals, waterfowls, passerine birds), domesticated animals (livestock) or humans. As we have seen above, global changes may nevertheless increase the contact between host-parasite systems, which could lead to the rapid changes in their dynamics. A better knowledge of the dynamics of these complex systems is thus required.

6.5 Perspectives

6.5.1 Monitoring of pathogens and parasites

As for any monitoring programme of biodiversity, the why, what and how should be considered seriously before engaging in the gathering of information and samples (Yoccoz *et al*. 2001). Particular attention to the spatial variability expected at different spatial (e.g., within and among colonies) and temporal scales (seasonality and inter-year variability) should be made. In particular, the small numbers of samples often screened in past published studies sometimes limit the inferences that can be made about factors potentially affecting parasite dynamics. Relatively descriptive studies investigating evidence of the presence of various parasites are nevertheless useful to plan more extensive surveys (Gauthier-Clerc *et al*. 2002, Uhart *et al*. 2003).

As part of monitoring programmes of seabird populations involving the handling of seabirds for marking and/or diet sampling, samples could easily be taken to enable the tracking parasitic agents among populations at small and wide spatial scales. Such investigations can rely on molecular techniques (PCR methods) or the detection of antibodies in plasma or sera samples using immunological assays (ELISA, Western blots). It should be noted that as seabirds are long-lived, serological approaches, which rely on the detection of antibodies which may last for months and years in the host individuals after their exposure to an antigen, may provide only limited information about the timing of exposure of individuals to antigens (Staszewski *et al*. 2007). If adults are difficult to capture, maternal antibodies can be detected in the egg yolk and the plasma of young chicks as these are available in an amount proportional to that circulating in the female plasma (Gasparini *et al*. 2002). It should nevertheless be noted that the presence of antibodies in a 5 day old chick does not mean that the parasite is currently circulating in the host population as the mother may have been exposed to the parasites several years before, a sufficient exposure for a strong humoral immune response to be initiated.

The culture of micro-organisms or the sequencing of their DNA from can enable researchers to investigate phylodynamic issues (origin of the strain and relationship with other strains) provided there are enough samples available on the studied organism (Grenfell *et al*. 2004). Such approaches should provide crucial elements for a better understanding of the processes responsible for the circulation of parasites in natural seabird populations. In the case of vector-born parasite, such approaches can also be used on the vector to disentangle factors responsible for strain differentiation (De Meeûs *et al*. 2007).

6.5.2 Perspective of research

As seen above, a lot of information is now available via classical parasitology studies as well as more recent work carried out in a more ecological and evolutionary framework. The use of population and evolutionary genetics should enable us to achieve a much better understanding of the circulation of parasitic agents. The current development of work at the interplay between immunology and ecology (immuno-ecology; Sheldon and Verhulst 1996, Viney *et al*. 2005) could also effect progress on some questions; for instance, the need to consider age-related effects and host immunity when undertaking quantitative studies of tick-borne pathogen transmission is becoming clear (Gasparini *et al*. 2001, Nunn *et al*. 2006b). Interactions between host immunity and life history issues such as stress involved with migration should also be considered (Gylfe *et al*. 2000).

The development of these perspectives of research should thus rely on data from monitoring programmes and surveillance activities conducted at large scales, but also on the development of specific case studies, which are necessary to complete our understanding of the ecology and epidemiology of seabird-parasite systems. Due to their relatively simple and spatially discrete structure, some seabird-parasite systems provide excellent opportunity for addressing questions of broad interest on the ecology and evolution of host-parasite interactions, as well on the effects of global changes on the risk of emerging infectious diseases.

6.6 References

Altizer, S., Dobson, A.P., Hosseini, P., Hudson, P.J., Pascual, M., and Rohani, P. 2006. Seasonality and the dynamics of infectious diseases. Ecology Letters, 9: 467-484.

Barton, T.R., Harris, M.P., Wanless, S., and Elston, D.A. 1996. The activity periods and life cycle of the tick *Ixodes uriae* (Acari: *Ixodidae*) in relation to host breeding strategies. Parasitology, 112: 571-580.

Benoit, B., Yoder, J.A., Lopez-Martinez, G., Elnitsky, M.A., Lee, R.E. Jr., and Denlinger, D.L. 2007. Habitat requirements of the seabird tick, *Ixodes uriae* (Acari: Ixodidae), from the Antarctic Peninsula in relation to water balance characteristics of eggs, nonfed and engorged stages. Journal of Comparative Physiology B: Biochemical, Systemic, and Environmental Physiology, 177: 205-215.

Boulinier, T., Ives, A.R. and Danchin, E. 1996. Measuring aggregation of parasites at different host population levels. Parasitology, 112: 581-587.

Boulinier, T., and Danchin, E. 1996. Population trends in Kittiwake *Rissa tridactyla* colonies in relation to tick infestation. Ibis, 138: 326-334.

Boulinier, T., Sorci, G., Monnat, J.-Y., and Danchin, E. 1997. Parent-offspring regression suggests heritable susceptibility to ectoparasites in a natural population of kittiwake *Rissa tridactyla*. Journal of Evolutionary Biology, 10: 77-85.

Boulinier, T., McCoy, K.D., and Sorci, G. 2001. Dispersal and parasitism. *In* Dispersal. Pages 169-179. Ed. by J. Clobert, E. Danchin, A. Dhondt, and J. D. Nichols. Oxford University Press, Oxford, UK.

Chastel, C. 1988. Tick-borne virus infections of Marine Birds. *In* Advances in disease vector research. Pages 25-60. Ed. by K.F. Harris, K.F. Springer-Verlag: New-York.

Chastel, C., Monnat, J.Y., Le Lay, G., Guiguen, C., Quillien, M.C., and Beaucournu, J.C. 1981. Studies on Bunyaviridae including Zaliv Terpeniya virus isolated from *Ixodes uriae* ticks (Acarina, Ixodidae) in Brittany, France. Arch. Virol., 70: 357-366.

Chastel, C., Monnat, J.Y., Le Lay, G. and Balouet, G. 1987. Infestation et hyperinfestation de la Mouette tridactyle *Rissa tridactyla* L. par des tiques (*Ixodes (Ceratixodes) uriae*, *Ornithodoros (Alectorobius) maritimus*): conséquences pathologiques. Annals de Parasitologie Humaine et Comparée 1967, 62: 492-504.

Chastel, C., Le Lay, G., and Monnat, J.-Y. 1990. Isolation of Soldado virus from a seabird (*Rissa tridactyla* L.) in France. Acta virologica, 34: 109.

Clayton, D.H. and Moore, J. 1997. Host-parasite evolution. General principles and avian models. Oxford University Press: Oxford.

Clifford, C.M. 1979. Tick-born viruses of seabirds. *In* Arctic and tropical arboviruses. Pages 83-100. Ed. by E. Kurstak. Academic Press: New York.

Clifford, C.M., Hoogstraal, H., Radovsky, F.J., Stiller, D., and Keirans, J.E. 1980. *Ornithodoros (Alectorobius) amblus* (Acarina: Ixodoidea: Argasidae): identity, marine bird and human hosts, virus infections, and distribution in Peru. Journal of Parasitology, 66: 312-323

Combes, C. 2001. Parasitism: The Ecology and Evolution of Intimate Interactions. University of Chicago Press, Chicago, USA.

Comstedt, P., Bergström, S., Olsen, ´B., Garpmo, U., Marjavaara, L., Mejlon, H., Barbour, A.G., and Bunikis, J. 2006. Migratory passerine birds as reservoirs of Lyme borreliosis in Europe. Emerging Infectious Diseases, 12: 1087-1095.

Converse, J.D., Hoogstraal, H., Moussa, M.I. *et al*. 1975. Soldado virus (Hughes group) associated from *Ornithodoros* (*Alectorobius*) *capensis* (Ixodoidea: Argasidae) infesting Sooty tern colonies in the Seychelles, Indian Ocean. American Journal of Tropical Medicine and Hygene, 24: 1010-1018.

Danchin, E. 1992. The incidence of the tick parasite *Ixodes uriae* in Kittiwake *Rissa tridactyla* colonies in relation to the age of the colony, and a mechanism of infecting new colonies. Ibis, 134: 134-141.

De Meeûs, T, McCoy, K.D., Prugnolle, F., Durand, P., Chevillon, C., Hurtrez-Boussès, S., and Renaud, F.. 2007. Population genetics and molecular epidemiology or how to "débusquer la bête". Infection, Genetics and Evolution, in press.

Duffy, D.C. 1983. The ecology of tick parasitism on densely nesting peruvian seabirds. Ecology, 64: 110-119.

Duneau, D., Boulinier, T., Gomez-Diaz, E., Petersen, A., Tveraa, T., Barrett, R.T. and McCoy, K.D. 2008. Prevalence and diversity of lyme borreliosis bacteria in marine birds. Infection, Genetics and Evolution, in press.

Feare, C.J. 1976. Desertion and abnormal development in a colony of Sooty Terns Sterna fuscata infested by virus-infected ticks. Ibis, 118: 112-115.

Frank, S.A. 2002. Immunology and evolution of infectious disease. Princeton University Press, Princeton, New Jersey, USA.

Furness, R.W. and Monaghan, P. 1987. Seabird ecology. Backie, Glasgow.

Gasparini, J., McCoy, K.D., Haussy, C., Tveraa, T., and Boulinier, T. 2001. Induced maternal response to the Lyme disease spirochaete *Borrelia burgdorferi sensu lato* in a colonial seabird, the kittiwake *Rissa tridactyla*. Proceedings of the Royal Society B, 268: 647-650.

Gasparini, J., McCoy, K.D., Tveraa, T., and Boulinier, T. 2002. Related concentrations of specific immunoglobulins against the Lyme disease agent *Borrelia burgdorferi* s.l. in eggs, young and adults of the kittiwake (*Rissa tridactyla*). Ecology Letters, 5: 519-524.

Gauthier-Clerc, M., Jaulhac, B., Frenot, Y., Bachelard, C., Monteil, H., Le Maho, Y., and Handrich, Y. 1999. Prevalence of *Borrelia burgdorferi* (the Lyme disease agent) antibodies in king penguin *Aptenodytes patagonicus* in Crozet Archipelago. Polar Biology, 22: 141-143.

Gauthier-Clerc, M., Eterradossi, N., Toquin, D., Guittet, M., Kuntz, G., and Le Maho, Y. 2002. Serological survey of the king penguin, *Aptenodytes patagonicus* in Crozet Archipelago for antibodies to infectious bursal disease, infleunza A and Newcastle disease viruses. Polar Biology, 25: 316-319.

Gauthier-Clerc, M., Moangin, S., Le Bohec, C., Gendner, J.-P., and Le Maho, Y. 2003. Comparision of behaviour, body mass, haematocrit level, site fidelity and ssurvival between infested and non-infested king penguin Aptenodytes patagonicus by ticks Ixodes uriae. Polar Biology, 26: 379-382.

Gerhardt, R. 2006. West Nile virus in the United States (1999-2005), Journal of the American Animal Hospital Association, 42: 170-177.

Grenfell, B.T., and Dobson, A.P. 1995. *Ecology of infectious diseases in natural populations*. Cambridge University Press, Cambridge, UK.

Grenfell, B.T., Pybus, O.G., Gog, J.R., Wood, J.L.N., Daly, J.M., Mumford, J.A. and Holmes, E.C. Unifying the epidemiological and evolutionary dynamics of pathogens. Science, 30: 327-332.

Guiguen, C. 1988. Anthropozoonoses et oiseaux marins: Contribution à l'étude des ectoparasites hématophages des espèces nicheuses sur les côtes françaises continentales et insulaires. Thèse pour l'obtention du diplôme d'Etat de Docteur en Biologie Humaine. Faculté de Médecine de Marseille.

Gylfe, A., Bergström, S., Lundstrom, J., and Olsen, B. 2000. Epidemiology: reactivation of *Borrelia* infection in birds. Nature, 403: 724-725.

Gylfe, Å., Olsen , B., Staševičius, D., Ras, N.M., Weihe, P., Noppa, L., Östberg, Y., Baranton, G., and Bergström, S. 1999. Isolation of Lyme disease *Borrelia* from puffins (*Fratercula arctica*) and seabird ticks (*Ixodes uriae*) on the Faeroe Islands. Journal of Clinical Microbiology, 37: 890-896.

Herrmann, B., Persson, H., Jens-Kjeld Jensen, J.-K., Debes Joensen, H., Klint, M., and Olsen, B. 2006. *Chlamydophila psittaci* in Fulmars, the Faroe Islands. 2006. Emerging Infectious Diseases, 12: 330-332.

Holt, R., and Boulinier, T. 2005. Ecosystem and parasitism: the spatial dimension. *In* Ecosystem and parasitism. Pages 68-84. Ed. by F. Thomas, F. Renaud and J.-F. Guegan. Oxford University Press, Oxford.

Hubalek, Z. 1994. Pathogenic microorganisms associated with free-living birds (A review). Acta Scientiarum Naturalium Academiae Scientiarum Bohemicae, Bron 5: 1-74.

Hubalek Z. 2004. An annotated checklist of pathogenic microorganisms associated with migratory birds. Journal of Wildlife Diseases, 40: 639-659.

Hudson, P.J., Rizzoli, A., Grenfell, B.T., Heesterbeek, H., and Dobson, A.P. 2002. The ecology of wildlife diseases. Oxford University Press, Oxford, UK.

King, K.A., Keith, J.O., and Keirans, J.E. 1977a. Ticks as a factor in nest desertion of California Brown Pelicans. Condor, 79: 507-509.

King, K.A., Blankinship, D.R., Paul, R.T., and Rice, R.C.A. 1977 b. Ticks as a factor in the 1975 nesting failure of Texas Brown Pelican. Wilson Bulletin, 89: 157-158.

Komar, N. 2001. West Nile virus surveillance using sentinels birds. Annals of the New York Academy of Sciences, 951:58-73.

Krauss, S., Obert, C.A., Franks, J. Walker, D., Jones, K., Seiler, P., Niles, L., Pryor, S.P., Obenauer, J.C., Naeve, C.W., Widjaja, L., Webby, R.J., Webster, R.G. 2007. Influenza in Migratory Birds and Evidence of Limited Intercontinental Virus Exchange. PLoS Pathog, 3(11): e167.

Lee, R.E. Jr., and Baust, J.G. 1982. Respiratory metabolism of the antarctic tick, *Ixodes uriae*. Comparative Biochemistry and Physiology, 72A: 167-171.

Loye, J.E., and Zuk, M. 1991. Bird-Parasite interactions. Ecology, evolution and behaviour. Oxford University Press, New York.

Main, A.J., Shope, R.E., and Wallis, R.C. 1976. Cape Wrath: a mew Kemerovo group orbivirus from *Ixodes uriae* (Acari: Ixodidae) in Scotland. Journal of Medical Entomology, 13: 304-308.

Mehl, R., and Traavik, T. 1983. The tick *Ixodes uriae* (Acari, Ixodites) in seabird colonies in Norway. Fauna norv. Ser. B., 30: 94-107.

McCoy, K.D., Boulinier, T., Chardine, J.W., Danchin, E., and Michalakis, Y. 1999. Dispersal and distribution of the tick *Ixodes uriae* within and among seabird host populations: the need for a population genetic approach. Journal of Parasitology, 85: 196-202.

McCoy, K.D., Boulinier, T., Schjoerring, S., and Michalakis, Y. 2002. Local adaptation of an ectoparasite *Ixodes uriae* to its seabird host. Evolutionary Ecology Research, 4: 441-456.

McCoy, K.D., Boulinier, T., Tirard, C., and Michalakis, Y. 2001. Host specificity of a generalist parasite: genetic evidence of sympatric host races in the seabird tick *Ixodes uriae*. Journal of Evolutionary Biology, 14: 395-405.

McCoy, K.D., Boulinier, T., Tirard, C., and Michalakis, Y. 2003. Host-dependent genetic structure of parasite populations: differential dispersal of seabird tick host races. Evolution, 57: 288-296.

McCoy, K.D., Tirard, C., and Michalakis, Y. 2003. Spatial genetic structure of the ectoparasite *Ixodes uriae* within breeding cliffs of its colonial seabird host. Heredity, 91: 422-429.

McCoy, K.D., Boulinier, T., and Tirard, C. 2005a. Comparative host-parasite population structures: disentangling prospecting and dispersal in the Black-legged kittiwake *Rissa tridactyla*. Molecular Ecology, 14: 2825-2838.

McCoy, K.D., Chapuis, E., Tirard, C., Boulinier, T., Michalakis, Y., LeBohec, C., LeMaho, Y., and Gauthier-Clerc, M. 2005b. Recurrent evolution of host-specialized races in a globally-distributed ectoparasite. Proceedings of the Royal Society of London B, 272: 2389-2395.

Monaghan, P., Shedden, C.B., and Ensor. K. 1985. *Salmonella* carriage by gulls (*Larus argentatus*) in the Clyde area of Scotland (U.K.) in relation to their feeding ecology. Journal of Applied Ecology, 22: 669-680.

Monceyron-Jonassen, C., Kofstad, T., Larsen, I.-L., Løvland, A., Handeland, K., Follestad, A. and Lillehaug, A. 2005. Molecular identification and characterization of novel coronavirus infecting graylag geese (*Anser anser*), feral pigeons (*Columbia livia*) and mallards (*Anas platyrhynchos*). Journal of General Virology, 86: 1597-1607.

Munster, V.J. *et al*. 2007. Spatial, temporal, and species variation in prevalence of Influenza A viruses in wild migratory birds. PLOS Pathogens, 3: e61.

Murray, M.D., and Vestjens, W.J.M. 1967. Studies on the ectoparasites of seals and penguins. III. The distribution of the tick *Ixodes uriae* White and the flea *Parapsyllus magellanicus* heardi De Meillon on Macquarie Island. Australian Journal of Zoology, 15: 715-725.

Muzaffar, S., and Jones, I.L. 2004. Parasites and diseases of the Auks (Alcidae) of the world and their ecology - a review. Marine Ornithology, 32: 121-146.

Muzaffar, S., Ydenberg, R.C. and Jones, I.L. 2006. Avian Influenza: An Ecological and Evolutionary Perspective for Waterbird Scientists. Waterbirds, 29: 243-257.

Nesse, L.L., Refsum, T., Heir, E., Nordby, K., Vardund, T., and Holstad, G. 2005. Molecular epidemiology of *Salmonella* spp. isolates from gulls, fish-meal factories, feed factories, animals and humans in Norway based on pulsed-field gel electrophoresis. Epidemiology and Infection, 133: 53-58.

Nunn, M.A., Barton, T.R., Wanless, S., Hails, R.S., Harris, M.P., and Nuttall, P.A. 2006. Tick-borne great island virus: identification of seabird host and evidence for co-feeding and viraemic transmission. Parasitology, 132: 233-240.

Nunn, M.A., Barton, T.R., Wanless, S., Hails, R.S., Harris, M.P., and Nuttall, P.A. 2006. Tick-borne Great Island Virus: (II) impact of age-related acquired immunity on transmission in a natural seabird host. Parasitology, 132: 241-253.

Nuttal, P.A. 1984. Tick-borne viruses in seabird colonies. Seabird, 7: 31-41.

Ogden, N.H., Bigras-Poulin, M., O'Callaghan, C.J., Barker, I.K., Lindsay, L.R., Maarouf, A., Smoyer-Tomic, K.E., Waltner-Toews, D., and Charron, D. 2005. A dynamic population model to investigate effects of climate on geographic range and seasonality of the tick *Ixodes scapularis*. International Journal of Parasitiology, 35: 375-389.

Olsen, B., Jaenson, T.G.T., Noppa, L., Bukinis, J., and Bergström, S. 1993. A lyme borreliosis cycle in seabirds and *Ixodes uriae* ticks. Nature, 362: 340-342.

Olsen, B., Duffy, D.C, Jaenson, T.G.T., Gylfe, A., Bonnedahl, J., and Bergström, S. 1995. Transhemispheric echange of Lyme disease spirochetes by seabirds. Journal of Clinical Microbiology, 33: 3270-3274.

Olsen, B., Munster, V.J., Wallensten, A., Waldenström, J., Osterhaus, A.D.M.E., and Fouchier, R.A.M. 2006. Global patterns of Influenza A virus in wild birds. Science, 312: 384-388.

Quillien, M.C., Monnat, J.Y., Lay, G., Le Goff, F., Hardy, E., and Chastel, C. 1986. Avalon virus, Sakhalin group (Nairovirus, Bunyviridae) from seabird tick *Ixodes* (*Ceratixodes*) *uriae* White 1852 in France. Acta virologica. 30: 418-427.

Rappole, J.H., and Hubalek, Z. 2003. Migratory birds and West Nile virus, Journal of Applied Microbiology, 94: 47S-58S.

Rothschild, M., and Clay, T. 1957. Fleas, flukes and cuckoos. London: Colins.

Sheldon, B. C., and Verhulst, S. 1996. Ecological immunology: costly parasite defences and trade-offs in evolutionary ecology. Trends in Ecology and Evolution, 11: 317-321.

Smith, R.P., Bin Muzaffar, S., Lavers, J., Lacombe, E.H., Cahill, B.K., Lubelczyk, C.B., Kinsler, A., Mathers, A.J., and Rand, P.W. 2006. *Borrelia garinii* in seabird ticks (*Ixodes uriae*), Atlantic coast, North America. Emerging Infectious Diseases, 12: 1909-1912.

Spence, R.P., Harrap, K.A., and Nuttal, P.A. 1985. The isolation of Kemerovo group orbiviruses and uukuniemi group viruses of the family Bunyaviridae from Ixodes uriae ticks from the isle of May, Scotland. Acta Virologica, 29: 129-136.

Staszewski, V., McCoy, K.D., Tveraa, T. and Boulinier, T. Interannual dynamics of antibody levels in naturally infected individuals of a long-lived colonial bird. Ecology, in press.

Steele, M., Davies, C.R., Jones, L.D., Nuttall, P.A., and Rideout, K. 1990. Life history of the seabird tick, *Ixodes* (*Ceratixodes*) *uriae*, at St Abb's Head, Scotland. Acarologia, 31: 125-130.

Steele, C.M., Brown, R.N., and Botzler, R.G. 2005. Prevalences of zoonotic bacteria among seabirds in rehabilitation centers along the Pacific Coast of California and Washington, USA. Journal of Wildlife Diseases, 41: 735-744.

Thomas, F., Renaud, F., and Guegan, J.-F. (Eds.) 2005. Ecosystem and parasitism. Oxford University Press, Oxford.

Threlfall, W. 1968. The helminth parasites of three species of gulls in Newfoundland. Canadian Journal of Zoology, 46: 827-830.

Uhart, M.M., Quintana, F., Karesh, W.B., and Braselton, W.E. 2003. Hematology, plasma biochemistry, and serosurvey for selected infectious agents in southern giant petrels from Patagonia, Argentina. Journal of Wildlife Diseases, 39: 359-365.

Viney, M.E., Riley, E.M., Buchanan, K.L. 2005. Optimal immune responses: immunocompetence revisited. Trends in Ecology and Evolution, 20: 665-669.

Wallensten, A., Munster, V.J., Elmberg, J., Osterhaus, A.D.M.E., Fouchier, R.A.M., and Olsen, B. 2005. Multiple gene segment reassortment between Eurasian and American lineages of influenza A virus (H6N2) in Guillemot (*Uria aalge*). Archives of Virology, 150: 1685-1692.

Wallensten, A., Munster, V.J., Osterhaus, A.D.M.E., Waldenstrom, J., Bonnedahl, J., Broman, T., Fouchier, R.A.M., and Olsen, B. 2006. Mounting evidence for the presence of influenza A virus in the avifauna of the Antarctic region. Antarctic Science, 18: 353-356.

Yoccoz, N.G., Nichols, J.D., and Boulinier, T. 2001. Monitoring biodiversity in space and time: concepts, methods and designs. Trends in Ecology and Evolution, 16: 446-453.

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Annex 2: English and scientific names of birds mentioned in this report

Southern royal albatross	*Diomedea epomophora*
Black-footed albatross	*Phoebastria nigripes*
Black-browed albatross	*Thalassarche melanophrys*
Northern fulmar	*Fulmarus glacialis*
White-chinned Petrel	*Procellaria aequinoctialis*
Cory's shearwater (Mediterranean)	*Calonectris d. diomedea*
Cory's shearwater (Atlantic)	*Calonectris d. borealis*
Great shearwater	*Puffinus gravis*
Sooty shearwater	*Puffinus griseus*
Short-tailed shearwater	*Puffinus tenuirostris*
Balearic shearwater	*Puffinus mauretanicus*
Yelkouan shearwater	*Puffinus yelkouan*
European storm-petrel	*Hydrobates pelagicus*
Leach's storm-petrel	*Oceanodroma leucorhoa*
Northern gannet	*Morus bassanus*
Double-crested cormorant	*Phalacrocorax auritus*
Great cormorant	*Phalacrocorax carbo*
European shag	*Phalacrocorax aristotelis*
European shag (Mediterranean)	*Phalacrocorax a. desmarestii*
Common pochard	*Aythya ferina*
Tufted duck	*Aythya fuligula*
Greater scaup	*Aythya marila*
Common eider	*Somateria mollissima*
Steller's eider	*Polysticta stelleri*
Long-tailed duck	*Clangula hyemalis*
Common scoter	*Melanitta nigra*
Velvet/white-winged scoter	*Melanitta f. fusca*
Common goldeneye	*Bucephala clangula*
Smew	*Mergellus albellus*
Red-breasted merganser	*Mergus serrator*
Goosander	*Mergus merganser*
Common eider	*Somateria mollissima*
Long-tailed duck	*Clangula hyenalis*
Arctic skua	*Stercorarius parasiticus*
Great skua	*Stercorarius skua*
Common gull	*Larus canus*
Audouin's gull	*Larus audouinii*
Kelp Gull	*Larus dominicanus*
Great black-backed gull	*Larus marinus*
Herring gull	*Larus argentatus*
Yellow-legged gull	*Larus michahellis (atlantis)*
Lesser black-backed gull	*Larus fuscus*

Black-headed gull	*Chroicocephalus ridibundus*
Mediterranean gull	*Larus melanocephalus*
Little gull	*Larus minutus*
Ivory gull	*Pagophila eburnea*
Black-legged kittiwake	*Rissa tridactyla*
Sandwich tern	*Sterna sandvicensis*
Common tern	*Sterna hirundo*
Black tern	*Chlidonias niger*
Little auk	*Alle alle*
Common guillemot	*Uria aalge*
Brunnich's guillemot	*Uria lomvia*
Razorbill	*Alca torda*
Black guillemot	*Cepphus grylle*
Marbled murrelet	*Brachyrampus marmoratus*
Ancient murrelet	*Sythliboramphus antiquus*
Japanese murrelet	*Sythliboramphus wumizusume*
Rhinoceros auklet	*Cerorhinca monocerata*
Atlantic puffin	*Fratercula arctica*

Annex 3: WGSE Draft Terms of Reference 2009

The **Working Group on Seabird Ecology** [WGSE] (Chair: Jim Reid, UK) will meet in Bruges, Belgium from 23–27 March 2009 to:

a) Review the status of relevant seabird populations in relation to the OSPAR ecological quality objective (EcoQO) for seabird populations and its component indicators;

b) Summarise the quality status of seabird populations in each of the OSPAR regions as a contribution to the QSR 2010;

c) Review studies of the distribution and habitat association of seabirds in ICES waters based on remote tracking of individual birds;

d) Review the extent to which bycatch in commercial fisheries may affect seabirds in the North Atlantic, including the Mediterranean and Baltic Seas;

e) Review the ecological roles of macroparasites such as ectoparasites (ticks, fleas, lice), fungi, and Protozoa in seabird populations.

WGSE will report by XXX to the attention of the Living Resources Committee.

Supporting Information

Priority:	This is the only forum for work being carried out by ICES in relation to marine birds. If ICES wishes to maintain its profile in this area of work, then the activities of WGSE must be regarded as of high priority.
Scientific justification and relation to action plan:	Term of Reference a) Convened in association with WGSE 2008, ICES WKSEQUIN has recommended that WGSE review annually the status of selected seabird populations in the context of the EcoQO on seabird populations it has formulated. Development of the EcoQO was in response to a request by OSPAR, and was recommended by WGSE in 2001. Term of Reference b) There is likely to be a request from OSPAR to ICES to contribute information on the main components of biodiversity, including seabirds, for the next Quality Status Report for the OSPAR Maritime Area. Term of Reference c) Identification of important seabird habitats is critically important for spatial planning and can help to identify Marine Protected Areas (required under the EU Marine Strategy Directive) and area of common usage by seabirds and fisheries; tracking of individual birds using satellite tags and other data loggers is one of the most important sources of information available for this purpose. Term of Reference d) In the light of the WGSE 2008 ToR on bycatch of seabirds in longline fisheries, WGSE considers that it is timely to review the wider issue of seabird bycatch in all fishing gears in the North Atlantic. Bycatch in the coastal and offshore gill nets and drift nets especially may be of concern for some seabirds. Term of Reference e) WGSE considers this issue to be of relevance because of current general interest in seabird-parasite interactions and the role of the latter in the demography of seabird populations
Resource requirements:	Facilities for WGSE to work in Bruges are anticipated to be excellent.

Participants:	Meetings of WGSE are usually attended by ca. 15 nominated and Chair-invited members. Although the Working Group should be able to achieve most of the above objectives, some members may not be able to attend through lack of funding. Funding of these members from Member Countries would be very welcome.
Secretariat facilities:	None
Financial:	Some little financial assistance may be required for participation and venue (non-institutional) costs.
Linkages to advisory committees:	ACOM
Linkages to other committees or groups:	WGSE is keen to continue the process of integration of seabird ecology into ICES.
Linkages to other organizations:	EU, OSPAR, HELCOM

Annex 4: Recommendations

Recommendation	For follow up by:
1.ICES to recommend to the European Union the formulation and implementation of a Community Plan of Action to mitigate the incidental catch of seabirds in longline fisheries operating in EU waters.	ACOM
2.Data on fishing effort in all EU waters and ICES Areas, including the Mediterranean and Black Seas, and in all gears, including longlining, gill nets, and drift nets, be made available by the relevant ICES WGs or EC Joint Research Centre to WGSE well in advance of its 2009 meeting.	ACOM

Annex 5: Technical Minutes from the Seabirds Review Group

- RGBIRD
- By Correspondence 14–18 April 2008
- Participants: Nicole le Boeuf (USA), Henrik Skov (Denmark), Kees Camphuysen (Netherlands)

Summary of Comments (suggested changes) on EU Longline Fisheries Interactions Section

General Comments: One reviewer noted that the document should include language drawing a stronger connection between adequate assessment of fishing activities, as well as seabird interactions, and the ability to develop more focused, targeted, and effective seabird bycatch mitigation. This reviewer also suggested including an example of this (e.g. where a particular species breeds as it overlaps with a fishery and how a closure might be applied in time and space to reduce bycatch).

One reviewer noted the need to describe any ongoing education and outreach activities (e.g. BirdLife International Malta) so that the point can be made that more needs to be taking place, particularly in certain regions. This includes working with fishers cooperatively to develop and test mitigation methods that work for particular fisheries. This would also include outreach and education with artisanal fisheries and/or fisheries where real-time monitoring and enforcement is not feasible and changing behaviour voluntarily will be of paramount importance.

One reviewer suggested that the absence of data (and the absence of interest seemingly of countries to investigate the bycatch issue) should be highlighted.

One reviewer suggested that the document stress the need to make detailed investigations into the type of birds captured (not just their numbers) and that a better knowledge of age-composition and sex ratio would assist in assessing the scale of any bycatch problem. This reviewer went on to recommend that this information is not difficult to obtain, but that this should be raised as an issue recommended for further investigation.

Comments on Sec. 3.3: One reviewer suggested adding any available information regarding possible reasons for population declines in populations of northern fulmar, sooty shearwater, and black-legged kittiwake. Where reasons for such decline remain uncle, the reviewer suggested noting this.

One reviewer noted that it would be helpful to characterise the potential vulnerability of individual species to fisheries interactions (e.g. their foraging ecology, behaviour behind vessels, tendency to aggregate in large numbers).

One reviewer suggested that the species descriptions were unbalanced in terms of there being substantial more information on the species than on bycatch.

Comment on Sec. 3.4 and elsewhere: One reviewer suggested a including discussion of whether the EC permits foreign-flagged vessels to fish in EU EEZs and, if so, the characteristics of these fisheries, and what is known about the impacts of these fisheries on seabirds. This would also include a discussion of whether the EC requires data collection and/or seabird bycatch mitigation conditions to fishing permits.

Comment on Sec. 3.5.2: One reviewer suggested adding clarification regarding the difference between there being a suite of mitigation methods for the EC/fishers to choose from, and there being some evidence that combinations of methods are more effective than methods used singly.

Comment on Sec. 3.5.8: One reviewer suggested adding minimal technical specifications for the individual mitigation methods under the descriptions of each. This would include a range of options for specifications, where appropriate, and whether such specifications have been proven effective.

Comment on Table 3.9: One reviewer recommended clarification regarding who has recommended regulations and to indicate that the WCPFC, ICCAT, CCSBT, and CCAMLR have adopted binding measures. For the latter, the commenter suggested including information on which EU nations have promulgated corresponding force of law through which to implement them. Alternatively, the commenter recommended that any actions taken by RFMOs be listed separately from those taken at the initiative of individual nation, noting the EC membership of each RFMO for contextual reference.

Comment on Sec. 3.8: One reviewer suggested stressing the fundamental need for fleet and fishing characterisation and/or reporting to the EC to be able to understand the impacts of fishing on the ecosystem, including that related to seabird bycatch. The reviewer also suggested that rather than suggesting wholesale monitoring that a focus on setting priorities for targeted programmes in specific regions or fisheries be applied.

Comment on Sec. 3.9 and elsewhere: One reviewer suggested a discussion of the presence and the need for cooperative research as an effective approach to the development and implementation of effective of seabird bycatch mitigation. This commenter also suggested emphasising the role of fishers in the development and application of effective mitigation methods.

Comment on Sec. 4.1.1: One reviewer suggested explaining why Spanish longline vessels are representative for the placement of observers.

Comment on Sec. 5.1.1: One reviewer noted that the lack of information on small gillnets in the Baltic Sea (and potentially other shallow and coastal areas) and the assessment of feasible mitigation measures should be highlighted.

Comment on Sec. 5.2: One reviewer suggested making it clearer that where there are no descriptions of trawl and gillnet fisheries this is due to a lack of information and not to oversight or because these fisheries do not threaten seabird populations.

Annex 6: Technical Minutes from the Working Group on Ecosystem Effects on Fishing Activities (WGECO)

Review report of Section 2 of Working Group of Seabirds Ecology (WGSE) report:

The review took place during the WGECO meting 6–13 May 2008 in Copenhagen.

Reviewers: Jake Rice (chair), Catherine L. Scott, Ellen L. Kenchington, Gerjan Piet, Keith Brander, Stuart I. Rogers, Øystein Skagseth

The reviewers provided written comments to the Section 2 of WGSE report. This section is related to WGSE ToR a).

General comments

Section 2 of WGSE report presents several examples of changes related to climate change effects building on the work of the previous WGSE report in 2007. These changes are categorized as:

- Changes in the breeding distribution
- Changes in non-breeding distribution
- Changes in reproductive success
- Changes in annual survival
- Changes in abundance
- Changes in migratory schedule
- Other phenological changes: laying dates, nest dates, fledging dates
- Seabird demography and population dynamics in relation to ocean climate: new analyses

For each of the categories identified the report gives several examples. The majority of examples are from OSPAR region II, but there are also examples from OSPAR I and II. The report (coupled with the 2007 report) provides species-specific information on the identified changes in a number of species. However, the connection with the climate change is not always clear. It is usually considered to be an indirect effect and mediated through the food chain or complicated by other factors. WGSE identify the variety of ways by which seabirds respond to climate change and variability.

WGSE address the aspects of modelling as an approach to better understand responses to climate change and consider a pre-defined list of explanatory variables would limit research and restrict the strength of inferences within the existing data. Rather environmental datasets relevant to the available seabird data should be used. WGSE considers modelling a viable tool.

It is fairly clear that future requests of this kind will require more detailed dialogue between the WG and the group carrying out the overview and analysis in order to ensure that there is a common basis and methodology and that the WG is clear about what information is required. A common source of data and products on changes in ocean climate is an essential part of this.