ICES WGSE REPORT 2011

SCICOM STEERING GROUP ON ECOSYSTEM FUNCTIONS

ICES CM 2011/SSGEF:07

REF. SCICOM, ACOM

Report of the Working Group on Seabird Ecology (WGSE)

1–4 November 2011

Madeira, Portugal

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

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

Recommended format for purposes of citation:

ICES. 2011. Report of the Working Group on Seabird Ecology (WGSE), 1–4 November 2011, Madeira, Portugal. ICES CM 2011/SSGEF:07. 73 pp.

Contents

Executive summary

The Working Group on Seabird Ecology met from 1 to 4 November 2011 in Machico, Madeira, Portugal, and was attended by 7 persons from five countries (Annex 1). Six were regular members of the group and one was invited by the Chair to attend. Three others participated by correspondence; these included two members and one invited to contribute by the Chair. During the meeting, WGSE addressed most terms of reference, except for (l) on "Biodiversity Indicators for assessment and management", and we were not able to extend the completed analysis of EcoQos that we completed for OSPAR Region II (The North Sea) to the other OSPAR Regions (II and IV) due to lack of data and analysis. We were short-staffed at this meeting, with half of our usual contingent, and could barely cover the large list of tasks that was assigned. We are exploring reasons for the low attendance this year, but note that attendance has steadily declined over the past few years (e.g. 17 persons in 2008). We also only very briefly summarized information on ToR (on Wet Renewable Energy), as little information is available and that which is available is capably summarized within a single published paper.

We were able to implement the EcoQo for OSPAR Region II for those species for which there were sufficient data to do so. Having done this analysis points to the need for further data on important species such as Northern Gannet and Northern Fulmar. The success with OSPAR Region II suggests that implementation of EcoQos to regions III and IV is feasible.

We summarized recent data on impacts of windfarms on seabirds, and cautiously conclude that the impacts are perhaps a bit less negative than expected, with the caveat that more data are needed from nights with reduced visibility, such as during fog, snow and rain, the conditions under which most birds strike structures, especially lighted ones.

What long-term studies are available of seabirds and their prey suggest that some birds can be very useful as indicators of prey stocks. There are complications arising from multiple prey taken by most species of birds, but nonetheless the largest impediment to using seabirds as indicators seems to be the lack of sufficiently long-tem studies that have sampled both seabirds and their prey. Our analysis suggests the importance of long-term collaborative studies among seabird and fisheries biologists and oceanographers.

The considerable advance in technology has enabled a broad diversity of tracking studies of seabirds, including especially birds previously too small to carry instruments. Recent findings include previously unknown feeding hotspots at sea, separation among sex and age classes of birds, and interannual variability in migration routes and wintering areas.

Collection of data on birds bycaught in fisheries continues to improve, especially in the Mediterranean and off the USA. We now have summaries from gill net, as well as longline, fisheries. Data are sufficient to begin to quantify risks to threatened species.

1 Opening of the meeting

The meeting was officially opened at 09:00 on 1 November 2011.

2 Adoption of the agenda

The group adopted the agenda set forth in resolution 2010/2/SSGEF05.

3 Ecological Quality Objectives on Seabird Population Trends in OSPAR Region II

3.1 Introduction

WGSE was asked to review progress with the draft EcoQO for seabird population trends in OSPAR II (Greater North Sea), including assessing the degree to which appropriate and available data had been used and the reliability that OSPAR might place on the values derived from the EcoQO. WGSE was also asked to make recommendations on the processes used to derive the EcoQO and for its future updating.

WGSE understands that there has been delay in producing the EcoQO OSPAR II report, and therefore it was unfortunately not possible for the group to review it during the ordinary meeting. However, this chapter became available in December 2011 and WGSE worked intersessionally to comply with the overall schedule for reporting to OSPAR BDC in January 2012.

3.2 Data and methods

Data on seabird breeding population trends were delivered by the different countries and for a range of years as follows:

Norway:	1980–2010
Sweden:	2001–2010
Denmark (Wadden Sea area only):	1991–2008
Germany:	1991–2008
The Netherlands:	1980–2010
Belgium:	1980–2010
United Kingdom:	1960–2010

Data were missing for France and for the non-Wadden Sea area of Denmark.

Based on the fact that finally almost all relevant data were supplied to ICES WGSE via the national OSPAR contact in Germany, it was decided to analyse seabird population trends for OSPAR region II for the 20-year period 1991–2010.

Most national data sets covered all species but earlier analysis of data from the UK suggested leaving out a few species for which data were considered not being sufficiently representative. Hence, the following 16 species were selected to comprise sufficient data throughout their breeding range in OSPAR region II:

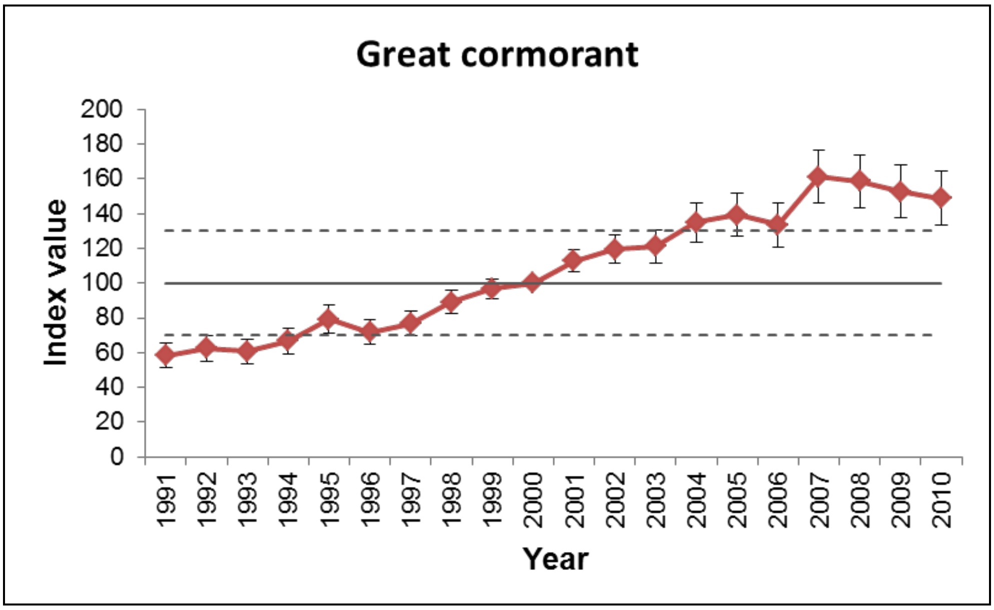
- Great cormorant, European shag, Arctic skua, Mediterranean gull, black-headed gull, common gull, lesser black-backed gull, herring gull, great black-backed gull, black-legged kittiwake, sandwich tern, common tern, Arctic tern, little tern, common guillemot, razorbill.

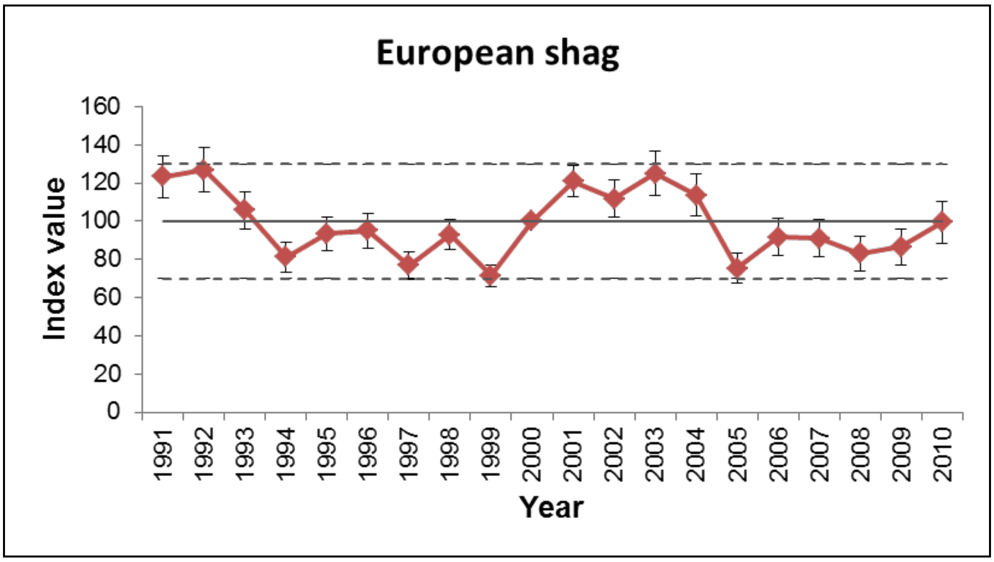
Population trends were analysed using TRIM version 3.53 (Statistics Netherlands). For each of the 16 species and each of the 20 years, annual trend indices were calculated. The intermediate year 2000 was set as the baseline index 100. As anthropogenic activities have influenced seabird populations over many decades, though to a different degree, it is impossible to state which period would be the one least influenced by humans. As a first approach, 2000 was taken as reference year in relation to which population developments were analysed.

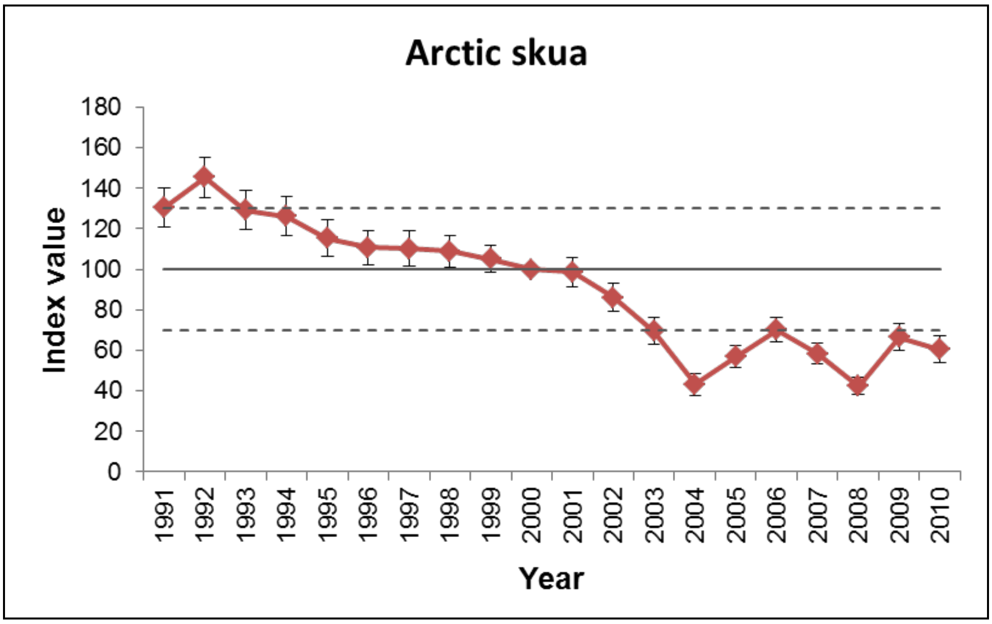
Based on ICES WKSEQUIN (2008) and later updates, the target levels for the trend indices were set to 130 (upper level) and 80 (single-egg laying species) or 70 (species laying more than one egg), respectively. The proportion of species that were within target levels for the respective years gives the final output for this EcoQO.

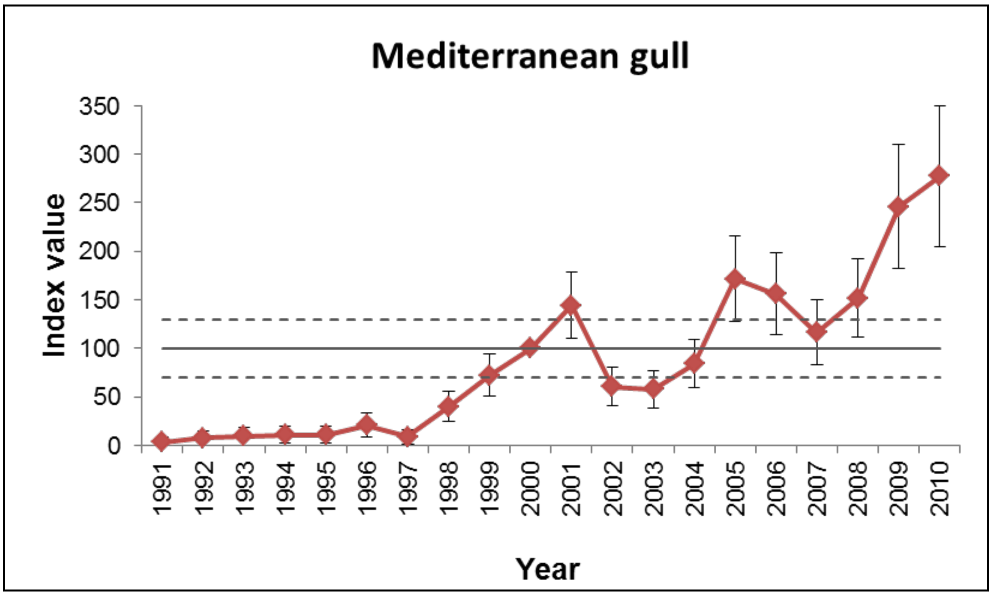
3.3 Results

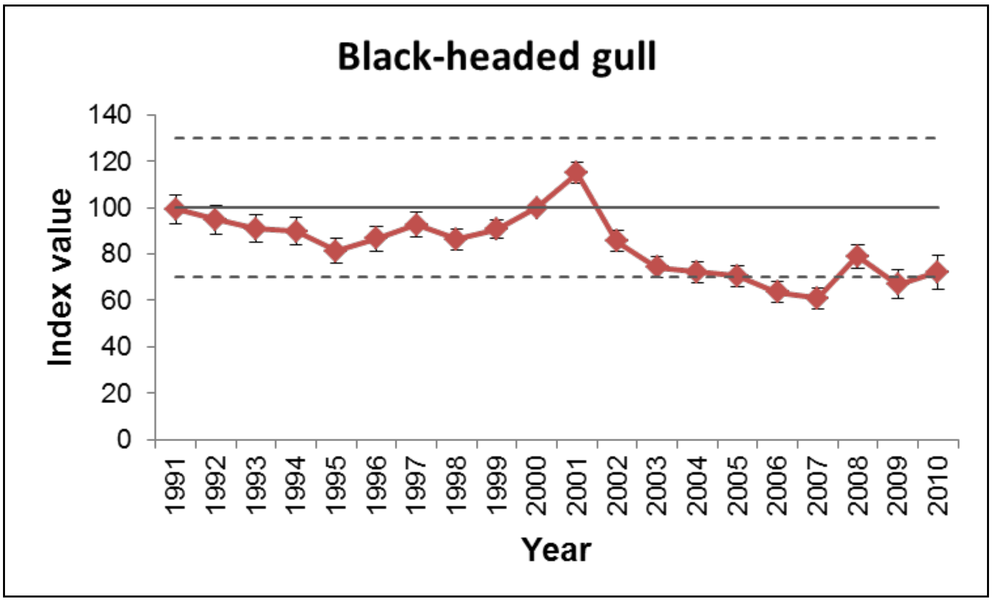
The populations of the 16 seabird species breeding in OSPAR region II have developed differently. Some species have increased or decreased throughout the study period, other showed increases, followed by later decreases (Figure 3.1).

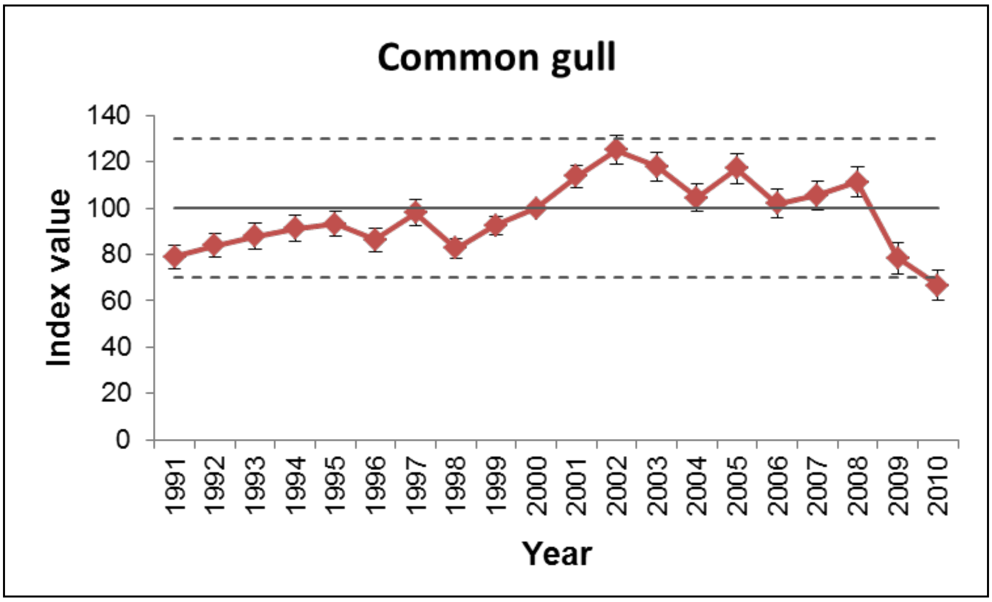


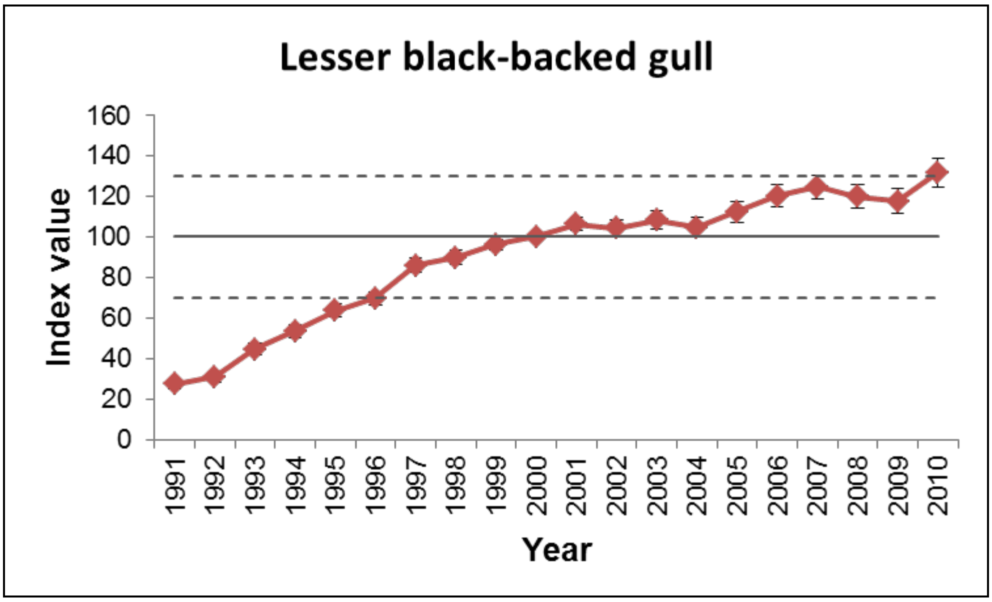

European shag
Index value
160
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

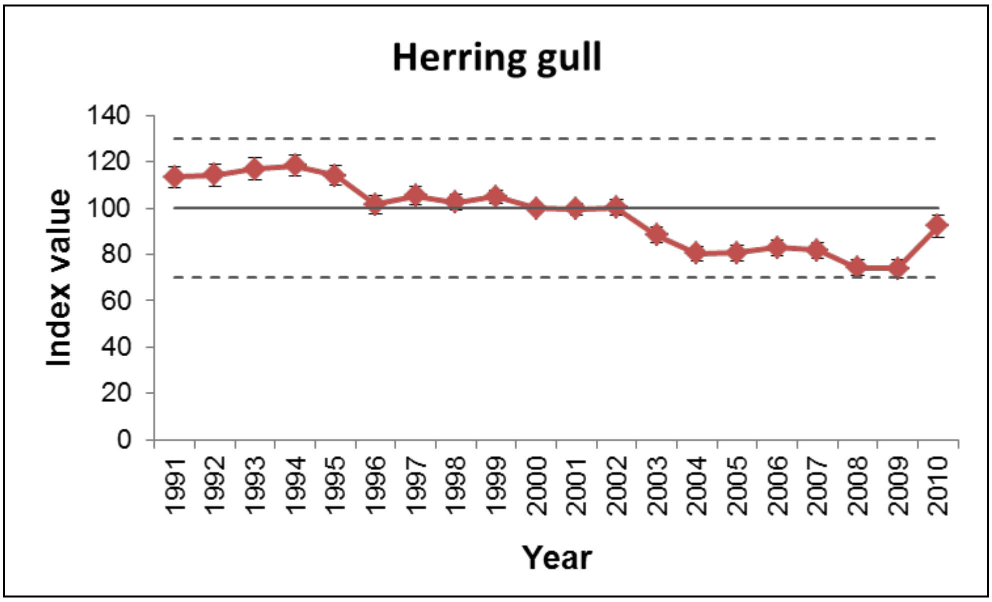

Arctic skua
Index value
180
160
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

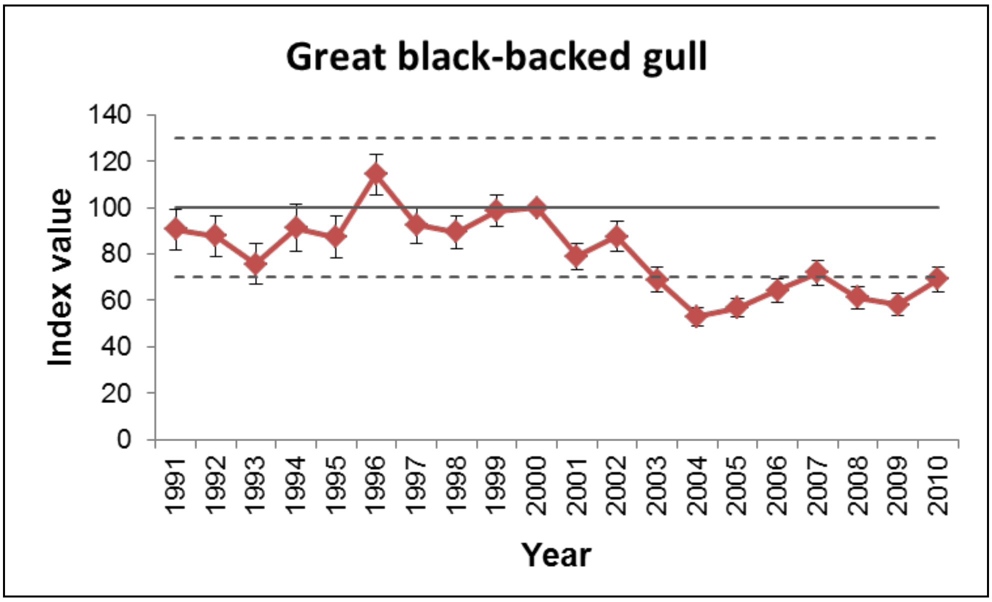

Mediterranean gull
Index value
350
300
250
200
150
100
50
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

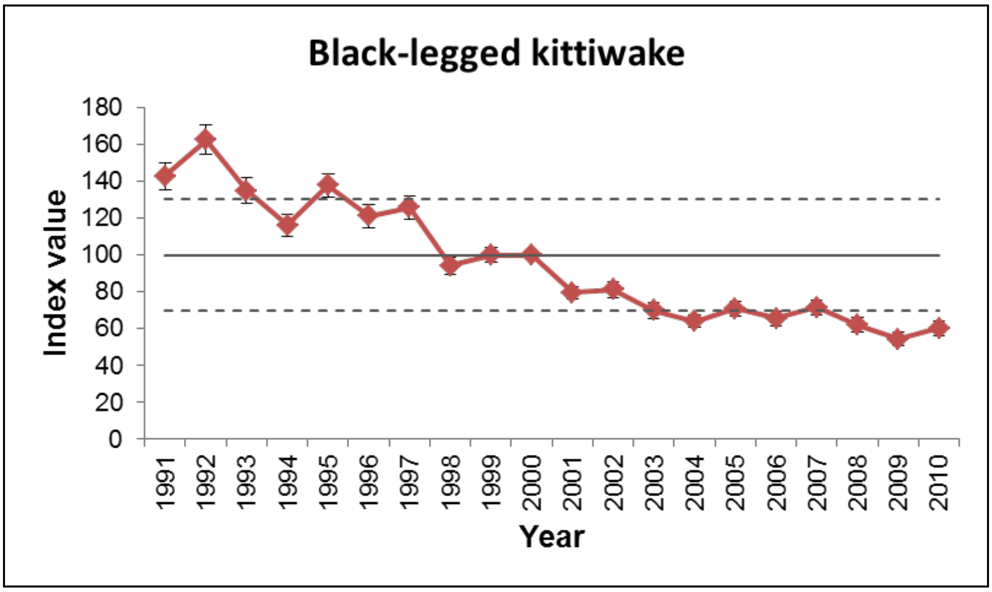

Black-headed gull
Index value
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

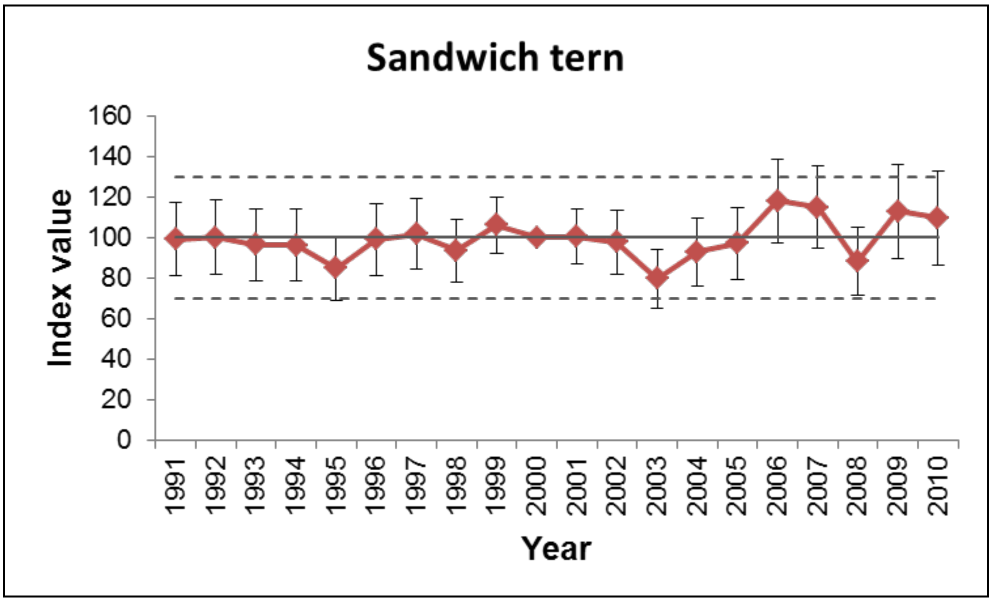

Common gull
Index value
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

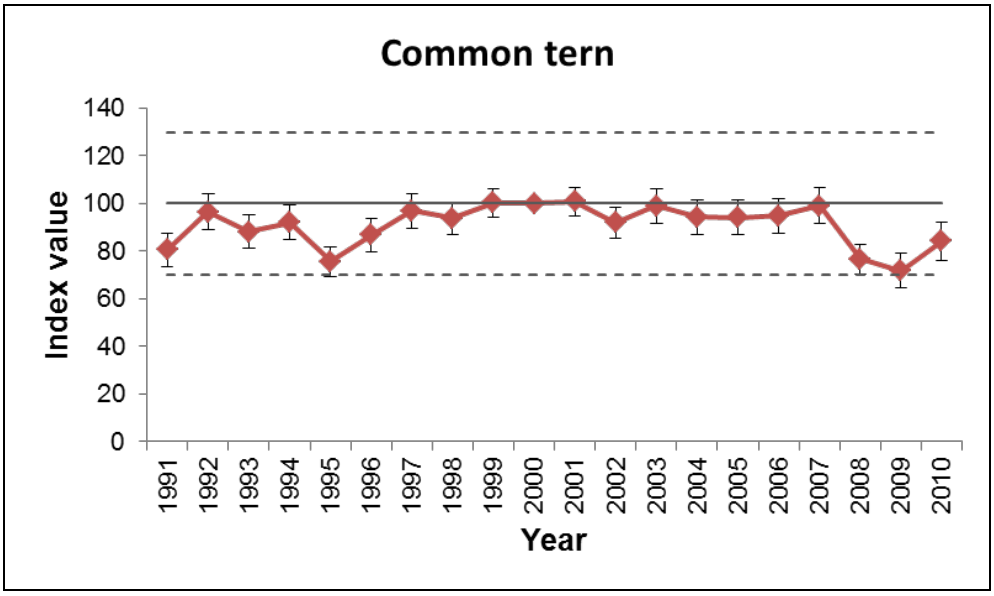

Lesser black-backed gull
Index value
160
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

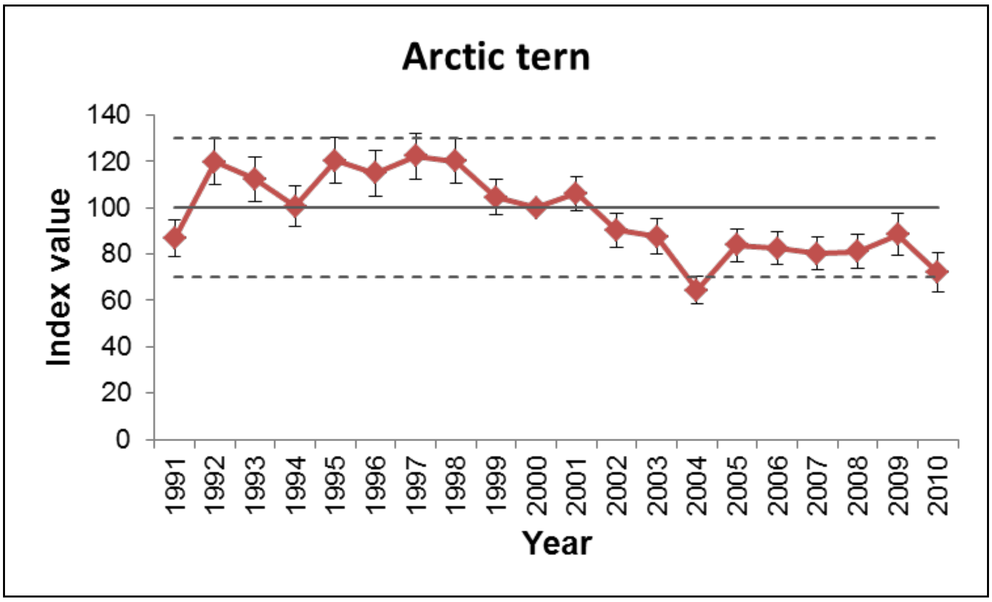

Herring gull
140
120
100
80
60
40
20
0
Index value
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

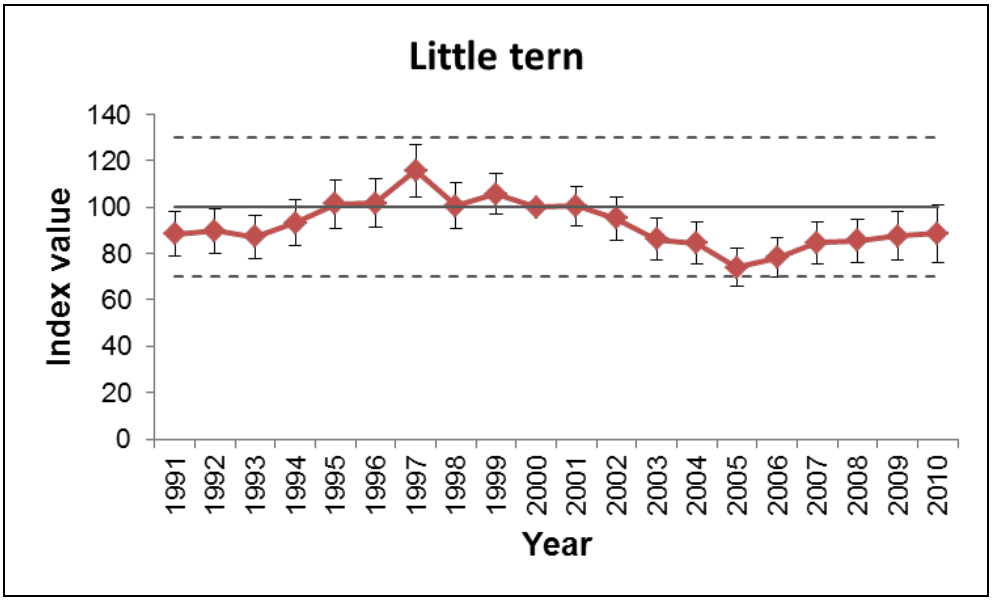

Great black-backed gull
140
120
100
80
60
40
20
0
Index value
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year

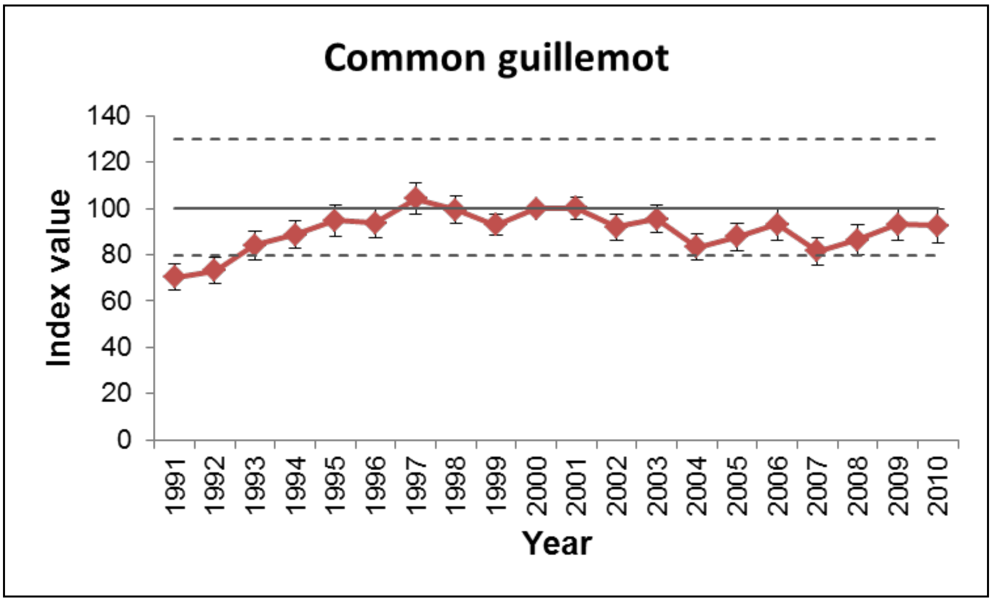

Black-legged kittiwake
Index value
Year
180
160
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


Sandwich tern
Index value
Year
160
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


Common tern
Index value
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Arctic tern
Index value
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year


Little tern
Index value
Year
0
20
40
60
80
100
120
140
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010


Common guillemot
Index value
Year
0
20
40
60
80
100
120
140
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

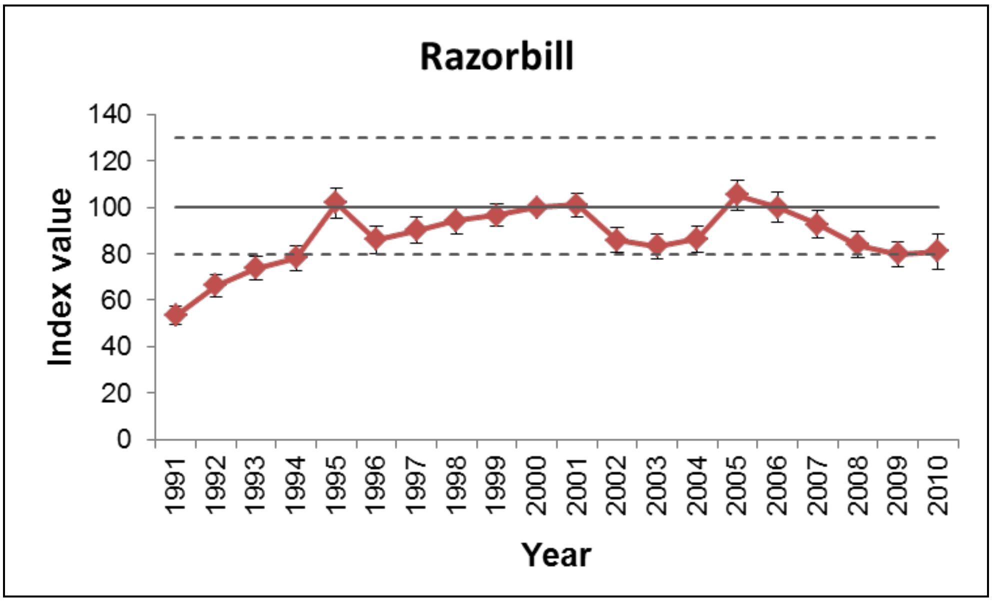


Figure 3.1. Population trends of sixteen seabird species breeding in OSPAR region II (Greater North Sea) from 1991–2010. The year 2000 was chosen as baseline with the index value set to 100. The vertical lines of the index values give the standard errors. The dashed lines indicate the range for the target values.

The EcoQO was not achieved in 1991–1993, 2004, 2006 and 2008–2010 (Figure 3.2). The number of species not reaching target levels increased recently from 3 (2007) to 8 (2010), the lowest value within the 20-year period. From the eight species that did not reach target levels, three were above and five below these targets.

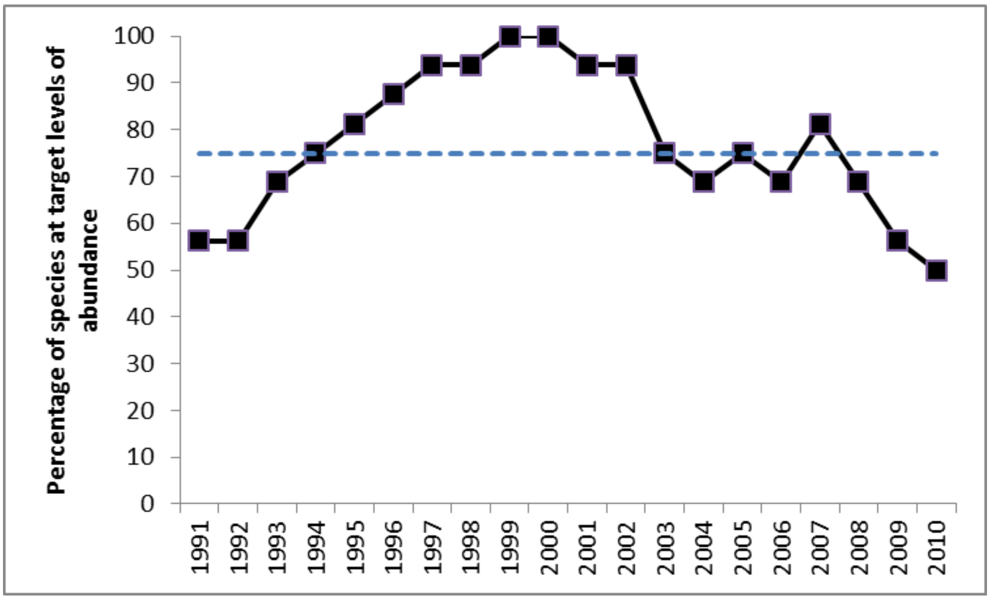


Figure 3.2. The proportion of species in OSPAR region II that were within target levels of abundance during 1991–2010, based on the population trends of the sixteen species shown in Figure 3.1. The EcoQO was not achieved in years when the proportion dropped below 75%.

3.4 Conclusions

By the end of the year 2011 it was finally possible to collate data on seabird population trends for almost all countries bordering the Greater North Sea area. Thus, the development of the EcoQO for this OSPAR region was now enabled. For sixteen major breeding seabird species it was possible to get annual, representative population trends to be included in the EcoQO analysis. The species that have not yet been included due to sufficiently representative data on an annual basis are northern fulmar, northern gannet, great skua and Atlantic puffin. Future effort is needed to include these species as well.

Because of the data structure and the time available, trend analysis was performed using TRIM as has been the case in similar EcoQO analyses before. Following recent success with implementing the Thomas method for OSPAR region III (ICES 2010) a similar update for region II should be evaluated.

ICES WGSE thanks all contributing parties for collecting and delivering data. Data from northern France as well as the non-Wadden Sea areas of Denmark should be included for the future to allow for an even better spatial coverage of seabird populations within OSPAR II.

More thoughts would be needed to evaluate the reference (baseline) periods (years) for analysis. While the year 2000 might be a good compromise for the study period and the different human pressures acting on the different species, species-specific periods may be a better alternative.

However, the basic structure of this EcoQO has been established before (ICES 2008, ICES 2010) and is considered useful and applicable for OSPAR region II. Possible future refinements would not alter the principal structure of this tool.

The years where the EcoQO has not been achieved is similar between OSPAR regions II and III, but the percentages of species that do not reach target values is much higher for region III (ICES 2010).

3.5 References

ICES. 2008. Report of the Workshop on Seabird Ecological Quality Indicator, 8-9 March 2008, Lisbon, Portugal. ICES CM 2008/LRC:06. 60 pp.

ICES. 2010. Report of the Working Group on Seabird Ecology (WGSE) 2010. ICES CM 2010/SSGEF:10. 81 pp.

4 Effects of Offshore Windfarms on Seabirds

4.1 Overview

The picture that emerges from functioning marine windfarms is of little observed bird mortality, and a tendency for seabirds to avoid the arrays of turbines when flying past. Most or all data, however, have been collected during fair weather, so the possibility of collisions during poor visibility and high winds has yet to be evaluated. There is evidence of less avoidance by landbirds during night time, but night-time data collected by radar are hampered due to interference by the wind turbines themselves.

Assessing the effects of offshore windfarms upon seabirds has three components. First, the area for the wind farm needs to be surveyed to determine which species use that area, during what seasons, and for what purpose (e.g. for feeding or just traversing). Second, once it has been determined that the use by seabirds of an area overlaps the proposed turbine site, the probability of collision needs to be determined. That is, given that birds are present in the vicinity of a turbine, what is the likelihood that these birds will collide with the turbine blade? There have been fairly substantial data amassed to address the first question, but almost none to address the latter: the probability of collision, given the spatial overlap or potential spatial overlap. Thirdly, once the wind farm has been constructed, it is then necessary to measure both of the above quantities (distribution and probability of collision in response to the presence of the turbines).

Theoretical impacts of proposed turbines have been summarized in Garthe and Hüppop (2005), Fox *et al.* (2006) and Masden *et al.* (2009, 2010). It is the goal of this report to summarize what has been learned from observations of birds in the vicinity of operational windfarms, and to review the voluminous literature on costs and benefits of the various methods of surveying birds both before and after construction.

Most post-construction data on seabirds to date are from the Horns Rev (North Sea) and Nysted (Baltic sea) wind farms off Denmark , which began operating in 2002 and 2003, with lesser amounts from Tunø Knob, Denmark and in Nogursund and Kalgursund, Sweden (Langston 2010). Most data are on reactions of birds to the presence of the turbines, taken both by radar and visually.

There is still very little data available to address how likely a given bird is to strike a turbine, provided that the bird encounters the turbine. Prominently lacking are any data that bear on strike probabilities during fog, rain, snow and high winds, when strikes are presumably most likely to occur. At the same time, there are no reports to date of large numbers of birds striking turbines or being found dead in their vicinity.

There has been much debate on how to best survey birds at seas in the vicinity of windfarms, and over areas where windfarms have been proposed (Camphuysen *et al*. 2004, Huddleston 2010). Choices are mainly among surveying from a boat using observers, surveying from a plane using observers and surveying from a plane using high definition video. Each method has its advantages, whereas the HD Video sampling is at an experimental stage and it is not clear whether this will prove a viable option. The best approach will undoubtedly be to use a combination of methods depending on what species are present and the general weather characteristics of the area to be surveyed.

4.2 Pre-Construction

Proposals for additional marine windfarms have generated a very large numbers of surveys designed to determine seabird usage of selected sites. Surveys have been conducted by ship and aircraft, using both human observers, and more recently, High Definition video mounted on aircraft. Recent advocates of the new HD Video technology (Thaxter and Burton 2009) promote its use as a replacement for more traditional boat-based and aircraft-based observer surveys. The jury is still out as to what constitutes the best method, and it is likely that a combination of methods will ultimately yield the highest quality information.

4.2.1 Boat Surveys

Shipboard surveys have the advantages of providing the most detailed data, including especially data on bird behaviour, the highest detection probabilities, and the ability to surveys in the broadest range of weather conditions. Further, shipboard surveys are the only way in which data on bird prey and basic oceanographic data can be collected simultaneously with the data on birds (Camphuysen *et al.* 2004, Veit *et al.* 2008). Boats generally travel at about 10 kn or less, especially if using echo-sounding equipment, and this of course limits the aerial coverage. Nevertheless, ships of opportunity often provide “free” platforms from which to gather data – an option that is rarely or never available on airplanes.

4.2.2 Aircraft Surveys

Aircraft surveys with observers have the advantage of fast spatial coverage, potentially less disturbance to some species (although some bird inevitably are disturbed by planes flying over regardless of elevation). Species identification is more difficult, and sometimes impossible, from a plane, and it is generally much more difficult to collect even the most basic data on behaviour when moving at flying speed (often about 100 kn). The latter can be a serious disadvantage, as it is critical to know whether birds are just passing through a given area or using it as a place to find food. Very basic data on behaviour (sitting, flying, feeding) can often help to resolve these issues (Camphuysen *et al.* 2004).

4.2.3 High Definition Video

HD Video, while still at an experimental stage, have the potential to provide even broader spatial coverage (since the aircraft can fly faster than possible when using human observers), increased safety due to higher flight altitude, and improved density estimates because a permanent record of the data can theoretically be maintained (Thaxter and Burton 2009). Nevertheless, HD Video is at the moment extremely expensive (up to 300 times the cost of boat surveys, in a recent USA estimate) and the ability of the HD Video to adequately resolve individual birds for identification and counting is still in development (Thaxter and Burton 2009, Langston *et al.* 2010). HD Video generates truly vast quantities of data, and the images need to be examined personally by trained observers to both identify and count the birds present in each frame.

Some direct comparisons of HD Video with both boat and airplane-with-human-observer surveys are in progress right now in the U.K. and the U.S.A and the results of such analyses will inform future choice of survey method. It remains to be seen whether HD Video: 1) Can resolve birds well enough to be identified and counted consistently; 2) Can be done at a reasonable cost (and much of the cost revolves about the unknown of having trained observers identify and count birds from the videos); 3) Is effective during other than perfectly clear and windless weather.

4.2.4 Radar

Radar is probably of little use for preconstruction surveys, except for measuring migration past fixed points (see below). While there is potential to use radar for monitoring during bad weather (as it can distinguish birds during rain and fog), it practice radars have too small a range to be effective for broadscale surveys. They are useful for monitoring migration past a single point, such as at the Avalon, New Jersey, USA seawatch (http://www.fws.gov/filedownloads/ftp_gis/CBFO/Census%20documents/Seawatch_Radar_Forsell.pdf), and such data can usefully identify those areas through which birds habitually travel during migration. On the other hand, radar can be very useful for monitoring strike probabilities once turbines have been constructed (Drewitt and Langston 2006, 2008).

4.2.5 Night

Tracking data have revealed that seabirds have activity patterns at night that are different from those during the day, and therefore special care needs to be taken to assess bird activity around wind turbines at night. Radar is effective at night, and the suggestion from studies cited above is that birds are somewhat less inclined to avoid turbines at night. There are few data from foggy or rainy nights, the conditions under which most birds are likely to strike (Rich and Longcore 2006). Therefore, there is a clear need for radar surveys conducted during poor visibility at night to assess whether birds are attracted to turbines, and whether they are likely to be struck.

4.2.6 Adverse Weather Conditions

It is highly likely that most of the damage done to seabirds by wind turbines will occur during inclement weather, when birds are less likely to be able to see the turbine blades, and less able to manoeuvre out of the way if they do see them. All of the techniques above are compromised by bad weather, and indeed there is a near absence of data collected during these conditions.

Recent work off North America will conduct simultaneous surveys off the middle Atlantic states using both boat surveys and aircraft-based HD Video to contrast abundance estimates using each technique. Until similar methodological comparisons have been made at a variety of locations it will not be possible to promote any one method as the "best".

4.3 Post Construction

4.3.1 Mortality

Pettersson (2005) monitored 10 wind turbines off Ooland, Sweden for three spring and fall migration seasons, using both visual and radar detection, and counted ~ 2 million sea ducks migrating past during that time. He recorded only one collision, in which one Common Eider was killed outright and four others knocked to the water but apparently survived. While more data are desirable, these extensive observations suggest that birds tend to avoid turbines and for this reason avoid being killed.

4.3.2 Habitat Loss

Analyses to date have focused on collision risk and avoidance (Desholm and Kahlert 2005, Blew *et al.* 2008) and have provided almost no information on impacts of loss of habitat, even though avoidance itself implies a certain amount of habitat loss.

4.3.3 Changed Behaviour

Data on impacts upon seabirds of existing windfarms are largely limited to three or more large windfarms in Denmark, and, more recently, from one windfarm in The Netherlands. There is evidence of some avoidance of turbines and the marine habitats in which they are situated. At Horns Rev and Nysted in Denmark, Common Eiders and Common Scoters were detected by radar to fly around the installed turbines, suggesting that the birds see the turbines and change their flight direction to avoid hitting them. Similarly, Northern Gannets avoided an array of turbines off the Netherlands (Dirksen *et al.* 2004). On the other hand, Common Eiders were struck by turbine blades as they passed an array of turbines off Sweden (Pettersson 2005); the suggestion was that the birds saw the array but nevertheless passed too close to the outermost turbine.

A major limitation of these Danish studies is that they were collected only during fair weather ("data collected in calm winds (< 10 m/sec) and no precipitation situations"; Desholm and Kahlert 2005), so the question of how birds would respond during a storm, or even if they could see the turbines under such conditions, remains unknown. Extensive data on tower kills of birds at other man-made structures (including ships and platforms at sea) clearly show that the bulk of mortality at such structures, especially lighted ones, occurs during rain, fog, snow and high winds when birds cannot see the structures, are attracted to lighting on the structures and are less able to manoevre about them (Wiese *et al.* 2001; Jones and Francis 2003; Erickson *et al.* 2005, Montevecchi 2006, Hüppop *et al.* 2006, Masden *et al.* 2009, 2010).

4.4 References

Barclay, R.M.R., E.F. Baerwald, and J.C. Gruver. 2007. Variation in bird and bat fatalities at wind energy facilities: assessing the effect of rotor size and tower height. Canadian J. of Zoology 85: 381- 387.

Blew, J., M. Hoffman, G. Nehls, V. Hennig. 2008. Investigations of the bird collision risk and the responses of harbour porpoises in the offshore wind farms Horns Rev, North Sea, Nysted, Baltic Sea, Denmark. Part I Birds. Bio Cosult SH Final report

Boehlert, G. W. and A.B. Gill. 2010. Environmental and ecological effects of ocean renewable energy development. Oceanography 23: 68-81.

Camphuysen, C.J., A.D. Fox, M.F. Leopold and I.K. Pedersen. 2004. Towards standardized seabirds at sea techniques in connection with environmental impact assessments for offshore wind farms in the U.K. A comparison of ship and aerial sampling methods for marine birds, and their applicability to offshore wind farm assessments. COWRIE – BAM- 02-2002.

de Lucas, M., G.E.E. Janss, and M. Ferrer. Birds and Wind Farms: Risk Assessment and Mitigation,

Desholm, M. 2006. Wind farm related mortality among avian migrants – a remote sensing study and model analysis. PhD Dissertation. University of Copenhagen.

Desholm, M. and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. Biology Letters 1: 296-298.

Dirksen, S., K.L. Krijgsveld, and R.C. Fijn. 2009. Offshore windenegjie: effecten op vogels. De levendre Natuur 110:284-286.

Drewitt, A.L. and R.H.W. Langston. 2006. Assessing the impacts of windfarms on birds. Ibis 148: 29-42.

Drewitt, A.L., R.H.W. Langston. 2008. Collision effects of wind power generators and other obstacles on birds. Ann. N.Y. Acad. Sci. 1134: 233–266.

Erickson, W.E., G.D. Johnson, and D.P. Young, Jr. 2005. A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. 2005.

Fox, A.D., M. Desholm, J. Kahlert, T.K. Christensen, and I.K. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore windfarms on birds. Ibis 148: 129-144.

Garthe, S. and O. Huppop. 2005. Scaling possible adverse effects of marine windfarms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41: 724-734.

Huddleston, J. (Ed.). 2010. Understanding the environmental impacts of offshore windfarms. COWRIE.

Hüppop, O., Dierschke, J., Exo, K.M., Fredrich, E. & Hill, R. 2006. Bird migration studies and potential collision risk with offshore wind turbines. Ibis 148: 90–109.

Jones, J. and C.M. Francis. 2003. The effects of light characteristics on avian mortality at lighthouses. Journal of Avian Biology 34: 328- 333.

Langston, R.H.W. 2010. Offshore wind farms and birds: Round 3 Zones, Extensions to Round 1 and Round 2 Sites, and Scottish Territorial waters. RSPB research report #39. ISBN 978-1-905601-25-7

Larsen, J.K. and M. Guillemette. 2007. Effects of wind turbines on flight behavior of wintering common eiders: implications for habitat use and collision risk. Journal of Applied Ecology 44: 516-522.

Masden, E.A., D.T. Haydon, A.D. Fox, R.W. Furness, R. Bullman, and M. Desholm. 2009. Barriers to movement: impacts of windfarms on migrating birds. ICES J. Marine Sci. 66: 746-753.

Masden, E.A., A.D. Fox, R.W. Furness, R. Bullman and D.T. Haydon. 2010. Cumulative impact assessments and bird/windfarm interactions: developing a conceptual framework. Environmental Impact Assessment Review (2009), doi:10.1016/j.eiar.2009.05.002

Montevecchi, W.A. 2006. Influences of artificial light on marine birds. Pages 94-113 in C. Rich and T. Longcore (eds) Ecological Consequences of Artificial Night Lighting. Island Press, Washington, D.C.

Pettersson, J. 2005. The impact of offshore wind farms on bird life in southern Kalmar Sound, Sweden. A final report based on studies 1999–2003. Report to the Swedish Energy Agency. ISBN 91-631-6878-2.

Rich, C. And T. Longcore (Eds). 2006. Ecological Consequences of Artificial Night Lighting. Island Press, Washington, D.C.

Thaxter, C.B. & Burton, N.H.K. (2009) High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols. British Trust for Ornithology Report Commissioned by Cowrie Ltd.

Veit, R.R., J.A. Santora and H. Owen. 2008. Using a video camcorder to quantify spatial association between seabirds and their prey. Marine Ornithology 36: 145-151.

Wiese, F.W., W.A. Montevecchi, G.K. Davoren, F. Huettman, A.W. Diamond and J. Linke. 2001, Seabirds at risk around offshore oil platforms in the Northwest Atlantic. Marine Pollution Bulletin 42: 1285-1290.

5 The existence and use of long-term seabird data-sets as indicators of recruitment in small pelagic schooling fish

Recruitment to small pelagic fish populations such as gadoids and sandeels is notoriously difficult to study directly. It is difficult to sample these fish in the field and it is not easy to model this key demographic parameter. It has proved possible to use certain seabird demographic data as a proxy for recruitment to some fish populations. A further exploration of this in more species of seabirds and fish species would be a worthwhile and cost-effective exercise. It could also prove a fertile collaboration between WGSE and relevant EGs working on small fish populations.

5.1 Introduction

Relationships between the relative abundance of certain fish stocks and biological characteristics of the predator populations (seabirds or marine mammals) have been investigated around the world (e.g. Anderson 1980, Cairns 1987, Monaghan *et al.* 1989, Cherel & Weimerskirch 1995, Barrett 2002, Diamond & Devlin 2003, Durant *et al.* 2003, Crawford *et al.* 2007, Kirkman *et al.* 2007). Comprehensive reviews have been published in recent years addressing the issue in depth (Montevecchi 1993, Tasker & Furness 2003, Sydeman *et al.* 2007, Parsons *et al.* 2008, Einoder 2009, Fauchald 2009, Gaston *et al.* 2009). Seabirds offer many advantages for study. They are highly visible animals in an environment in which most organisms are hidden under water. They are easily enumerated as they travel or forage in productive marine hotspots. Most species are colonial and gather annually in large numbers at relatively few locations in order to reproduce, a convenient occurrence that allows one to census populations and monitor trends of multiple coexisting species at various trophic levels simultaneously. Furthermore, some species are easy to observe and capture at colonies, allowing measurements of a wide variety of demographic, behavioural and physiological parameters. Given their relative ease of study, seabirds have frequently been identified as useful indicators of the health and status of marine ecosystems (Piatt *et al.* 2007).

Many studies have shown that seabirds are sensitive to changes in food supply, and therefore have potential as monitors of fish stocks. Breeding failures in Peruvian guano birds (boobies, pelicans, cormorants) heralded the collapse of the anchoveta *Engraulis ringens* fishery during the 1950s and 1960s (Duffy 1994). Reproductive failures of the Atlantic puffin *Fratercula arctica* presaged the collapse of herring *Clupea harengus* stocks off Norway during the 1970s (Barth 1978, Lid 1981, Vader *et al.* 1989, Anker-Nilssen 1992). Evidence has been provided showing that several species of seabirds breeding at Røst, Lofoten Islands breed successfully only when larval and 0-group stages of herring are abundant (e.g. Bakken 1989; Anker-Nilssen 1992; Anker-Nilssen & Øyan 1995; Anker-Nilssen *et al.*, 1997; Durant *et al.* 2003). The crash of common guillemot populations in the Barents Sea during the 1980s signalled the collapse of the capelin *Mallotus villosus* in the region (Vader 1988, Anker-Nilssen *et al.* 1997). Widespread failures in breeding of the black-legged kittiwake on Shetland (N North Sea) during the late 1980s indicated the collapse of sandeel *Ammodytes* sp. stocks and a widespread change in environmental conditions in the North Sea (Heubeck 1989, Danchin 1992, Poloczanska *et al.* 2004). The robustness of many of these published relationships indicated that levels of pelagic prey harvest by seabirds can provide reliable indices of prey abundance within and probably also outside reproductive seasons and foraging ranges around breeding colonies (Montevecchi & Myers 1995).

For most seabird species, however, breeding parameters suitable for biomonitoring have to be measured over a wide range of prey densities. It is clear that responses vary among species and care must be taken when interpreting seabird data as a proxy for fish abundance (Furness & Camphuysen 1992). In most studies, biological characteristics such as foraging behaviour, nest attendance, chick predation, reproductive success or other factors were simply correlated with fish abundance. Fairly strong correlations have been found, indicating that diet studies are potentially useful for monitoring changes in resource availability and (prey fish) recruitment. In other case studies, time series of diet data were investigated, for example by using Generalized Linear Models, with the estimated annual stock sizes or catches of fish prey included as independent effects. However, biological characteristics in seabirds may not be good indicators of prey availability in situations where the predators have more options. Our ability to accurately infer prey composition and availability from a measured response is limited by the variability of a species' response to changing prey density, and requires an understanding of the functional relationship between each seabird parameter and food supply (Einoder 2009).

Recruitment to small (pelagic) fish populations such as gadoids and sandeels is notoriously difficult to study directly. Seabirds and marine fish share habitats and food webs, but there is (too) little contact between the disciplines that study them. Fish stock assessment models, designed for use on teleost fishes with high fecundity, high recruitment variability, and continued growth throughout life, may be strengthened by inclusion of seabird data (Cairns 1992). Monaghan (1996), based on studies of four seabird species on Shetland feeding on sandeels, suggested that that parameters concerned with foraging behaviour offered the most useful indices of the status of prey populations. Moreover, she concluded that differences between seabird species in their responses to changes in prey availability were demonstrated to be useful to provide information on the abundance, distribution and age structure of the fish "far more cheaply than conventional fisheries surveys" (Monaghan 1996). Marine ecosystems are complex, however, and there are many good reasons not to be overly optimistic about the use of certain seabird demographic data as proxies for the condition of the prey stock, let alone as proxies for recruitment to fish populations. However, a further exploration of seabird data in this context could be worthwhile and may lead to a fertile collaboration between WGSE and relevant EGs working on small fish populations.

5.2 Methods

Greenstreet *et al.* (1999) have reviewed consumption of pre-recruit fish by seabirds and the possible use of this as an indicator of fish stock recruitment. Here we have revisited this issue and investigated the existence and use of long-term seabird datasets as indicators of recruitment, with emphasis on North Atlantic species. Some overlap between the earlier review and the present one was inevitable. First we briefly summarise case studies in which a link between certain population trends or demographical parameters and fish stocks was found (Table 5.1). Our searches for data have been restricted to published, preferably peer-reviewed sources, but included studies in which post-recruit fish formed the main prey (seabirds as indicators or marine resources). Second, based on this inventory, we have assessed which species (or types) of seabirds yielded the most promising results and highlight the best studies as examples. Third we have summarised ongoing monitoring programmes that seemingly yield useful results.

5.3 Case studies

In Table 5.1, case studies have been listed to provide examples of observed demographical, behavioural, or population level effects of (major) fluctuations of prey stocks on seabirds around the world. Observed variables that provided the link between predators and prey are indicated and briefly commented on. The summary is by no means exhaustive, but serves as an overview of the demonstrated possibilities and constraints when using seabirds as indicators of prey fish abundance.

Table 5.1. Case studies as examples of the use of seabird data-sets as indicators of prey fish stocks.

Predator	Variable	Prey	Comment	Reference
Brown Pelican	breeding status fledging rates	Anchovy	Pelican fledging success depends largely on levels of anchovy abundance and availability. The diet of breeding pelicans from was comprised of 92% anchovies.	Anderson *et al.* 1980 Brown pelican breeding effort (numbers of pairs that attempt to breed each year) is *probably* dependent largely on regional levels of anchovy abundance.
Puffin	diet, chick growth	capelin, herring, 0-group cod	Amounts of capelin, herring and 0-group cod fed to Atlantic puffin chicks were good indicators of fish availability	Barrett 2002 Varying proportions in numbers and masses of capelin, herring and cod in seabird diet showed clear responses to independently measured prey stocks.
Common Guillemot	diet, chick growth	herring	Amounts of herring fed to common guillemot chicks were correlated with the biomass of 1-	Barrett 2002 (See above)

			group herring in the region	
Puffin Common guillemot	mortality	sprat	Populations of puffins on Isle of May (Scotland) increased during the 1960s and 1970s, while these increases ceased in the 1980s. Breeding success remained high but there were declines in the survival rates. These changes appeared to be linked with a change in the number and distribution of sprats.	Harris & Bailey 1992
Common Tern	(1) percentage fish accepted by chicks, (2) foraging time, (3) chick growth	Alewife, smelt, emerald shiner, common shiner, bluntnose minnow, and trout-perch	More food was presented to the chicks than they could eat. Food acceptance levels increased with chick age and brood size and ranged from 43.5 to 91.5%. Tern pairs spent 45–64% of daylight hours foraging.	Courtney & Blokpoel 1980 (non-marine) food of common terns nesting on the lower Great Lakes was studied in 1979
common guillemot kittiwake, razorbill	winter distribution, mortality	sprat	In the early 1980s, a major southward and eastward shift in the wintering distribution of occurred in the North Sea, which was apparently related to a retreat of the sprat stock from the northern North Sea.	Camphuysen 1990 Seabird mass strandings and large-scale fluctuations in wintering distribution of seabirds followed changes in prey stock abundance or prey availability in winter.
kittiwake	nest attendance hatching rates fledging success duration of incubation shifts	(herring)	On average, the chick-rearing stage contained more sensitive indicators of food availability than prelaying or incubation stages. Overall, rates of hatching and fledging success, and the mean duration of incubation shifts were the most food-sensitive parameters studied.	Gill *et al.* 2002 Behaviour such as nest relief during incubation and adult attendance with older chicks were highly responsive to supplemental food and may be useful for monitoring environmental conditions in studies of shorter duration.
Common Guillemot, Kittiwake, Arctic Tern, European Shag	foraging behaviour	sandeels	Parameters concerned with foraging behaviour offered the most useful indices of the status of prey populations.	Monaghan 1996
Arctic Tern	breeding success	sandeels	Terns in Shetland had difficulty in finding sandeels of suitable size (4-8 cm size-class) to feed chicks, and the adults themselves were in poor condition prior to the chicks hatching. Adult arctic terns appeared to adjust their breeding effort in response to body condition.	Monaghan *et al.* 1989ab
25 species	breeding success index based on seabird size, cost of foraging, potential foraging range, ability to dive, amount of 'spare' time in the daily budget, and ability to switch diet.	sandeels	Testing the index with empirical data from Shetland during periods of reduced sandeel abundance showed a close correlation between seabird breeding performance and predictions from the index.	Furness & Tasker (2000) Presented a quantitative index of the sensitivity of different seabird species' breeding success to reduced abundance of sandeels

Heermans Gull Elegant Tern	diet	anchovy	Strong positive correlations between proportion of sardine in the seabirds' diet and sardine landings. Strong negative correlations between proportions of sardine vs the proportion of anchovy in the seabirds' diet and anchovy landings. Proportion of sardine landings was negatively correlated with the proportion of anchovy in the seabirds' diet and with the proportion of the landings of both anchovy and mackerel. The proportion of anchovy in seabirds' diet was positively correlated with anchovy landings. A low, marginally positive correlation was found between the proportion of mackerel in the diet and the proportion of mackerel landed.	Velarde *et al.* 1994 Dietary studies of seabirds provided reliable data on species composition of fish stocks, estimates of relative abundance, and availability of fish populations to higher trophic levels in this area. They also provided real-time, predictive, catch-independent data and complement commercial and research catch information.
kittiwake	diet	1+ and 0-group sandeels	Kittiwakes switched from feeding on 1+ group to 0 group sandlance, and results up until 2003 indicated that availability of both age classes had a positive effect on breeding success.	Wanless *et al.* 2006 Monitoring of reproductive success of kittiwakes, although useful, was not sufficient to tease apart the complex causation underlying poor breeding in one season. Complementary detailed research to identify the mechanisms involved was required.
puffin	fledging success	0-group herring	Year-class strength for the Norwegian spring-spawning herring is predominantly determined before most of the herring larvae have passed puffin colonies in July. Extremely good year-classes, (1983, 1991 and 1992), are characterized by very low mortality north of the colonies Jul-Aug. Based on the mean temperature in the Barents Sea in Jan (prior to spawning), the number of high wind speed events off northern Norway in Apr and fledging success of puffin, the year-class strength of herring in can be predicted.	Sætre *et al.* 2002 Study examines recruitment variability of herring emphasizing environmental influences on the determination of year-class strength, and on environmental signals indicating recruitment strength, such as conditions for breeding seabird populations
Cape Gannet	population	sardine, anchovy	Longterm changes at colonies are thought to be largely attributable to an altered abundance and distribution of sardine (Sardinops sagax) and anchovy (Engraulis encrasicolus)	Crawford *et al.* 2007
arctic tern, common tern, puffin, razorbiill	breeding success	0-group herring	A major new finding is the considerable inter-annual variation in the energy density	Diamond & Devlin 2003

			(fat content) of juvenile herring that are the main seabird prey; breeding success of both species of tern varied in parallel with the energy density of juvenile herring in the diet.	
Arctic skua	chick growth territorial attendance fledging rates	sandeel	Territorial attendance, chick growth rate and breeding success in Shetland were lowest in the late 1980s when recruitment of Sandeels in the surrounding waters was poor.	Phillips *et al.* 1996ab
Common tern	breeding performance chick diet	0-group herring	In German Wadden Sea colonies, the amount of clupeids in chick diet was positively correlated with the herring larvae density in the south eastern North Sea. A high clupeid proportion in tern diet apparently indicates a good stock of pre-recruiting clupeids, especially herring	Greenstreet *et al.* 1999 Example of seabirds that show fairly strong correlations between diet composition or food provisioning (or chick growth rate) and the abundance of pre-recruit fish
Great skua	diet	sandeels	At the population level skuas feed mainly on sandeels and fishery discards, but responded to declines in fish availability to facultatively prey on other seabirds.	Votier *et al.* 2007
Pigeon Guillemot	diet	sand dab	This study is one of the first to suggest that seabird diet can be used as an indicator of spatial variability in recruitment and settlement of demersal forage fish.	Robinette *et al.* 2007
Common Guillemot	foraging time, nest attendance	multi species (hydroacoustic surveys)	Empirical data on the time allocation of common murres in relation to measures of local prey density to examine whether adults provisioning chicks are more sensitive to changes in prey density than birds that are incubating eggs.	Harding *et al.* 2007
European shag	diet	0-group saithe	When comparing 1985 to 1986, in the second year the diet contained fewer saithe with a shift toward a higher proportion of older fish indicating that 1986 was a poor year for 0-group recruits in the area. This corroborated results of newly developed 0-group surveys which ran in 1985–92.	Barrett 1991 Data from sampling shag diet provided indications of low saithe production 2-3 years sooner than could be determined from ICES VPA data
Common Guillemot	chick fledging mass	sprat	Large-scale and long-term ecosystem changes resulting mainly from overfishing and recruitment failure of cod (main fish predator of sprat), affected natural-history patterns in common guillemots	Österblom *et al.* 2006
Tufted puffins	diet	1-group pollock	The proportion of pollock in	Hatch & Sanger 1992

Fratercula cirrhata and horned puffins *E. comiculata*			puffin diets at the Semidi Islands was strongly correlated with independent estimates of cohort strength in 3 years. Puffins provided a useful index of distribution and year- class abundance of first-year pollock.	
Rhinoceros Auklet	chick growth	0+ sandeel	Concurrent measures of chick growth rate, indexes of ocean production, and the proportion of sandeels in groundfish stomach samples were highest in 1985. The study suggests a linkage between ocean production, 0+sandeel abundance, and events on seabird colonies over a broad geographic range.	Bertram & Kaiser 1993 Collected data suggest that long-term monitoring on seabird colonies can contribute timely and inexpensive information on the recruitment of sand lance stocks in Canadian waters
Sandwich tern	chick diet	sprat, sandeel	Highly specialised piscivorous seabirds, like Sandwich Terns have limited capacity to switch to alternative prey species when the availability of a particular prey species is low. Therefore, variations in the diet of such species are likely to reflect fluctuations in food availability.	Stienen *et al.* 2000 Distinct diurnal rhythms in food transport coincided with diel vertical migration patterns in clupeids and sandeel. Clupeids' were mostly brought to the colony early in the morning and late in the evening, while the transport of sandeels was highest around noon.

In the case studies listed in Table 5.1, highlighted variables included a variety of parameters indicating reproductive success: breeding status (breeding or not), breeding success as a general indicator, or more specific values such as hatching rates, nest attendance, territorial attendance, duration of incubation shifts, chick growth, fledging mass, and fledging rates. Other parameters were indicating foraging success or foraging behaviour, such as diet composition, chick diet, percentage fish accepted by chicks, foraging time, foraging range. In some cases population size was the indicator used, or annual (winter) mortality, winter distribution, and the incidence of wrecks. Further factors (in fact highlighting species-specific sensitivity to changes in prey stocks) included the amount of 'spare' time in the daily budget of breeding seabirds, the species-specific cost of foraging and abilities to switch diet.

Greenstreet *et al.* (1999) concluded earlier that strong correlations between diet composition or food provisioning (or chick growth rate) and the abundance of pre-recruit fish were apparent in case studies reviewed by them. They commented that fisheries-derived and survey-derived estimates of recruitment apply to entire stocks or to very large geographical areas, so are on a much larger spatial scale than the distribution of fish providing food to seabird chicks at a particular colony. Some additional case studies were included in the current review. Long-term studies in which both the age of the prey fish is acknowledged and which provide a clear signal in demographical parameters are not common and are restricted to relatively well studied seabird populations in Europe (notably Norway, the United Kingdom, the Baltic, and some studies in Germany). Consequently, the contribution to fisheries science by seabird biologists is bound to be geographically restricted.

5.4 Key examples to use certain seabird demographic data as proxies for recruitment to some fish populations

Sætre *et al.* (2002) showed that the Norwegian spring-spawning herring is characterised by large, long-term stock size variations in which the main population dynamics mechanism explaining these fluctuations is variation in recruitment by nearly three orders of magnitude. The Atlantic puffin is an important predator of 0-group herring and colonies in northern Norway are strategically situated to signal recruitment strength. The year-class strength for Norwegian spring-spawning herring is predominantly determined before most of the herring larvae have passed the puffin colonies (in July). The extremely good year-classes, such as 1983, 1991 and 1992, seem to be characterized by very low mortality north of the colonies (July–August). Based on the mean temperature in the Barents Sea in January (prior to spawning), the number of high wind speed events off northern Norway in April and the fledging success of puffins, year-class strength of herring in July could be predicted.

Greenstreet *et al.* (1999) concluded that the reproduction of common terns on the southern North Sea coast (Germany) was strongly linked to the annual stock of juvenile herring, their main food source. Consequently, terns were considered to yield very useful data in addition to the fisheries' data to indicate abundance of the young herring stock. However, they proposed that some important points had to be clarified: (1) Decisive for the terns was the herring year class two calendar years before the respective breeding season (i.e. 1-ring in the breeding season). This may indicate that the 1-group herring is more important for tern reproduction than 0-group. (2) The correlations of tern data with the herring larvae abundance estimates are much closer than those with IBTS herring index (1-ring), suggesting that the sampling of larvae gave a better annual figure of the herring population 1 year later than the sampling of 1-ringers in the current year. Fish catches of 1-ringers may be taken more by chance than larvae sampling.

Greenstreet *et al.* (1999) also reviewed the potential of cormorants and shags to be used as a tool in assessing the relative abundance of 0-group saithe in Norway. 0-group saithe live in shallow, inshore waters that are notoriously difficult to sample. It is relevant to note that the relationship between VPA estimates of 1-group saithe and the numbers of young fish detected in surveys is very weak. Therefore, systematic surveys of prey harvests of shags breeding on inshore islands as supplementary inputs to models on fish abundance could be useful (Barrett 1991). Pellets were sampled on Bleiksøy (N. Norway). Saithe otoliths made up 81% and 58% of all items identified in these two years and the birds mainly took 0- and 1-group fish. When comparing 1985 to 1986, in the second year the diet contained fewer saithe with a shift toward a higher proportion of older fish. This indicates that 1986 was a poor year for 0-group recruits in the area. This corroborated results of newly developed 0-group surveys which ran in 1985–1992. It is worth noting here that the data from sampling shag diet provided indications of low saithe production two or three years sooner than could be determined from VPA data (ICES, 1997a).

Barrett (2002) reported that between 1980 and 2000, Atlantic puffins and common guillemots breeding in the southern Barents Sea fed their chicks on varying proportions of four main categories of prey: capelin, sandeels, 1-group herring *Clupea harengus* and 0-group cod *Gadus morhua*. The varying proportions in both numbers and masses of the capelin, herring and cod in the seabird diet showed clear responses to the independently measured prey stocks. Amounts of capelin, herring and 0-group cod fed to Atlantic puffin chicks appeared to be good indicators of fish availability, whereas only amounts of herring fed to common guillemot chicks were correlated with the biomass of 1-group herring in the region. The more general response by the Atlantic puffins probably resulted from their ability to catch only small fishes.

Sand dabs *Citharichthys* sp. are an abundant neritic fish of Central California, an area of persistent upwelling. 'Upwelling shadows' that develop in the lee of coastal promontories, retain surface waters and may promote spatial variation in fish settlement. Robinette *et al.* (2007) tested this hypothesis by studying the diet and foraging dimensions of Pigeon Guillemots *Cepphus columba* specialising in sanddab consumption at windward and leeward sites over a 6 yr period. The bird's take of sanddab was integrated with information on upwelling intensity and variability and sanddab larval abundance based on net sampling. Seabird diet at both sub-colonies was variable, but dominated by 1-group sanddabs. Persistent upwelling led to regional increases in sanddab larval abundance which in turn resulted in enhanced recruitment to leeward waters, as reflected in seabird diet. This study is one of the few to suggest that seabird diet can be used as an indicator of spatial variability in recruitment and settlement of demersal forage fish.

Frederiksen *et al.* (2007) used principal component analysis (PCA) to extract common signals from a number of intercorrelated time series. Response variables, whether breeding productivity of one species measured at several sites, or breeding performance of several species measured at one site, tended to be well correlated. Examples demonstrated that such common signals are correlated with physical and biological environmental variables. Data could therefore profitably be combined to identify common signals (regional means or principal components), which in turn were highly positively correlated with the original time series. Breeding productivities of European shag, black-legged kittiwake, razorbill and Atlantic puffin were mainly positively correlated. PC1 explained 51% of the total inter-annual variation in breeding productivity, and loadings were high and positive for all original time series. Breeding productivity was significantly positively associated with the sandeel larval index for European shag and black-legged kittiwake, but not for razorbill and Atlantic puffin. PC1 was also significantly correlated with the sandeel index, with a slightly lower proportion of variation explained than for shags and kittiwakes.

Diamond & Devlin (2003) compared 6–8 years of data on the biology (diet, and breeding success) of arctic and common tern (which feed at the sea surface); and Atlantic puffin and razorbill (deep diving seabirds) breeding on Machias Seal Island (MSI) in the Bay of Fundy with meteorological and oceanographic measurements. The date were compared with fisheries data on changes in the main prey of all the seabirds concerned (juvenile or 0-group herring), which are the most direct link between the seabirds and the physical properties of the marine system. Relationships between seabird productivity and diet, and other aspects of both herring biology (larval surveys, and fat content) and oceanography were explored. The proportion of herring in the diet of terns over 6 years varied inversely with herring larval abundance the previous autumn; but this relationship was not statistically significant in the puffin and razorbill. Breeding success of both species of terns varied in parallel with the energy density of juvenile herring in the diet until the last two years of the study, when sandeels and euphausid shrimp predominated in the diet.

Zooplankton-feeding sprat *Sprattus sprattus* is a major food source for breeding seabirds and piscivorous fish in the Baltic, and an important resource for commercial fisheries. Large-scale and long-term ecosystem changes resulting mainly from overfishing and recruitment failure of cod *Gadus morhua*, which is the main fish predator of sprat, affected natural-history patterns the common guillemot in a complex way.

As the sprat stock increased, leading to lower energy content of fish, common guillemot chick body mass at fledging decreased. However, chick fledging body mass recovered in recent years as the sprat stock diminished, which brought about corresponding increases in sprat weight-at-age and energy content (Österblom *et al.* 2006, see also Kadin *et al.* in press).

Stienen *et al.* (2000) studied food provisioning of Sandwich Tern chicks on Griend (Wadden Sea, Netherlands) in 1992-1998. Distinct patterns in food transport rate, diet composition and prey size were associated with weather conditions and diurnal or tidal rhythms. Wind speed also had a large impact on prey size and diet composition, with a decreasing proportion of Clupeidae brought to the chicks as foraging conditions became worse. Distinct diurnal rhythms in food transport coincided with diel vertical migration patterns in Clupeidae and Ammodytidae. Clupeidae were mostly brought to the colony early in the morning and late in the evening, while the transport of Ammodytidae was highest around noon. Tidal patterns in food delivery rate were probably related to tide-specific foraging areas used by the terns. A fish monitoring programme showed considerable variation in food abundance within the foraging area of the terns. Especially Clupeidae had a patchy distribution and most clupeids were caught in the coastal areas around Vlieland. In accordance to the pattern found in the colony, Clupeidae caught in 1996 and 1997 towards fledging of the chicks and just after hatching of the chicks in 1998 were relatively small.

5.5 Confounding factors

The above case studies provide examples of the effects of fluctuations of prey stocks on seabirds. Major declines in fish stocks can have easy to measure effects on seabirds such as reductions in the duration of incubation shifts, nest attendance, chick growth, fledging rates, and even population size, or increases in foraging trip duration, feeding range, and mortality rates. Many published studies provide simple correlations between biological parameters and stock size and not all these correlations turned out to be highly significant. Also, it is not clear in every cited case if certain reductions in prey *availability* for seabirds (notably for surface feeding birds; or more in general for birds with a higher 'sensitivity index' such as proposed by Furness & Tasker 2000) had always been caused by a reduction of the size of the prey stock, or rather by alterations in accessibility, the timing of appearance, shifts in the distribution and/or the densities of prey fish. Moreover, measured responses varied or were not always in accordance with the simplest of expectations (e.g. larger prey stock - higher breeding success, smaller stock – reduced success), so that warnings needed to be issued. Clearly, more (environmental) factors were involved in most if not all cases. So to repeat, while responses by seabirds to changes in prey availability could be useful to provide information on the fish themselves (Monaghan 1996), our ability to accurately infer prey composition and availability from a measured response requires a deep understanding of the functional relationship between each seabird parameter and the resource (Einoder 2009).

One rather recently highlighted confounding factor was the quality of prey; an aspect that has not been given attention in many studies of seabird diets. Several recent studies have demonstrated the effects of a marked change in the lipid contents (energy density) of prey fish, including contrasting effects of food quality and quantity on seabirds (Kadin *et al.* in press):

Diamond & Devlin (2003) compared 6–8 years of data on the biology of arctic and common terns. Their 'major new finding' was the considerable inter-annual variation in the energy density (fat content) of juvenile herring. Breeding success of the terns varied in parallel with the energy density of juvenile herring in the diet. Wanless *et al.* (2006) reported on unexpectedly low breeding success of Black-legged Kittiwakes on the Isle of May (North Sea) during a fishery ban implemented to enhance breeding conditions for seabirds. Initially this closure seemed to be beneficial for kittiwakes with breeding success recovering to pre-fishery levels. Despite the ban continuing, kittiwakes and many other seabird species in the North Sea suffered severe breeding failures in 2004. The low breeding success of kittiwakes in 2004 was consistent with the late appearance and small body size of 0 group sandeel but at odds with the two variables likely to operate via 1+ group availability (lagged winter sea surface temperature and larval sandeel cohort strength in 2003). Analysis of 1+ group sandeel body composition indicated that lipid content in 2004 was extremely low and thus fish eaten by kittiwakes during pre-breeding and early incubation were likely to be of poor quality. Monitoring of reproductive success of kittiwakes, although useful, was clearly not sufficient to tease apart the complex causation underlying the 2004 event. Monitoring programmes such as this therefore need to be complemented by detailed research to identify the mechanisms involved, and attribute and predict the effects of environmental change. Guillemot chick fledging body mass in the Baltic recovered in recent years as the sprat stock diminished, which brought about corresponding increases in sprat weight-at-age and energy content (Österblom *et al.* 2006). In an earlier study (Österblom *et al.* 2001), chick fledging body mass of the common guillemots breeding at Stora Karlsö in the Baltic had been found to decline, and so had the condition of sprat that had significantly increased in overall abundance. These studies clearly showed that the condition of fish preyed upon by seabirds, in addition to availability, may be an important factor when studying seabird-fish interactions.

Frederiksen *et al.* (2007) observed that while breeding performance of seabirds may reflect foraging conditions in the marine environment, any individual parameter (e.g. breeding success of a particular species at one site) may also be affected by drivers other than food supply. Selecting a suitable univariate indicator can therefore be difficult. They have proposed to combine several data sets to overcome this limitation: if a given temporal pattern occurs for several parameters measured at one site, or for the same parameter measured at several sites, it is likely to reflect important spatio-temporal environmental variation, probably linked to food supply. Multivariate statistical techniques, such as principal component analysis (PCA), could be used to extract common signals from intercorrelated time series.

Greenstreet *et al.* (1999) remarked that although a strong positive relationship between breeding success of Atlantic puffins and independently obtained indices of 0-group herring abundance over a 22 year period (1975–1996) was demonstrated by Anker-Nilssen *et al.* (1997), there was a clear threshold above which fledging success was at a maximum and could not increase with increases in herring abundance. This suggests that any changes above certain indices of herring 0-group abundance would not be detectable in puffin breeding success alone. A similar positive relationship between kittiwake breeding success and 0- group herring abundance at Røst was found between 1980–1996, but again there was a threshold above which breeding success did not increase further. Similarly, Barrett (2002) commented that despite large inter-annual differences in prey consumption plus gradual changes in meal sizes, the growth rates of chicks of puffins and guillemots in the Barents Sea remained near their maximum, suggesting physiological restraints in growth during plentiful years.

Fauchald (2009) reviewed recent theoretical advances in spatial predator-prey interactions and related these with studies of seabirds and pelagic schooling fish and crustaceans. Studies on seabirds and prey generally assume that prey are non-responsive.

Predator-prey interactions should, however, be viewed as a 2-way spatial game where seabirds track concentrations of prey while prey move away from areas with high risk of predation. The outcome of the game depends on how seabirds and prey are spatially constrained. Constraints include the spatial distribution of resources, interspecific competition, the location of spawning and breeding areas, and limitations on diving depth.

Parsons *et al.* (2008) observed that although changes in the productivity of groups of Scottish seabirds appeared to be related to changes in sandeel availability, the contributing causative factors varied among species. Therefore, multispecies groupings could not be recommended as indicators of specific environmental signals. Instead, given the importance of sandeels in the diet of many seabird species, the productivity of a single sandeel specialist might serve as an indicator of sandeel availability to predators. Black-legged kittiwake were listed as the best candidate, because this species is particularly reliant on the availability of sandeels at the sea surface and because (in contrast to terns, for instance) it nests on inaccessible cliff ledges and is therefore less affected by mammalian predators. The potential sensitivity of black-legged kittiwakes to food availability was supported by experimental evidence obtained by providing supplementary food to individuals in a colony while recording a suite of breeding parameters.

Scott *et al.* (2006) considered factors that would affect prey availability other than stock size. If availability reflected absolute prey abundance, different species preying on the same prey population should show synchronized variation in breeding success. If, on the other hand, species-specific foraging techniques coupled with prevailing oceanographic conditions result in differential access to prey, then, breeding success is likely to vary asynchronously between species. Currently, commercial fishing quotas are set on the assumption that prey abundance is the only important factor for multispecies management. The advocated therefore, that it is essential to understand prey availability in the context of both a climate change and fishing pressure. The authors demonstrated the potential of combining long-term demographic data from seabirds with output from one-dimensional physical-biological model. Using data from the North Sea, relationships between breeding performance and biologically meaningful indices of the physical environment were examined during a period of years with and without an industrial fishery. It is speculated upon how contrasting responses shown by two seabird species might reflect differences in prey availability mediated by foraging technique.

5.6 Suitable species

In line with Furness & Tasker (2000), most case studies suggest that seabirds with a low ability to switch diet (specialists rather than generalists), with a limited potential foraging range and/or a high cost of foraging (the most 'sensitive' species), are more likely to demonstrate immediate effects of shifts in prey availability. In contrast with these authors, however, have several deep-diving species with a considerable feeding range, such as auks, produced very useful data, suggesting that even if they may not be overly sensitive to reduced abundance of food in the vicinity of their colonies (according to the sensitivity index proposed by the authors), they can still provide very useful data (Monaghan 1996, Barrett 2002, Diamond & Devlin 2003). Generalists, such as most large gull species, could better be avoided during attempts to monitor prey fish stocks via biological characteristics of the predators.

Parsons *et al.* (2008) reported on the development of seabird indicators that could support the Scottish Biodiversity Strategy. The application of high-quality monitoring data on breeding abundance and productivity in Scotland was explored in three ways: as indicators of seabird status in its own right, as indicators of the "health" of the marine environment, and as indicators of the food supply of vertebrate predators. Data on breeding productivity of seabirds, which responds more immediately to environmental variation than adult abundance, provided a novel supplement to indicators based solely on abundance trends. Grouping of species according to ecological guilds provided indicators of change in particular aspects of the marine environment.

The species list in Table 5.2 includes only species that breed in the North Atlantic, and ranks species as **highly useful** (several published case studies available), **apparently useful** (one or two known case studies), and **not** particularly **useful** (mixed diets, no known evidence, or no easy to identify effects of prey stocks on breeding performance and survival), or **potentially useful** in the absence of data but under the expectation that useful data could be derived (based on case studies of similar species).

Table 5.2. North Atlantic seabird species and the likelihood that biological information on the predators might yield information on specific fish prey species.

Species name	Scientific name	main prey	usefulness	season
Red-throated Diver	*Gavia stellata*	fish	not useful	winter
Black-throated Diver	*Gavia arctica*	fish	not useful	winter
Great Northern Diver	*Gavia immer*	fish	not useful	winter
White-billed Diver	*Gavia adamsii*	fish	not useful	winter
Northern Fulmar	*Fulmarus glacialis*	mixed	not useful	year-round
Soft-plumaged Petrel	*Pterodroma feae/madeira/mollis*		not useful	
Bulwer's Petrel	*Bulweria bulwerii*		not useful	
Cory's Shearwater	*Calonectris borealis*	fish	not useful	year-round
Manx Shearwater	*Puffinus puffinus*	fish	not useful	summer
Balearic Shearwater	*Puffinus mauretanicus*	fish	not useful	year-round
Little Shearwater	*Puffinus assimilis*	fish	not useful	year-round
White-faced Storm-petrel	*Pelagodroma marina*	planktonic	not useful	
European Storm-petrel	*Hydrobates pelagicus*	planktonic	not useful	summer
Leach's Storm-petrel	*Oceanodroma leucorhoa*	planktonic	not useful	summer
Swinhoe's Storm-petrel	*Oceanodroma monorhis*	planktonic	not useful	
Band-rumped Storm-petrel	*Oceanodroma castro*	planktonic	not useful	
Red-billed Tropicbird	*Phaethon aethereus*	fish	not useful	
Brown Booby	*Sula leucogaster*	fish		year-round
Northern Gannet	*Morus bassanus*	fish	not useful	summer
Great Cormorant	*Phalacrocorax carbo*	fish	not useful	summer
European Shag	*Phalacrocorax aristotelis*	fish	apparently useful	year-round
Greater Scaup	*Aythya marila*	bivalves	not useful	
Common Eider	*Somateria mollissima*	bivalves	not useful	winter
Common Scoter	*Melanitta nigra nigra*	bivalves	not useful	winter
Velvet Scoter	*Melanitta fusca*	bivalves	not useful	winter

Species name	Scientific name	main prey	usefulness	season
Barrow's Goldeneye	*Bucephala islandica*	bivalves	not useful	winter
Common Goldeneye	*Bucephala clangula*	bivalves	not useful	winter
Long-tailed Duck	*Clangula hyemalis*	fish/bivalves	not useful	winter
Smew	*Mergellus albellus*	fish	potentially	winter
Red-breasted Merganser	*Mergus serrator*	fish	potentially	winter
Goosander	*Mergus merganser*	fish	potentially	winter
Red-necked Phalarope	*Phalaropus lobatus*	planktonic	not useful	
Grey Phalarope	*Phalaropus fulicarius*	planktonic	not useful	
Pomarine Skua	*Stercorarius pomarinus*	mixed	not useful	
Arctic Skua	*Stercorarius parasiticus*	mixed	apparently useful	summer
Long-tailed Skua	*Stercorarius longicaudus*	mixed	not useful	summer
Great Skua	*Stercorarius skua*	mixed	apparently useful	summer
Mediterranean Gull	*Larus melanocephalus*	mixed/terr	not useful	year-round
Little Gull	*Larus minutus*	fish larvae	not useful	migration
Sabine's Gull	*Larus sabini*		not useful	migration
Black-headed Gull	*Larus ridibundus*	mixed	not useful	year-round
Slender-billed Gull	*Larus genei*			
Audouin's Gull	*Larus audouinii*		not useful	year-round
Common Gull	*Larus canus*	mixed	not useful	year-round
Lesser Black-backed Gull	*Larus fuscus*	mixed	not useful	year-round
Baltic Gull	*Larus fuscus fuscus*	mixed	potentially	summer
Herring Gull	*Larus argentatus*	mixed	not useful	year-round
Pontic Gull	*Larus cachinnans*	mixed	not useful	year-round
Yellow-legged Gull	*Larus michahellis*	mixed	not useful	year-round
Iceland Gull	*Larus glaucoides*	mixed	not useful	year-round
Glaucous Gull	*Larus hyperboreus*	mixed	not useful	year-round
Great Black-backed Gull	*Larus marinus*	mixed	not useful	year-round
Black-legged Kittiwake	*Rissa tridactyla*	fish	highly useful	summer
Ivory Gull	*Pagophila eburnea*	mixed	not useful	summer
Gull-billed Tern	*Gelochelidon nilotica*	mixed/terr	not useful	migration
Caspian Tern	*Sterna caspia*	fish	potentially	summer
Royal Tern	*Sterna maxima*	fish	potentially	summer
Crested Tern	*Sterna bergii*	fish	potentially	summer
Lesser Crested Tern	*Sterna bengalensis*	fish	potentially	summer
Sandwich Tern	*Sterna sandvicensis*	fish	potentially	summer
Roseate Tern	*Sterna dougallii*	fish	apparently useful	summer
Common Tern	*Sterna hirundo*	fish	apparently useful	summer
Arctic Tern	*Sterna paradisaea*	fish	highly useful	summer

Species name	Scientific name	main prey	usefulness	season
Little Tern	*Sterna albifrons*	fish	not useful	summer
Black Tern	*Chlidonias niger*		not useful	summer
White-winged Black Tern	*Chlidonias leucopterus*		not useful	migration
Common Guillemot	*Uria aalge*	fish	highly useful	summer
Brünnich's Guillemot	*Uria lomvia*	fish	highly useful	summer
Razorbill	*Alca torda*	fish	highly useful	summer
Black Guillemot	*Cepphus grylle*	fish	not useful	summer
Little Auk	*Alle alle*	planktonic	not useful	summer
Atlantic Puffin	*Fratercula arctica*	fish	highly useful	summer

North Atlantic species appearing most regularly in case studies highlighting the usefulness of seabird studies as indicators of changes in prey abundance and fish community composition are Black-legged Kittiwake, Arctic Tern, Common Tern, Common Guillemot, Razorbill and Atlantic Puffin. European Shag, Northern Gannet, Arctic Skua, Great Skua, and Sandwich Tern were encountered less frequently.

5.7 Monitoring programmes

The most comprehensive case studies and the most promising long-term data sets were derived from Canada, the United Kingdom, and Norway, with some from Sweden, The Netherlands and Germany. Table 5.3 lists the most promising data series and studies with example references highlighting their significance with regard to their usefulness as indicators of changes in prey fish populations.

Table 5.3. Existing monitoring programmes as indicators of fish stock changes.

Species name	Scientific name	Prey	Country	Reference
Arctic skua	*Stercorarius parasiticus*	sandeel	Shetlands	Phillips *et al.* 1996
Arctic tern	*Sterna paradisaea*	sandeel	Shetlands	Monaghan 1996
		0-group herring	Canada	Diamond & Devlin 2003
Atlantic puffin	*Fratercula arctica*	0-group herring	Norway	Sætre *et al.* 2002
		sandeel	UK	
		capelin	N Norway	Barrett 2002
		herring	N Norway	Barrett 2002
		0-group cod	N Norway	Barrett 2002
		0-group herring	Canada	Diamond & Devlin 2003
Black-legged kittiwake	*Rissa tridactyla*	sandeel	UK	Wanless *et al.* 2006
		sandeel	Shetlands	Monaghan 1996
Brünnich's guillemot	*Uria lomvia*			
Common guillemot	*Uria aalge*	capelin	N Norway	
		1-group herring	N Norway	Barrett 2002
		sandeel	Shetlands	Monaghan 1996
		sprat	Baltic	Österblom *et al.* 2006
Common tern	*Sterna hirundo*	0-group herring	Canada	Diamond & Devlin 2003
		0-group herring	Germany	Greenstreet *et al.* 1999
European shag	*Phalacrocorax aristotelis*	sandeel	Shetlands	Monaghan 1996
			UK	
Northern gannet	Morus bassanus	mackerel	Newfoundland	Montevecchi & Myers 1995

Great skua	*Stercorarius skua*	mixed	Shetland	
Razorbill	*Alca torda*	0-group herring	Canada	Diamond & Devlin 2003
Sandwich tern	*Sterna sandvicensis*	sandeel, sprat	Netherlands	Stienen *et al.* 2000 (research discontinued)

5.8 Discussion

To investigate interactions between seabird reproduction and fish stocks, breeding seabird numbers or overall breeding success are often considered, but parameters more directly linked to food availability such as chick growth, rate of chick starvation or fledging success should be assessed as they may be expected to provide a more direct and sensitive indicator of food supply (Greenstreet *et al.* 1999). The case studies presented by Greenstreet *et al.* (1999) and the data presented in the current review underline the importance of long term data series as a key tool to understand interactions between seabirds and fish.

Cairns (1987) predicted that parameters of seabird biology and behaviour would vary in curvilinear fashion with changes in food supply, and that the threshold of prey density over which birds responded would be different for each parameter. Different seabird species would respond differently to variation in food availability depending on foraging behaviour and their ability to adjust time budgets (cf Furness & Tasker 2000). Piatt *et al.* (2007) tested these predictions using data collected at colonies of common guillemots and black-legged kittiwakes in Cook Inlet (Alaska). Of 22 seabird responses fitted with linear and non-linear functions, 16 responses exhibited significant curvilinear shapes, and Akaike's information criterion (AIC) analysis indicated that curvilinear functions provided the best-fitting model for 12 of those. However, there were few differences among parameters in their threshold to prey density, presumably because most responses ultimately depend upon a single threshold for prey acquisition at sea. (3) There were similarities and some differences in how species responded to variability in prey density. It appeared that common guillemots were able to buffer breeding success (by reallocating discretionary 'loafing' time to foraging effort) in response to declining prey density. Kittiwakes had little or no discretionary time, and fledging success was a more direct function of local prey density.

Rather promising examples have been provided in this brief overview, suggesting that indeed, biological characteristics of predatory seabirds could provide highly useful data on the (recruitment of) pelagic and demersal fish they prey upon. We would advocate, however, that the most useful results could be obtained during close collaborations between seabird biologists, fishery biologists, and oceanographers, teams of researchers in other words that should always be alert on flaws in the data, caused by environmental factors not fully taken into account before. Such close collaborations are not common, but they could be highly rewarding, in particular for species that are hard to study otherwise (for example in more conventional fisheries research cruises).

The scarcity of case studies from other countries than the one mentioned in this review is remarkable. We do not believe that there would not be any potential in these countries, but rather a lack of long-term studies in which relationships between demographical parameters, population trends, and/or foraging behaviour of seabirds have been evaluated in the context of their marine resources. It is quite likely that studies have been overlooked given the short time available for the present review, and it is expected that further, important studies will be published in the near-future, and we would therefore propose that the issue is addressed again during the next session of WGSE.

5.9 References

Anderson D.W., Gress F., Mais K.F. & Kelly P.R. 1980. Brown Pelicans as anchovy stock indicators and their relationships to commercial fishing. Calif. Coop. Ocean. Fish. Ind. Reports 21: 54-61.

Anker-Nilssen T. & Øyan H.S. 1995. Hekkebiologiske langtidsstudier av lunder på Røst. Fagrapport 015, Norsk Institutt for Naturforskning, Trondheim, 48pp.

Anker-Nilssen T. 1992. Food supply as a determinant of reproduction and population development in Norwegian Puffins *Fratercula arctica*. Dr. scient. thesis terr. ecology, Univ. Trondheim.

Anker-Nilssen T., Barrett R.T. & Krasnov J.V. 1997. Long-term and short-term responses of seabirds in the Norwegian and Barents Seas to changes in stocks of prey fish. In: Anon. (ed.) Forage fishes in marine ecosystems: 683-698. Proc. Int. Symp. on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report 97-01, Univ. of Alaska, Fairbanks.

Bakken V. 1989. The population development of Common Guillemot *Uria aalge* on Vedøy, Røst. Fauna Norv. Ser. C., Cinclus 12: 41-46.

Barrett R.T. 1991. Shags *Phalacrocorax aristotelis* as potential samples of juvenile Saithe (*Pollachius virens* (L.)). Sarsia 76: 153-156.

Barrett R.T. 2002. Atlantic puffin *Fratercula arctica* and common guillemot *Uria aalge* chick diet and growth as indicators of fish stocks in the Barents Sea. Mar. Ecol. Progr. Ser. 230: 275-287.

Barrett R.T. 2002. Atlantic puffin Fratercula arctica and common guillemot Uria aalge chick diet and growth as indicators of fish stocks in the Barents Sea. Mar. Ecol. Progr. Ser. 230: 275-287.

Barth E.K. 1978. Lundetragedien på Røst. Fauna (Oslo) 31: 273-274.

Cairns D.K. 1987. Seabirds as indicators of marine food supplies. Biol. Oceanogr. 5: 261-271.

Cairns D.K. 1992. Bridging the gap between ornithology and fisheries science: use of seabird data in stock assessment models. Condor 94: 811-824.

Camphuysen C. J. 1990. Fish stocks, fisheries and seabirds in the North Sea. Technical Rapport Vogelbescherming 5. Nederlandse Vereniging tot Bescherming van Vogels, Zeist, 119 pp

Cherel Y. & H. Weimerskirch 1995. Seabirds as indicators of marine resources: Black-browed Albatrosses feeding on Ommastrephid squids in Kerguelen waters. Mar. Ecol. Progr Ser. 129: 295-300.

Courtney P.A. & H. Blokpoel 1980. Food and indicators of food availability for common terns on the lower Great Lakes. Can. J. Zool. 58: 1318-1323.

Crawford R.J.M., Dundee B.L., Dyer B.M., Klages N.T., Meijer M.A. & Upfold, L. 2007. Trends in numbers of Cape gannets (Moruscapensis), 1956/57-2005/06, with a consideration of the influence of food and other factors. ICES Journal of Marine Science 64: 169-177.

Danchin É. 1992. Food shortage as a factor in the 1988 Kittiwake *Rissa tridactyla* breeding failure in Shetland. Ardea 80: 93-98.

Diamond A.W. & C. M. Devlin 2003. Seabirds as indicators of changes in marine ecosystems: ecological monitoring on Machies Seal Island. Environm. Monit. Assessm. 88: 153-175.

Durant J.M., Anker-Nilssen, T. & Stenseth, N.C. 2003. Trophic interactions under climate fluctuations: the Atlantic puffin as an example. Proc. R. Soc. Lond. B 270: 1461-1466.

Einoder L.D. 2009. A review of the use of seabirds as indicators in fisheries and ecosystem management. Fisheries Research 95: 6-13.

Fauchald P. 2009. Spatial interaction between seabirds and prey: review and synthesis. Mar. Ecol. Progr. Ser. 391: 139-151.

Frederiksen M, R.A. Mavor & S. Wanless 2007. Seabirds as environmental indicators: the advantages of combining data sets. Mar. Ecol. Progr. Ser. 352: 205-211.

Furness R.W. & Camphuysen C.J. 1997. Seabirds as monitors of the marine environment. ICES J. Mar. Sc. 54: 726-737.

Furness R.W. & Tasker M.L. 2000. Seabird-fishery interactions: quantifying the sensitivity of seabirds to reductions in sandeel abundance, and identification of key areas for sensitive seabirds in the North Sea. Mar. Ecol. Prog. Ser. 202: 253-264.

Gaston A.J., D.F. Bertram, A.W. Boyne, J.W. Chardine, G. Davoren, A.W. Diamond, A. Hedd, W.A. Montevecchi, J. M. Hipfner, M.J.F. Lemon, M.L. Mallory, J-F. Rail & G.J. Robertson 2009. Changes in Canadian seabird populations and ecology since 1970 in relation to changes in oceanography and food webs. Environ. Rev. 17: 267-286.

Greenstreet S.P.R., Becker P.H., Barrett R.T., Fossum P. & Leopold M.F. 1999. Consumption of pre-recruit fish by seabirds and the possible use of this as an indicator of fish stock recruitment. In: Furness R.W. & Tasker M.L. (eds) Diets of seabirds and consequences of changes in food supply: 6-17. ICES Coop. Res. Report No. 232, International Council for the Exploration of the Sea, Copenhagen.

Harding A.M.A., J.F. Piatt & J.A. Schmutz 2007. Seabird behavior as an indicator of food supplies: sensitivity across the breeding season. Mar. Ecol. Prog. Ser. 352: 269-274.

Harris M.P. & Bailey R.S. 1992. Mortality rates of puffin and guillemot and fish abundance in the North Sea. Biol. Conserv. 60: 39-46.

Hatch S.A. & G.A. Sanger 1992. Puffins as samplers of juvenile pollock and other forage fish in the Gulf of Alaska. Mar. Ecol. Progr. Ser. 80: 1-14.

Heubeck M. (ed.) 1989. Seabirds and sandeels: proceedings of a seminar held in Lerwick, Shetland, 15-16th October 1988. Shetland Bird Club, Lerwick, 81 pp.

Kadin M., Österblom H., Hentati-Sundberg J. & Olsson O. 2011. Contrasting effects of food quality and quantity on a marine top predator. Mar. Ecol. Progr. Ser. in press.

Kirkman S.P., W.H. Oosthuizen, M.A. Meÿer, P.G.H. Kotze, M. Boucher & L.G. Underhill 2007. Ecological responses of Cape Fur Seals in South Africa to temporal shifts in pelagic prey availability. In: Kirkman S.P. (ed.) Final Report of BCLME (Benguela Current Large Marine Ecosystem) Project on Top Predators as Biological Indicators of Ecosystem Change in the BCLME: 53-65. Avian Demography Unit, Cape Town.

Lid G. 1981. Reproduction of the Puffin on Røst in the Lofoten Islands in 1964-1980. Fauna Norv. Ser. C, Cinclus 4: 30-39.

Monaghan P. 1996. Relevance of the behaviour of seabirds to the conservation of marine environments. Oikos 77: 227-237.

Monaghan P., Uttley J.D. & Okill J.D. 1989a. Terns and sandeels: seabirds as indicators of marine fish populations. J. Fish Biol. (suppl. A) 35: 339-340.

Monaghan P., Uttley J.D., Burns M.D., Thaine C. & Blackwood J. 1989b. The relationship between food supply, reproductive effort and breeding success in Arctic Terns *Sterna paradisaea*. J. Anim. Ecol. 58: 261-274.

Montevecchi W.A. 1993. Birds as indicators of change in marine prey stocks. Furness R.W. & J.J.D. Greenwood (eds). Birds as Monitors of Environmental Change. Chapman & Hall, London: 217-266.

Montevecchi W.A. & R.A. Myers 1995. Prey harvests of seabirds reflect pelagic fish and squid abundance on multiple spatial and temporal scales. Mar. Ecol. Progr. Ser. 117: 1-9.

Österblom H., A. Bignert, T. Fransson & Olof Olsson 2001. A decrease in fledging body mass in common guillemot *Uria aalge* chicks in the Baltic Sea. Mar.Ecol.rogr. Ser. 224: 305-309.

Österblom H., M. Casini, O. Olsson & A. Bignert 2006. Fish, seabirds and trophic cascades in the Baltic Sea. Mar. Ecol. Progr. Ser. 323: 233- 238.

Parsons M., Mitchell I., Butler A., Ratcliffe N., Frederiksen M., Foster S. & Reid J.B. 2008. Seabirds as indicators of the marine environment. ICES J. Mar. Sc. 65: 1520-1526.

Phillips R.A., Caldow R.W.G. & Furness R.W. 1996a. The influence of food availability on the breeding effort and reproductive success of Arctic Skuas *Stercorarius parasiticus*. Ibis 138: 410-419.

Phillips R.A., Furness R.W. & Caldow R.W.G. 1996b. Behavioural responses of Arctic skuas *Stercorarius parasiticus* to changes in sandeel availability. In: Greenstreet S.P.R. & Tasker M.L. (eds). Aquatic predators and their prey: 17-25. Fishing News Books, University Press, Cambridge.

Piatt J.F., A.M.A. Harding, M. Shultz, S.G. Speckman, T.I. van Pelt, G.S. Drew & A.B. Kettle 2007. Seabirds as indicators of marine food supplies: Cairns revisited. Mar. Ecol. Progr. Ser. 352: 221-234.

Piatt J.F., W.J. Sydeman & F. Wiese 2007. Introduction: a modern role for seabirds as indicators. Mar. Ecol. Prog. Ser. 352: 199-204.

Poloczanska E.S., R.M. Cook, G.D. Ruxton & P.J. Wright 2004. Fishing vs. natural recruitment variation in sandeels as a cause of seabird breeding failure at Shetland: a modelling approach. ICES Journal of Marine Science 61: 788-797.

Regehr H.M. & 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. Mar. Ecol. Progr. Series 155: 249-260.

Robinette D.P., J. Howar, W.J. Sydeman & N. Nur 2007. Spatial patterns of recruitment in a demersal fish as revealed by seabird diet. Mar. Ecol. Prog. Ser. 352: 259-268.

Scott B.E., Sharples J., Wanless S., Ross O.N., Frederiksen M. & Daunt F. 2006. The use of biologically meaningful oceanographic indices to separate the effects of climate and fisheries on seabird breeding success. In: In: Boyd I.J., Wanless S. and Camphuysen C.J. (eds) Top predators in Marine Ecosystems: monitoring change in upper trophic levels: 46-62. Cambridge Univ. Press, Cambridge.

Stienen E.W.M., Beers P.W.M. van, Brenninkmeijer A., Habraken J.M.P.M., Raaijmaakers M.H.J.E. & P.G.M. van Tienen 2000. Reflections of a specialist: patterns in food provisioning and foraging conditions in Sandwich Terns Sterna sandvicensis. Ardea 88: 33-49.

Sydeman W.J., J.F. Piatt & H.I. Browman 2007. Seabirds as indicators of marine ecosystems. Mar. Ecol. Porgr. Ser. (Theme Section) vol. 352.

Tasker M.L. & Furness R.W. (eds) 2003. Seabirds as monitors of the marine environment. ICES Coop. Res. Rep. 258, ICES CIEM, Copenhagen, 73pp.

Vader W. 1988. Where have all the Guillemots *Uria aalge* gone?. In: Tasker M.L. (ed.). Seabird food and feeding ecology, p. 39-40. Proc. 3rd int. Conf. Seabird Group, Cambridge.

Vader W., Anker-Nilssen T., Bakken V., Barrett R. & Strann K.B. 1989. Regional and temporal differences in breeding success and population development of fisheating seabirds in Norway after collapses of herring and capelin stocks. Trans. 19th IUGB Congress, Trondheim 1989: 143-150.

Votier S.C., S. Bearhop, J.E. Crane, J.M. Arcos & R.W. Furness 2007. Seabird predation by great skuas *Stercorarius skua* - intra-specific competition for food? J. Avian Biol. 38: 234-246.

Wanless S., M. Frederiksen, F. Daunt, B.E. Scott & M.P. Harris 2006. Top predators as indicators of environmental change in the North Sea: evidence from long-term studies of black-legged kittiwakes. Progress in Oceanography 72: 30-38.

Williams T.D. & Croxall J.P. 1990. Is chick fledging weight a good index of food availability in seabird populations? Oikos 59(3): 414-416.

6 Tracking Studies of Seabirds

The first term of reference aimed at summarizing the results of the distribution and habitat associations of seabirds in ICES waters was formulated at the WGSE 2008 meeting. It was addressed for the first time in 2009 (ICES 2009) when focus was put on technological and analytical issues and a presentation of a preliminary review of published and ongoing studies. This was followed up in 2010 (ICES 2010) with focus more on the results and insights obtained through these studies, and a presentation of a few case studies selected to illustrate what can be achieved by tracking seabirds.

As the technology has improved and prices and weights of loggers and other devices dropped, it is no exaggeration to say that remote tracking of seabirds is currently one of the most rapidly expanding topics of seabird research, and it is already difficult to keep up with the output of published results. As such, there is a continuing need to review the progress in the field, and to identify key insights in the identification of important seabird habitats. Such identification is important for spatial planning and can, for example, help to identify Marine Protected Areas or areas of potential conflict between seabirds and fisheries.

6.1 Introduction

Pelagic marine predators face unprecedented challenges and uncertain futures. Overexploitation and climate variability impact the abundance and distribution of top predators in ocean ecosystems. Improved understanding of ecological patterns, evolutionary constraints and ecosystem function is critical for preventing extinctions, loss of biodiversity and disruption of ecosystem services. Recent advances in electronic tagging techniques have provided the capacity to observe the movements and long-distance migrations of animals in relation to ocean processes across a range of ecological scales (Block *et al.* 2011).

Seabirds are highly mobile and undertake some of the longest migrations known, often trans-oceanic and/or trans-Equatorial. This is a successful strategy because food abundance in any one region is often highly seasonal, and seabirds are forced to seek productive waters generally far from their breeding sites. Seabird mortality is highest outside the breeding season when birds undergo an energy-demanding moult to replace their feathers and when, especially in winter, food abundance is depressed and its availability often low due to bad weather and/or, at higher latitudes, shortened day length. Compared to the breeding season when seabird ecology has been studied in depth for decades, the non-breeding ecology of seabirds is poorly known. This has serious implications for our knowledge of what factors impact seabird population dynamics. For conservation and management, it is thus important to know where seabirds spend this period, what factors explain their patterns of migration, and how they optimize their use of the food resources available. Potential spatial and temporal changes in their vulnerability to anthropogenic impacts are also important to document.

Smaller-scale movements within the breeding season are, however, also important to study. When breeding, seabirds are constrained to forage close to the nest, and how and where seabirds find food for themselves and their offspring are key factors determining their breeding success. Especially for colonial species, interaction between conspecifics in terms of competition and information sharing, as well as their vulnerability to predation are also important factors in this context. Prey often occur in patches that vary both spatially and temporally over a wide range of scales resulting in considerable plasticity in both diet and the diving and foraging behaviour within a given species. Thus again, knowledge of the foraging strategies and feeding behaviour of seabirds is essential to improve managerial practices.

An understanding of the overall ecological role of seabirds in the marine ecosystem is also highly dependent on our knowledge of where and how they feed both during and outside the breeding season.

As reviewed in the two previous WGSE reports (ICES 2009, 2010), the recent development of small tracking and logging devices has revolutionised our capability to document where individual birds are at any one time. With the additional deployment of small time-depth recorders with or without a temperature sensor and/or biochemical analyses of tissues such as feathers or muscle, it is further possible to examine the search behaviour and/or diet of individuals when far at sea (but see Vandenabeele *et al.* (2011) for possible side-effects of instrumentation).

Here we review recent tracking studies at two temporal and spatial scales; the geographically wide-ranging movement of seabirds during the long non-breeding period and the much more local and short-term movements of breeding seabirds that are bound to their nest. The review is limited to published papers appearing in 2009–2011 that were not included in the previous reviews (ICES 2009, 2010). It is very strongly biased towards studies from the northern hemisphere and builds heavily on their summaries and abstracts from which I have (un)ashamedly "cut and pasted"!

6.2 Non-breeding season

For some species, electronic tracking is the only practical means of documenting post-breeding movements and possible key stop-over or wintering areas. The declining and extremely threatened ivory gull is such a species, and the use of satellite transmitters deployed in three breeding areas (Greenland, Svalbard and Franz Josef Land) has provided the first comprehensive picture of the post-breeding movements of this species (Gilg *et al.* 2010). The results of the work in Spitsbergen and Russia can also be viewed in greater detail at http://ivorygull.npolar.no/ivorygull/en/index.html.

Similarly, Votier *et al.* (2011) use of GPS transmitters, radio-tracking and isotopes of carbon and nitrogen to investigate movements and foraging ecology of immature northern gannets provided insights into previously unknown foraging, prospecting and dispersal behaviour of immature seabirds, that may have important implications for understanding seabird ecology and conservation. Kohno & Yoda (2011) also applied GPS-loggers as a tool to study the development of flight skills and post-fledging dependence of hand-reared brown-boobies.

Further insights into migration strategies made possible by the deployment of electronic tracking was exemplified by Klaasen *et al.* (2011) who showed that lesser black-backed gulls moving from Britain to the Iberian Peninsula did not minimize duration of migration as expected but rather the costs of migration. Another example is provided by Nisbeth *et al.* (2011) whose GLS study of common terns breeding on Bird Island, USA added to the previous knowledge of the species. Ringing data had suggested that Common Terns have extensive post-breeding dispersal movements to the northeast and southwest, but all their birds remained close to Cape Cod throughout the post-breeding period, with no evidence of movement to the north and only a few fixes nominally 100–200 km to the east or west.

6.2.1 Colony-specific winter areas

Based on traditional ringing recoveries there has, until very recently, been little evidence of seabird populations spending the non-breeding season in colony-specific areas, but GLS-logger studies are now revealing that this may be the case for at least some species.

A pan-North Atlantic study of the movements of black-legged kittiwakes from 18 colonies has shown that while there is indeed a high degree of mixing of all populations in the western Atlantic in winter, colonies closer to each other show a larger overlap and birds from Ireland and western Britain tend to remain on the European side of the Atlantic (Frederiksen *et al.* in press). Taking this a step further using a combination of information on moult patterns, tracking data and a stable isotope analysis of feathers, Gonzalis-Solis *et al.* (2011) demonstrated a more consistent directional movement of North Norwegian kittiwakes than previously suggested based on ring recoveries.

On a smaller spatial scale, a GLS study of movements of Brünnich's guillemots showed that adults from two colonies in eastern Canada (NE Hudson Bay and E. Baffin Island, 1000 km apart) were completely segregated in winter (Gaston *et al.* 2011). And even within a colony, there is now evidence that different parts of a seabird population may choose different wintering areas as shown by the returns of GLS-carrying black-legged kittiwakes in a colony in SE Scotland. Those that suffered breeding failure left the colony earlier, and travelled further west into the Atlantic than successful breeders, demonstrating important links between reproductive performance and winter distribution (Bogdanova *et al.* 2011).

Even at individual level there is evidence of consistency. For example, Atlantic puffins breeding on Skomer, Wales follow a dispersive pattern of movements that changes through the non-breeding period, but individuals show remarkable consistency in their own migratory routes among years (Guilford *et al.* 2011). This was also true for individual northern gannets from Bass Rock, Scotland that spent the winter in relatively small, well-defined home ranges and south polar skuas where, although birds from same colony in Antarctica moved into both the N Atlantic and N and S Pacific Oceans, individuals chose the same area for consecutive wintering. Eighty seven % also used the same stopover sites on return to colony (Kubetzki *et al.* 2009, Kopp *et al.* 2011). That being said, GLS tracking of 72 migrations of Cory's shearwaters, including 14 birds tracked for more than one non-breeding season, showed a remarkable capacity to change winter destinations between years (Dias *et al.* 2011). Some birds exhibited high site fidelity but others shifted from S to N Atlantic, from W to E South Atlantic and even from Atlantic to Indian Ocean. Similarly, GLS, isotopic and comparison of genetically distinct populations of Cook's petrel exhibited trans-equatorial separation of non-breeding ranges (Rayner *et al.* 2011).

6.2.2 Hot-spots and risk analyses

Traditional studies of seabird movements outside the breeding season based on ring recoveries or surveys at sea have rarely defined important localities at sea that are critical for understanding migration processes or for identifying e.g. marine protection areas. This is rapidly changing through the deployment of telemetry systems, and several studies have already revealed hitherto unknown marine areas important for seabirds. Admittedly based on tracks of 12 birds only, Guilford *et al.* (2009) suggest that Manx shearwaters breeding in the UK are dependent on a remarkably restricted area close to the coast of Argentina and south of that expected from ringing recoveries as an overwintering area. Similarly little auks from E Greenland quickly moved north-eastwards to stay for several weeks within a restricted area in the Greenland Sea where activity patterns suggested this was the primary moulting region for the species, and Atlantic puffins from the Isle of May, Scotland also gather within a fairly restricted area in late winter/early spring (Mosbech *et al.* 2011, Harris *et al.* 2010).

Huge numbers of razorbills of unknown origin were observed wintering in the Bay of Fundy, Canada in the 1990s. Not until the deployment of radio transmitters on birds in several colonies in 2007 was it revealed that the razorbills were from all the major centres of their North American breeding distribution (Clarke *et al.* 2010), making this limited area in the already degraded (by overexploitation) and threatened (by pollution) Bay of Fundy one of the most critical for this species.

In their study of black-legged kittiwake movements from a North Norwegian colony, Gonzales-Solis *et al.* (2011) found a remarkable and stable cohesion in an initial movement north to an area SE of Spitsbergen where they supposedly recovered from the breeding effort and moult their feathers prior to their wider-scale movements across the Atlantic. This same, post breeding directional movement of Norwegian birds was also found by Frederiksen *et al.* (in press). Likewise Australasian gannets breeding in New Zealand display a high level of individual variability in migratory routes, timing, duration and destination but data from three GLS-logged birds, though consistent with records of band recoveries, revealed that they all frequented limited areas prior to and after their trans-Tasman flights (Ismar *et al.* 2011).

Although not gathering in a single restricted area, pelagic cormorants that bred on Middleton Island, Alaska displayed a decidedly migratory habit (as opposed a normal dispersion) and remained in narrowly circumscribed inshore locations (ca. 10 km radius) within the Alaska Current system for the winter (Hatch *et al.* 2011).

These studies provide important information for the conservation of seabird species and emphasises the need for further studies at a larger scale. Seabirds are at risk from human activities both directly and indirectly and migration tracking now provides new means to assess far-reaching environmental impacts (e.g. Hedd *et al.* 2011 who integrated year-round tracking and vessel studies to assess risks for common guillemots). This was neatly illustrated in a recent analysis of bird-borne tracking data that indicated that four times as many (up to 25%) of the North American population of northern gannets migrate to the *Deepwater Horizon* oil pollution zone in the Gulf of Mexico as earlier ring-recovery data suggested (Montevecchi *et al.* 2011). Other examples are Rayner *et al.* (2011) study of non-breeding flesh-footed shearwaters from New Zealand that occupied a region of high fisheries activity and, Hatch *et al.* (2010) Alaskan four-site study of satellite-tracked northern fulmars that showed that the Pribilof Islands population was disproportionally affected by the E Bering Sea winter longline fishery. Gaston *et al.* (2011) study of GLS-logged Brünnich's guillemots showed that, although the winter niche was much broader than assumed beforehand, birds from one of two colonies entered the area of the Newfoundland winter hunt demonstrating that separate populations may experience different selection pressures in the face of climate change. This same hunting area was avoided by common guillemots breeding on Funk Island (Hedd *et al.* 2011).

Zydelis *et al.* (2011) modelled habitats for Laysan and black-footed albatrosses using telemetry data and relating their occurrence probabilities to observations of Hawaii-based longline fisheries in 1997–2000. They found that modelled habitat preference probabilities of black-footed albatrosses were high within some areas of the fishing range of the Hawaiian fleet and such preferences were important in explaining by-catch occurrence. Conversely, modelled habitats of Laysan albatrosses overlapped little with Hawaii-based longline fisheries and did little to explain the bycatch of this species. Such niche separation was evident during the post-breeding phase among the congeneric species in June–December in the North Pacific where black-footed albatrosses were associated with a broader range of higher SSTs primarily in the eastern Pacific, whereas Laysan albatrosses were associated with a narrower range of lower SSTs in the western and central North Pacific (Block *et al.* 2011). These case studies demonstrate that dynamic habitat models based on telemetry data may help to project interactions with pelagic animals relative to environmental features and that such an approach can serve as a tool to guide conservation and management decisions.

Similarly, the high degree of mixing of North Atlantic black-legged kittiwake populations in winter implies the overall population could be sensitive to potentially deteriorating environmental conditions in the western Atlantic (Frederiksen *et al.* in press), or the fact that macro-scale segregation may be associated with breeding success is also relevant to defining important wintering areas, especially among species repeatedly experiencing breeding failures (Bogdanova *et al.* 2011).

Conversely, birds that have a high diversity of migration patterns or do not exhibit spatially limited areas of distribution, such as south polar skuas and Cory's shearwaters respectively may be in a better position than many other long-distance migrants to face the consequence of a climate change and other human-induced threats (Dias *et al.* 2011, Kopp *et al.* 2011). That being said, the consistence of stopover sites on the return of the south polar skuas may increase risk during the pre-breeding period (Kopp *et al.* 2011).

6.3 Breeding season

During the breeding season, seabirds are 'central-place foragers', with foraging time including transit time to and from the nest site, and search, capture and handling time. A maximization of efficiency implies minimizing the time spent in these activities and an optimization of the quality of prey caught and, during the chick-rearing period, brought back to the chick(s).

Again, recent development of remote tracking possibilities has revolutionized the possibilities of documenting such activity, not only when the birds are commuting to and from the feeding areas, but also when searching for and catching prey underwater.

For example, it enabled Elliott *et al.* (2009) to carry out the second ever direct test of the "Storer-Ashmole halo" hypothesis that predicts that prey items close to the colony will be preferred to those further away. Through the use of TDRs and monitoring prey deliveries of Brünnich's guillemots, they were able to demonstrate that pelagic prey species responded to seabird foraging pressure by moving away from the colony, while benthic species were depleted from the nearby shelf but remained abundant at a greater distance. This evidence of the formation of the "halo" is suggested by the authors that populations of central-place foragers are partially regulated by prey depletion.

Similarly, Kotzerka *et al.* (2010) were among the first to deploy GPS loggers on black-legged kittiwakes (on Middleton Island in the Gulf of Alaska) and documented an apparent bimodal distribution of foraging ranges and hence new insight in the foraging behaviour of the species.

Crucial in our understanding of foraging behaviour is documentation of the scales of seabirds interaction with the environment, as addressed by Hamer *et al.* (2009) who gathered fine-scale movement and activity data (using GPS, temperature and depth loggers) and suggested that foraging success of northern gannets was linked to their ability to match the hierarchical distribution of prey. Similarly Paiva *et al.* (2010a) also used GPS-loggers to demonstrate that Cory's shearwaters adopt scale-dependent adjustments of movement in relation to hierachical distribution of the environment they exploit. Other recent studies addressing foraging strategy include Regular *et al.* (2010) who found, using TDRs, that diurnal patterns of diving activities of common guillemots closely reflected changes in the vertical distribution and movements of capelin and that they showed exceptional behavioural flexibility in their efforts to access capelin throughout their daily vertical migration and Davoren *et al.* (2010) and Montevecchi *et al.* (2009) logger studies of the foraging patterns of northern gannets breeding in Newfoundland in relation to the distributional patterns of its main prey. Here a mixed strategy of memory-based and local enhancement foraging tactics appeared to play important roles in minimizing the effort to access prey. In another study of sulids, Young *et al.* (2010) demonstrated how, using GPs tracking, there were pronounced interspecific differences in foraging patterns among two closely related species, the masked booby and red-footed booby, breeding in the same colony. Data suggested that physiological differences were a more plausible mechanism than competitive interactions. A second study of foraging segregation between two closely related species breeding in sympatry was that of Navarro *et al.* (2009). They used analysis of stable isotopes in blood and feathers combined with satellite tracking during the chick-rearing period of two subspecies of Cory’s shearwater and found that spatial segregation in foraging areas can display considerable variation throughout the annual cycle and is probably the main mechanism facilitating coexistence between closely related taxa. Such foraging plasticity of Cory’s shearwaters was also clearly demonstrated by Paiva *et al.* (2010b) in the multi-site study along a neritic shelf and in pelagic oceanic areas.

Among penguins, differences in foraging plasticity may explain why some populations have remained stable while others have declined. Miller *at al*. (2009) deployed TDRs on gentoo penguins over a five year period and showed that, because they were able to adjust their foraging strategy in relation to prey availability, their population remained stable while two congeners with less flexible foraging strategies had declined.

A slightly different approach was made by Mullers & Navarro (2010) who addressed foraging behaviour of Cape gannets as a measure of colony health status. Using GPS loggers deployed at two colonies, they could distinguish between birds flying far to gather live, good quality prey and those scavenging fishery discards closer to the colony. The former resulted in faster-growing chicks with higher survival rates, but foraging behaviour alone was not adequate to predict overall colony health status.

6.3.1 Risk areas

As from studies in the non-breeding season, recent tracking technology has enabled us to identify areas of potential and actual conflict for breeding birds.

Two examples taken from the southern hemisphere both addressed foraging of Cape gannets in the Benguela upwelling region (Okes *et al.* 2009, Pichegru *et al.* 2009). The first, using GPS-tracking, echo-sounding of pelagic fish and vessel logs, located overlap areas between bird foraging ranges, pelagic fish distribution and fishing activities and demonstrated that the fishery's catch was significant in terms of its potential impact on gannets. A strong case is presented to consider and experiment with at sea 'no-take' areas for purse-seine fishery in attempt to protect the vulnerable gannet population. The second that also considered another vulnerable species, the African penguin, documented a significant overlap between the foraging ranges of both species and the area where purse seiners caught most fish, suggesting potential for intense competition between purse-seine fisheries and decreasing seabird populations. The implementation of marine protected areas closed to fishing is mooted to improve breeding success.

A positive response to fishing activity was revealed by Votier *et al.* (2010) who used GPS tracking of northern gannets and the Vessel Monitoring System (VMS) to document the influence of fishing vessels on gannet at-sea behaviour through the gannets' exploitation of discards, although this varied among individuals. They propose a combination of stable isotope analysis, GPS and VMS to study fishery/scavenger interactions in order to answer fundamental questions about scavenging behaviour. They also warn managers against the removal of discard supplies without ensuring scavenging species have sufficient alternative food.

Foraging hot-spots where individual breeding pelagic cormorants dived in distinct patterns were documented near a colony in Alaska by Kotzerka *et al.* (2011). Such distinct, specialized foraging behaviour may be advantageous in reducing intra- and interspecific competition, but the use of limited forging areas may also render the species vulnerable to changing environmental conditions. This is highlighted in a radio-telemetry study that documented the rafting behaviour and range (4–9 km off shore) of Manx shearwaters off two Welsh and one Scottish colony in preparation for the implementation of protection requirements of Manx shearwaters in the UK and the delineation of SPA boundaries (Wilson *et al.* 2009). Whereas the rafting behaviour of shearwaters was well known, a GPS study of lesser black-backed gulls in the Netherlands revealed a previously unknown and intriguing behavioural pattern as of birds sitting passively on, and drifting with the sea for several hours on end (Shamoun-Baranes *et al.* 2011). If widespread, this kind of behaviour may increase their exposure to e.g. oil spills.

6.4 References

Block, B.A., Jonsen, I.D. *et al.* 2011. Tracking apex marine predator movements in a dynamic ocean. Nature 475: 86-90.

Bogdanova, M.I., Daunt, F. *et al.* 2011. Seasonal interactions in the black-legged kittiwake, *Rissa tridactyla*: links between breeding performance and winter distribution. Proc. Roy. Soc. B 278: 2412-2418.

Clarke, T.C.R., Diamond, A.W. & Chardine, J.W. 2010. Origin of Canadian razorbills (*Alca torda*) wintering in outer Bay of Fundy confirmed by radio-tracking. Waterbirds 33: 541-545.

Davoren, G.K., Garthe, S. *et al.* 2010. Influence of prey behaviour and other predators of the foraging activities of a marine predator in a Low Arctic system. Mar. Ecol. Prog. Ser. 404: 275-287.

Dias, M.P., Granadeiro, J.P. *et al.* 2011. Breaking the routine: individual Cory's shearwaters shift winter destinations between hemispheres and across ocean basins. Proc. Roy. Soc. B 278:1786-1793.

Elliott, K.H., Woo, K.J. *et al.* 2009. Central-place foraging in an arctic seabird provides evidence for Storer-Ashmole's halo. The Auk 126: 613-625.

Frederiksen, M., Moe, B. *et al.* In press. Multi-colony tracking reveals the winter distribution of a pelagic seabird on an ocean basin scale. Div. & Distrib.

Gaston, A.J., Smith, P.A. *et al.* 2011. Movements and wintering areas of breeding age thick-billed murre *Uria lomvia* from two colonies in Nunavut, Canada. Mar. Biol. 158:1929-1941.

Gilg, O., Strøm, H. *et al.* 2010. Post-breeding movements of northeast Atlantic ivory gull *Pagophila eburnea* populations. J. Avian Biol. 41: 532-542.

Gonzales-Solis, J., Smyrli, M. *et al.* 2011. Combining stable isotope analyses and geolocation to reveal kittiwake migration. Mar. Ecol. Prog. Ser. 435: 252-261.

Guilford, T., Freeman, R. *et al.* 2011. A dispersive migration in the Atlantic puffin and its implications for migratory migration. PLoS ONE 6(7) e21336.

Guilford, T., Meade, J. *et al.* 2009. Migration and stopover in a small pelagic seabird, the Manx shearwater *Puffinus puffinus*: insights from machine learning. Proc. Roy. Soc. B 276. 1215-1223.

Hamer, K.C., Humphreys, E.M. *et al.* 2009. Fine-scale foraging behaviour of a medium-ranging marine predator. J. Anim. Ecol. 78: 880-889.

Harris, M.P., Daunt, F. *et al.* 2010. Wintering areas of adult Atlantic puffins *Fratercula arctica* from a North Sea colony as revealed by geolocation technology. Mar. Biol. 157:827-836.

Hatch, S.A., Gill, V.A. & Mulcahy, D.M. 2010. Individual and colony-specific wintering areas of Pacific northern fulmars (*Fulmarus glacialis*). Can. J. Fish. Aquat. Sci. 67: 386-400.

Hatch, S.A., Gill, V.A. & Mulcahy, D.M. 2011. Migration and wintering sites of pelagic cormorants determined by satellite telemtry. J. Field Ornithol. 82: 269-278.

Hedd, A., Montevecchi, W.A. *et al.* 2011. Reducing uncertainty on the Grand Bank: tracking and vessel surveys indicate mortality risks for common murres in the North-West Atlantic. Animal Conserv. DOI: 10.1111/j.1469-1795.2011.00479.x

Ismar, S.M.H., Phillips, R.A. *et al.* 2011. Geolocation tracking of the annual migration of the Australian gannet (*Morus serrator*) breeding in New Zealand. Wilson J. Ornithol. 123: 121-125.

Klaassen, R.H.G., Ens, B.J. *et al.* 2011. Migration strategy of a flight generalist, the lesser black-backed gull *Larus fuscus*. Behav. Ecol. DOI:10.1093/beheco/arr150

Kohno, H. & Yoda, K. 2011. The development of activity ranges in juvenile brown boobies *Sula leucogaster*. Ibis 153: 611-615.

Kopp, M., Peter, H.-U. *et al.* 2011. South polar skuas from a single breeding population overwinter in different oceans though show similar migration patterns. Mar. Ecol. Prog. Ser. 435: 263-267.

Kotzerka, J., Garthe, S. & Hatch, S.A. 2010. GPS tracking devices reveal foraging strategies of black-legged kittiwakes. J. Ornithol. 151: 459-467.

Kotzerka, J., Hatch, S.A. & Garthe, S. 2011. Evidence for foraging-site fidelity and individual foraging behavior of pelagic cormorants rearing chicks in the Gulf of Alsaka. The Condor 113: 80-88.

Kubetzki, U., Garthe, S. *et al.* 2009. Individual migratory schedules and wintering areas of northern gannets. Mar. Ecol. Prog. Ser. 391: 257-276.

Miller, A.K., Karnovzky, N.J. & Trivelpiece, W.Z. 2009. Flexible foraging strategies of gentoo penguins *Pygoscelis papua* over 5 years in the South Shetland Islands, Antarctica. Mar. Biol. 156: 2527-2537.

Montevecchi, W.A, Fifield, D. *et al.* 2011. Tracking long-distance migration to assess marine pollution impact. Biol. Letters doi: 10.1098/rsbl.2011.0880

Montevecchi, W.A., Benvenuti, S. *et al.* 2009. Flexible foraging tactics by a large opportunistic seabird preying on forage- and large pelagic fishes. Mar. Ecol. Prog. Ser. 385: 295-306.

Mosbech, A., Johansen, K.L. *et al.* 2011. Inter-breeding movements of little auks *Alle alle* reveal a key post-breeding staging area in the Greenland Sea. Polar Biol. DOI 10.1007/s00300-011-1064-4

Mullers, R.H.E. & Navarro, R.A. 2010. Foraging behaviour of Cape gannets as an indicator of colony health status. Endangered Sp. Res. 12: 193-202.

Navarro, J., Forero, M.G. *et al.* 2009. Foraging segregation between two closely related shearwaters breeding in sympatry. Biol. Letters 5: 545-548.

Nisbet, I.C.T., Mostello, C.S. *et al.* 2011. Migrations and winter quarters of five common terns tracked using geolocators. Waterbirds 34: 32-39.

Okes, N.C., Hockey, P.A.R. *et al.* 2009. Competition for shifting resources in the southern Benguela upwelling: seabirds versus purse-seine fisheries. Biol. Conserv. 142: 2361-2368.

Paiva, V.H., Geraldes, P. *et al.* 2010a. How area restricted search of a pelagic seabird changes while performing a dual foraging strategy. Oikos 119: 1423-1434.

Paiva, V.H., Geraldes, P. *et al.* 2010b. Foraging plasticity in a pelagic seabird species along a marine productivity gradient. Mar. Ecol. Prog. Ser. 398: 259-274.

Pichegru, L., Ryan, *et al.* 2009. Overlap between vulnerable top predators and fisheries in the Benguela upwelling sysytem: implications for marine protected areas. Mar. Ecol. Prog. Ser. 391: 199-208.

Rayner, M.J., Hauber, M.E. *et al.* 2011. Contemporary and historical separation of transequatorial migration between genetically distinct seabird populations. Nature Comm. 2:232, DOI: 10.1038/ncomms1330

Rayner, M.J., Taylor, G.A. *et al.* 2011. Migration and diving activity in three non-breeding flesh-footed shearwaters *Puffinus carneipes*. J. Avian Biol. 42: 266-270.

Regular, P.M., Davoren, G.K. *et al.* 2010. Crepuscular foraging by a pursuit-diving seabird: tactics of common murres in response to diel vertical migration of capelin. Mar. Ecol. Prog. Ser. 415: 295-304.

Shamun-Baranes, J., Bouten, W. *et al.* 2011. Riding the tide: intriguing observations of gulls resting at sea during breeding. Ibis 153: 411-415.

Vandenabeele, S.P.,Wilson, R-P. & Grogan, A. 2011. Tags on seabirds: how seriously are instrument-induced behaviours considered? Animal Welfare 20: 559-571.

Votier, S.C., Bearhop, S. *et al.* 2010. Individual responses of seabirds to commercial fisheries using GPS tracking, stable isotopes and vessel monitoring systems. J. Appl. Ecol. 47: 487-497.

Votier, S.C., Grecian, W.J. *et al.* 2011. Inter-colony movements, at-sea behaviour and foraging in an immature seabird: results from GPS-PPT tracking, radio-tracking and stable isotope analysis. Mar. Biol. 158:355-362.

Wilson, L.J., McSorley, C.A. *et al.* 2009. Radio-telemetry as a tool to define protected areas for seabirds in the marine environment. Biol. Conserv. 142: 1808-1817.

Young, H.S., Shaffer, S.A. *et al.* 2010. Resource partitioning by species but not sex in sympatric boobies in the central Pacific Ocean. Mar. Ecol. Prog. Ser. 403: 291-301.

Zydelis, R., Lewison, R.L. *et al.* 2011. Dynamic habitat models: using telemetry data to project fisheries bycatch. Proc. Roy. Soc. B doi:10.1098/rspb.2011.0330

7 Progress towards a Community Plan of Action to reduce seabird bycatch in EU waters

7.1 Introduction

In response to several requests by the Commission, WGSE reported on the problem of incidental catch of seabirds in fisheries in EU waters in 2008 (ICES 2008 chapters 3–5) and 2009 (ICES 2009, chapter 4). In relation to the need to address this problem at the policy level, this working group has called several times for the need to approve and implement a European Community Plan of Action (EC-PoA).

7.1.1 European Community Plan of Action (EC-PoA)

BirdLife International (2009) produced a proposal for an Action Plan for the EU to reduce the bycatch of seabirds in fisheries. The proposal produced the following components to such an Action Plan:

1) Extend the IPOA-Seabirds to other relevant fishing gear including trawls and gillnets
2) Uptake of seabird measures by RFMOs/RFMAs
3) Defining an incidental catch problem
4) Mitigation measures and related standards
5) Mitigation research
6) Education, training and outreach
7) Observer programmes
8) Seabird incidental catch reduction objectives
9) Monitoring and reporting framework for NPOA-Seabirds and regional plans
10) Periodic performance review

Early in 2010, DG Mare produced a ToR for an impact assessment of incidental catches of seabirds in Community waters; this was awarded to the UK Marine Resources Assessment Group (MRAG), who has carried this study over the Winter of 2010 and Spring 2011. MRAG delivered the final report to the Commission in early summer 2011, this is document is not in the public domain.

According to the latest information, the European Commission anticipates bringing forward a proposal for a plan by the end of 2011, which we expect to be called 'EU action for reducing incidental catches of seabirds in fishing gears'. It should be the blueprint for addressing seabird bycatch in EU fisheries, both by EU-flagged vessels in internal and international waters outside the EU. As such, we expect the plan to address some specifications for Regional Fisheries Management Organisations. We also expect the focus to be mainly on longlines and gill-nets, less so for trawls and purse seines (these are research areas in need of attention in EU waters). That said, there is evidence of shearwaters being caught/drowned in purse seines and this fisheries being actually the one most responsible for bycatch events for the Critically Endangered Balearic shearwater in Portuguese waters (Iván Ramírez *pers. comm.*), there are also some other reports indicating similar problems outside EU waters (flesh-footed shearwaters succumbing to purse seines in Chile - Oli Yates, *pers. comm.*).

The International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (IPOA-seabirds), under which this plan is drawn up, is not legally binding, and so we expect the European Commission proposal will not have any legal standing unless linked to the relevant EU fisheries regulations that are now subject to review and reform. In particular, measures need to be incorporated in the basic regulation of the new Common Fisheries Policy (CFP), which establishes the basic rules for EU vessels wherever they operate; and the EU Data Collection Framework[1] (DCF) that defines rules for the collection and use of fisheries data.

7.2 Reform of the Common Fisheries Policy (CFP)

The EC began the review of the existing CFP by publishing a Green Paper[2] followed by a consultation period with a closure of written responses on 31 December 2009; 382 contributions were received and the results of this process is available on the website on the so-called Commission Staff Working Document (CSWD)[3].

The CSWD is currently being discussed in the European Parliament and in the Council, with the calendar pointing to 2013 as the year when the reformed CFP will enter into force.

BirdLife International in their proposal for an Action Plan for the EU to reduce bycatch of seabirds in fisheries calls for the new CFP to include:

- An ambitious objective of minimising and, where possible, eliminating unwanted catches;
- A robust definition of unwanted catches (currently there is an unbalanced focus on fish discards to the exclusion of non-target species);
- Strong provisions allowing bycatch to be tackled in the framework of the Multi-Annual (fisheries) Plans and through the technical measures Regulations (Technical Conservation Measures Framework);
- A new way of distributing access to fisheries resources, based on sustainability criteria, including better gear selectivity which minimises the incidental capture of seabirds and other non-target species.

7.3 EU Data Collection Framework (DCF)

The EU Data Collection Framework is a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the CFP. This EC regulation requires Member States to collect data on Biological and Economic aspects of many European fisheries and related fisheries sectors. Unfortunately, the DCF only requires collection and reporting of the impacts of fisheries on fish stocks, so it does not require the collection of data on seabird bycatch. BirdLife understands the DCF should be amended so direct estimation of seabird bycatch is assessed, similar to the existing recommendations on RFMOs such as ACAP[4]. If DCF cannot be amended, then it recommends the creation of a new mechanism for broadening the scope of data collection, so this becomes compulsory. This is particularly relevant in the context of the relatively new (adopted in 2008) EU

[1] Commission Regulation (EC) No. 665/2008 of the 14 July 2008

[2] Green Paper on the Reform of the Common Fisheries Policy (COM(2009) 163 final, 22 April 2009)

[3] http://ec.europa.eu/fisheries/reform/sec(2010)0428_en.pdf

[4] http://www.acap.aq/

Marine Strategy Framework Directive[5], which requires EU waters to be in 'good environmental status' by 2020.

7.4 Update on Bycatch of Seabirds in Fisheries

7.4.1 Bycatch in EU waters

According to the latest information published, it is estimated that more than 200,000 seabirds die as bycatch every year in Europe (Anderson *et al.* 2011). These are mainly bycatches from longlines and gillnets but trawlers and purse seiners also account for this figure. The Gran Sol Atlantic area, the Baltic and eastern North Sea probably account for at least half of this toll. All seabird species are protected under the EU Birds Directive (Directive 2009/147/EC) and for some, such as the endemic Balearic shearwater, this level of bycatch will have direct consequences, threatening the species with extinction in the next 40 years (Anderson *et al.* 2011). The data available so far indicate that the areas of strongest concern are some with previously unidentified bycatch problems (e.g. Spanish Gran Sol demersal fleet) and those where bycatch was identified, but where persistent data gaps prevented adequate assessments of the scale of the impact (e.g. Nordic demersal fisheries, lumpsucker gillnet fisheries (Nordic Council of Ministers, 2010) (Anderson *et al.* 2011). A very recent review by Wagner and Boersma (2011) concludes that the seabirds functional group most negatively affected by fisheries, both directly and indirectly, is pursuit-divers (where shearwaters are included).

7.4.2 New data from bycatch observer programmes or fishermen questionnaires

Spanish Mediterranean

There are now fairly good seabird bycatch data obtained through observer programmes from the Spanish pelagic longline fleet in the western Mediterranean (Garcia-Barcelona *et al.* 2009, Garcia-Barcelona *et al.* 2010a, Garcia-Barcelona *et al.* 2010b, Valeiras 2003, Belda & Sanchez 2001, Cooper *et al.* 2003). According to these reports, seabirds are being caught mostly by the pelagic fleet (overall CPUE from Spanish fleet 2000–2009 is 0.0483 birds/1000 hooks, Garcia-Barcelona *et al*. 2010a). Recently, Garcia-Barcelona *et al.* (2010b) estimated 506 (of which 239 were Cory's shearwaters) birds being killed per year in Spanish longline fleet with the species most frequently caught being Cory's Shearwater and Yellow-Legged Gull (both classified as Least Concern according to IUCN Red List criteria). In the same study, two Balearic Shearwaters were recorded caught in the albacore fishery (two out of the 18 birds caught from ca. 400 000 hooks in that fishery, Garcia-Barcelona *et al.* 2010b). Despite this figure, events of several tens of shearwaters (usually Mediterranean and Balearic, but also Cory's Shearwaters) are reported from time to time on demersal and fairly small longline vessels. This mortality is difficult to detect but could sum up to the figures reported by observer programmes so far. (J Arcos *pers. comm.*). Other authors also reported unusually high catch numbers of Procellariiformes in longlines operating in the North-East of Spain. In that region, 32 Cory's shearwaters were caught on 5 October 2004 (Ramos *et al.* 2009) and at least 60 Balearic Shearwaters on 16 May 2008 (C Carboneras, *pers. comm.*). The nature of the variables that could be causing such high seabird catch events in this area deserves a more in-depth study (Garcia-Barcelona *et al.* 2010b). As another recent example, in July 2011, one small longline vessel caught nearly 100 seabirds on all the fishing events of a single day and 50 of the individuals

---

[5]http://ec.europa.eu/environment/water/marine/directive_en.htm

caught were Balearic Shearwaters (J. González-Solis unpublished data). Estimated total effort for albacore longline fleet is 3.3 million hooks pa (2000–2008), equating to 17 Balearic Shearwaters killed per year (Task II data, plus BirdLife extrapolation).

Apart from the observer programmes, a volunteer scheme for the recovery of seabird carcasses has been put in place in Catalonia (Spain) since 2003. To date, 463 seabirds from artisanal longliners operating on the Catalan coast have been recovered, of which 129 were Balearic shearwaters (which equates to >3% of the breeding adult population), Cory's and Mediterranean Shearwaters, but also gull species, including critically endangered Audouin's Gulls, have also been collected through this programme (J. González-Solis unpublished data). Preliminary results indicate a record of 0.005 birds/1000 hooks caught in albacore tuna fleets operating around the Columbretes, Catalan coast, Mediterranean sea. These figures are believed to be a mere representation of much higher numbers of bycatch individuals (J. González-Solis *pers. comm.*, see Proposed Special box González-Sólis).

Portuguese Atlantic waters

From November 2008 and May 2009, SPEA (BirdLife partner in Portugal) analysed 235 questionnaire responses in 7 Portuguese fishing ports. Overall, 261 seabirds were caught during this period, showing Gannets (61.8%), Yellow-legged Gulls (46.2%), and Balearic Shearwaters (13.9%) as the most affected species.

In relation to the critically endangered Balearic Shearwater, the fishing port with more bycatch events was Figueira da Foz (33.3%), with purse seiners (13.0%) and longliners (12.9%) being responsible for most of the bycatch (I. Ramírez *pers. comm.*).

From June 2010 to April 2011, SPEA has analysed another 39 responses by fishermen to questionnaires (within the MarPro[6] project), at two Portuguese harbours (Peniche and Sesimbra). These new data still shows Gannets are the most affected species (42.4%), followed by Razorbill (18.1%), Yellow-legged Gull (18.2%) and Balearic Shearwater (9.1%). Gillnets and longlines had the biggest impact in terms of different seabird species caught (6 species), while purse seine was the gear with more seabird capture events identified (16.7%) (I. Ramírez *pers. comm.*).

Portugal is not the only country currently collecting seabird bycatch evidence from fishermen questionnaires across Europe. Some other BirdLife International partners are also doing so (Iván Ramírez *pers.comm.*) and it would be highly advisable to publish these data, even if preliminary, to ascertain the exact levels of bycatch across the Central and Eastern Mediterranean and the European Atlantic waters.

Norwegian waters

Recently, bycatch surveys (i.e. interviews with fishermen) collected by the Norwegian Institute of Marine Research (IMR) estimate that very high numbers of seabirds were caught between 2009/2010 (about 10 000–12 000 individuals). The study indicates that northern fulmars, cormorants (*Phalacrocorax* spp.), black guillemots, Atlantic puffins and razorbills are the bird species that most often drown in fishing gear in Norway. (see Special BOX for details; Fangel *et al.* 2011).

---

[6] http://marprolife.org/

7.4.3 Bycatch Elsewhere in North Atlantic

New data has emerged for SW Greenland (Merkell 2011) and USA waters (Shields, unpublished; Tables 7.2 and 7.3). Some important conclusions could be taken from these reports to the EU fisheries policy: a) broadscale observer programs are feasible b) while we have no other data on mortality against which to test these observer-based data, at least the rank-ordering of species by abundance are consistent with previous predictions about what species should be most susceptible (e.g. Tasker *et al.* 2000) and c) contrary to the date commented above from Spain and Portugal, gillnet fisheries seem to be by far the most damaging and are responsible for most of the deaths off Greenland (Eiders and murres) and off the USA (Great Shearwaters and Red-throated divers).

Table 7.1a. Estimated annual bycatch of seabirds in ICES regions. Data from WGSE (2008), updated with Zydelis (2009), Garcia-Barcelona (2010) and Anderson (2011).

Species	ICES Region									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Divers			2500–6500	300						
Northern fulmar					43000	12000				
Great shearwater							56000			
Sooty shearwater						1600				
Shearwater spp.									>4000	
Great cormorant			9000		1000s					
Northern gannet								Mod-high	>3000	
Common eider			300–400		1000s					
Great Black-backed Gull						1200				
Black-legged Kitttiwake						5000				
Sandwich Tern									750	
Common Guillemot			500–6500	1200	1000s	1600				
Razorbill				1200	1000s	750			130	

Table 7.1b. Estimated seabird bycatch in the Mediterranean. Data from WGSE (2008) and from Garcia-Barcelona (2010).

MEDITERRANEAN			
	I	**II**	**III**
Balearic Shearwater	100s+		
Cory's Shearwater	1000s	1000s	1000s
Yelkouan Shearwater	100s	100s	100s
European Shag	10s		
Great Cormorant		10s	
Northern Gannet	100s	10s	
Great Skua	<10s		
Audouin's Gull	10s–100s	10s	10s
Mediterranean Gull	10s	10s	
Black-headed Gull	10s		
Yellow-legged Gull	10s	100s	100s
Black-legged Kittiwake	10s		
Sandwich Tern		10s	
Black Tern		10s	

Table 7.2. Bycatch of seabirds off North America and Greenland. Data from Gina Shields, NOAA, Woods Hole, USA.

SPECIES	Number	Percent of Total Bycatch	Estimated Annual Bycatch	SW Greenland
Red-throated Loon	1	0.002	1000–2000[a]	
Northern Fulmar	14	0.02	10s–100s	
Great Shearwater	565	85	1500–12 000	
Sooty Shearwater	10	0.02	10s–2000	
Storm-Petrel, Wilson's and unidentified	2	.003	6–40	
Cormorant, unidentified	1	0.002	3–20	
Northern Gannet	12	0.018	36–2000	
Common Eider	2	0.003	6–40	6000–20 000
Great Black-backed Gull	11	0.017	30–2000	
Herring Gull	18	0.027	50–4000	
Gull, spp.	11	0.017	30–2000	
Guillemot, mainly Common	6	0.009	20–120	600–2000
Total	665	100	3000–13 000	

[a] **from Warden (2010)**

Table 7.3. Observer coverage for fisheries off North America. Data from Gina Shields, NOAA Woods Hole, MA, USA.

	Total Seadays	Approx % coverage	Total No. seabird takes
Fishery			
Northeast and Mid-Atlantic Bottom Otter Trawl	6610	5–30%	38
Northeast Bottom Longline	267	30%	9
Northeast and MidAtlantic Gillnet	2819	5–30%	589
Herring Purse Seine	93	20%	2
Scallop Dredge	2388	10%	9
Herring/Mackerel Midwater and Pelagic Paired Trawl	856	20–50%	18
Pelagic Longline*		9%	

Special BOX for Recent Data from Norway

i) This study's aim was to improve knowledge regarding bycatch of seabirds in Norwegian coastal gillnet and longline fisheries. The results are used to rank the fisheries and identify those that are recommended for further studies of seabird bycatch rates.

ii) One objective of this project was to try out different methods for collecting data on current levels of seabird bycatch in Norwegian fisheries. We chose an *in situ* survey with personal interviews with fishermen to obtain sufficient confidence between respondent and interviewer. We also arranged three meetings with three separate focal groups: coastal fishermen from the Sunnmøre region, demersal longline fishermen, and wardens/ornithologists. Additionally, we analysed data on seabirds taken as bycatch from 2006 to 2009 in the coastal reference fleet program that is managed by the Norwegian Institute of Marine Research (IMR).

iii) Three fisheries were preselected for this survey: gillnet fisheries for cod on the coast of Troms and Finnmark, and for lumpsucker along the coast from Vesterålen to Finnmark, and the driftnet fishery for mackerel south of 62°N (i.e., in the North Sea). However, as part of this survey it became clear that fishing with driftnets for mackerel has been significantly reduced and replaced with other gear, primarily trawling. Therefore, this fishery was not subject to analysis in this study. The interviews with fishermen revealed however that the longline fishery for Greenland halibut might have comparatively high rates of seabird bycatch, so this fishery was also given attention in the study.

iv) From May 2009 to May 2010, we conducted 133 interviews with fishermen who mainly carried out a coastal fishery from boats less than 15 m long. We also interviewed 17 fishermen using salmon nets. Ninety percent of the interviews were conducted in northern Norway. For each fishery, we calculated a bycatch coefficient (seabird bycatch per metric ton landed target fish) based on data from the survey and data from the reference fleet. The coefficient was used to estimate the total yearly bycatch of seabirds within the fishery, based on publicly available statistics for the yearly total catch of target fish (tonnes landed) within the fishery in question. Public statistics on fishing effort are not presently available, which is why we used fish catch for this extrapolation.

v) The lumpsucker fishery is one of two fisheries where the bycatch coefficient was relatively high (0.693 seabirds/ton lumpsucker), and ten times higher than in other gillnet fisheries in our study. The bycatch coefficient for the longline fishery for Greenland halibut was 0.279 seabirds/1000 hooks or 0.759 seabirds/ton halibut. The number of respondents was limited for both fisheries, and our estimates should therefore be considered with some caution. The estimates are also somewhat higher than those reported in other studies of seabird bycatch in longline halibut fisheries.

vi) Our estimates suggest that a total of 10 000–12 000 seabirds died in the study fisheries each year in 2009 and 2010. If we use the bycatch coefficients based on data from the reference fleet alone, the estimates are somewhat lower. Our study indicates northern fulmars, cormorants (*Phalacrocorax* spp.), black guillemots, Atlantic puffins and razorbills are the bird species that most often drown in fishing gear in Norway. It should however be noted that in an episodic bycatch event, 200 common guillemots were recorded drowned in gillnets set for lumpsucker. These data were not included in our bycatch estimates because we did not have any measure on the frequency of such events.

vii) The northern fulmar is the seabird species most often reported as bycatch in the fisheries studied. If all the bycatch of fulmars were of adults from the Norwegian mainland population, the reported bycatch rate in Norway's fishery for Greenland halibut alone would equal the level of what is generally known to be the natural mortality rate of adult fulmars. Data from the reference fleet indicate that approximately the same number of fulmars drown in the gillnet fishery for cod. Evaluating the population impact of bycatch requires detailed knowledge on which age-groups and breeding populations are affected because there are great regional and national differences in the size and status of the populations. Such data were not available in this study. For the black guillemot, which was the most numerous bycatch species in the lumpsucker fishery, the potential increase in mortality was less extensive than for fulmars, with an estimated 22% increase in areas were lumpsucker fishing takes place. Because adult black guillemots do not migrate long from their colonies, however, it is reasonable to assume that it is primarily local birds that drown in gillnets. Both the northern fulmar and the black guillemot are on the 2010 Norwegian Red List of threatened species.

viii) We recommend more detailed studies of seabird bycatch in Norway's lumpsucker and Greenland halibut longline fisheries to provide more accurate data on bycatch and evaluate different measures to mitigate seabird bycatch. Additionally, we suggest more detailed data collection on bycatch of seabirds through existing sampling systems as the reference fleet programs managed by IMR and the Norwegian Directorate of Fisheries' Monitoring Service, especially related to longline fisheries.

ix) *Contact person*

x) Kirstin Fangel, NINA, Fakkelgården, NO-2624 Lillehammer, Norway. kirstin.fangel@nina.no

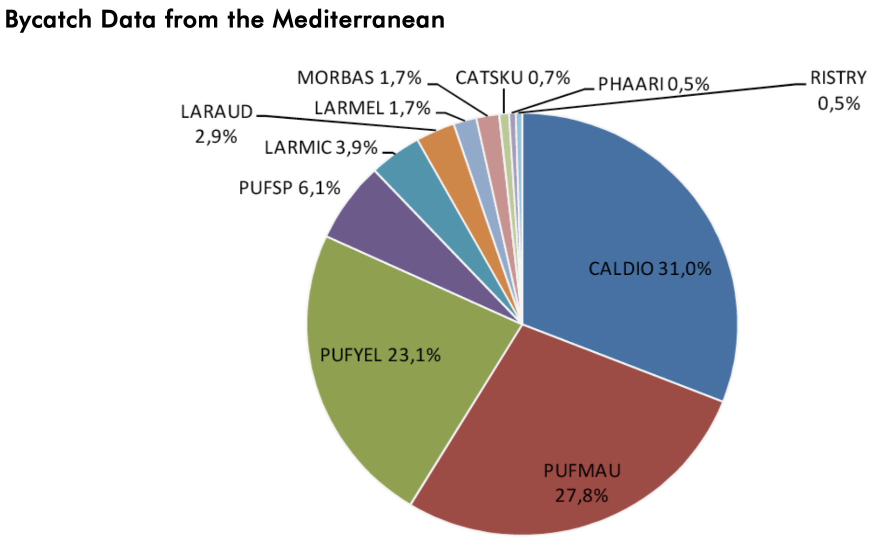


Figure 11. Percentage of seabird carcasses collected by fishermen. CALDIO = *Calonectris diomedea*, PUFMAU = *Puffinus mauretanicus*, PUFYEL = *Puffinus yelkouan*, PUFSP = *Puffinus sp*, MORBAS = *Morus bassanus*, CATSKU = *Catharacta skua*, LARRID = *Larus ridibundus*, LARMEL = *Larus melanocephalus*, LARMIC = *Larus michahellis*, LARAUD = *Larus audouinii*, RISTRY = *Rissa tridactyla*

The mortality was mainly made up of the three shearwaters species in similar proportions. Note that the higher abundance recorded of these birds, especially small shearwaters, was due to massive catches that have occurred in the same setting at a certain time, generating peak catches during the periods in which there was more interaction with longliners.

7.5 Indirect Impacts of Fisheries upon Seabirds

It was agreed that the three most important indirect effects of fisheries upon seabird populations are (1) harvesting of seabird food, (2) discards as food subsidies, and (3) damage done to marine habitats by dredges and trawls.

7.5.1 Harvesting of seabird food

Many seabird prey species, such as sand eels, herring, pilchards and sprat are fished commercially, so that fishing pressure can deplete seabird prey directly. Furthermore, fishery on one species can result in the increase of another competitor that is in turn prey for seabirds. Finally, fishery on larger ground fish such as cod or haddock can result in an increase of those species upon which such groundfish feed. All these foodweb relationships are complex and it is difficult to attribute population changes to any of the former factors with confidence; nevertheless it must be true that mortality of seabird prey due to fisheries impacts populations of seabirds.

7.5.2 Discards as food subsidies

Many seabirds have benefitted from fish discarded from commercial operations. Those that have likely been impacted the most are those that ordinarily scavenge to a certain extent anyway, such as fulmars, shearwaters, skuas and gulls. For example, it has recently been reported that the presence of fisheries discard activity modify the natural way in which Cory's and Balearic shearwaters explore the seascape to look for resources in the Mediterranean (Bartumeus *et al.* 2010). Specifically, both species altered their movement patterns at regional scales to match those of trawlers targeting demersal species (Bartumeus *et al.* 2010). Also in the Meditterranean, Cory's shearwaters were seen to attend to bottom-trawling discards, with more frequency than expected from local population figures (Louzao *et al.* 2011). Critical endangered Balearic Shearwaters attended vessels much more frequently during winter and spring (i.e. the non-breeding phase of the species) than during summer and autumn (i.e. breeding period for the species). The most frequent and abundant species attending vessels all-year round were the Yellow-Legged gull. Conversely, the remaining breeding species (i.e. Audouin's Gull and Mediterranean Gull) occurred in lower numbers than expected according to their local breeding populations, suggesting that discards were of relatively little importance for those species. Discarding activity took place over the entire shelf and continental slope surrounding Mallorca (Louzao *et al.* 2011). Potentially increases of scavengers feeding upon discards (e.g. gulls, skuas) can have negative impacts upon species that share breeding sites and are subject to mortality or displacement (e.g. auks, terns). Moreover, there is evidence that a reliance on discards can have farther-reaching behavioural consequences. Such is the case with herring gulls (*Larus argentatus)* and lesser black-backed gulls (*Larus fuscus)* in the North Sea. Both species breed in mixed colonies, and eat or attack the others' chicks (Wagner and Boersma 2011).

7.5.3 Physical degradation of habitat

Fishery operations that use dredges and otter trawls can scour the ocean floor and have profound impacts on the biota there. Such activities inevitably impact marine communities and probably affect seabirds, though it is undoubtedly difficult to untangle the specific links between fishing activity and seabird impact.

7.6 References

Bartumeus, F., Giuggioli, L., Louzao, M., Bretagnolle, V., Oro, D., & Levin, S. A. (2010). Fishery Discards Impact on Seabird Movement Patterns at Regional Scales. Current Biology, 1–8. Elsevier Ltd. doi:10.1016/j.cub.2009.11.073

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

BirdLife International. 2009. European Community Plan of Action (ECPOA) for reducing incidental bycatch of seabirds in fisheries. Proposal by BirdLife Interna- tional, September 2009.

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

Christensen-Dalsgaard, S., Fangel, K., Dervo, B.K., and Anker-Nilssen, T. 2008. Bifangst av sjøfugl i norske fiskerier - eksisterende kunnskab og forslag til kartleg- gingsprosjekt. Norsk Institutt for Naturforskning, Trondheim, NINA Rapport 382. 62 pp.

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

Dunn, E. & Steel, C. 2001. The impact of longline fishing on seabirds in the north- east Atlantic: recommendations for reduc-ing mortality. Unpublished report to RSPB, NOF, JNCC and BirdLife International. 108 pp.

Fangel, K., Wold, L.C, Aas, Ø., Christensen-Dalsgaard, S., Qvenild, M. & Anker-Nilssen, T. 2011. Bycatch of seabirds in Norwegian coastal fisheries. A mapping and methodology study with focus on gillnet and longline fisheries. - NINA Report 719. 73 pp + appendix.

Fangel, K., Wold, L.C, Aas, Ø., Christensen-Dalsgaard, S., Qvenild, M. & Anker-Nilssen, T. 2011. Bycatch of seabirds in Norwegian coastal fisheries. A mapping and methodology study with focus on gillnet and longline fisheries. - NINA Report 719. 73 pp + appendix.

García-Barcelona S, Macías D, Ortiz de Urbina JM, Estrada A, Real R, Baez JC. (2010a). Modelling abundance and distribution of seabird by-catch in the Spanish Mediterranean longline fishery. Ardeola 57 (Especial), 65-78.

García-Barcelona S, Ortiz de Urbina JM, de la Serna JM, Alot E, Macías D (2009) Seabird by-catch in Spanish Mediterranean large pelagic longline fisheries, 2000-2008. International Commission for the Conservation of Atlantic Tuna (ICCAT) Meeting of the Standing Committee on Research and Statistics, 5-9 October 2009, Madrid, Spain, ICCAT-SCRS-2009-136

García-Barcelona S, Ortiz de Urbina JM, de la Serna JM, Alot E, Macías D (2010b). Seabird by-catch in Spanish Mediterranean large pelagic longline fisheries, 2000-2008. Aquatic Living Resources / Volume 23 / Issue 04, October 2010, pp 363 - 371

Garcia-Barcelona, S., Ortiz de Urbina, J.M., de la Serna, J.M., Alot, E., and Macias, D. 2010. Seabird bycatch in Spanish Mediterranean large pelagic longline fisheries, 200-2008. Aquatic Living Resources

Kies, B. & Tomek, T. 1990. Bird mortality in fishing nets in the Gulf of Gdansk, Polish Baltic Coast. Pelagicus 5: 23-27.

Laneri, K., Louzao, M., Martinez-Abrain, A., Arcos, J. M., Belda, E. J., Guallart, J., Sanchez, A., Gimenez, M., ORO, D. (2010). Trawling regime influences longline seabird bycatch in the Mediterranean: new insights from a small-scale fishery. Marine Ecology Progress Series, 420, 241–U599. doi:10.3354/meps08847

Lewison, R.L., Crowder, L.B., Read, A.J. & Freeman, S.A. 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology & Evolution 19: 598-604.

Louzao, M., Arcos, J. M., GUIJARRO, B., VALLS, M., & Oro, D. (2011). Seabird-trawling interactions: factors affecting species-specific to regional community utilisation of fisheries waste. Fisheries Oceanography, Seabird-trawler interactions: species versus community, 20(4), 263–277. doi:10.1111/j.1365-2419.2011.00579.x

Melvin, E.F., Parrish, J.K. & Conquest, L.L. 1999. Novel tools to reduce sea-bird bycatch in coastal gillnet fisheries. Conservation Biology 13: 1386-1397.

Merkel, F.R. 2011. Gillnet bycatch of seabirds in Southwest Greenland, 2003 - 2008. Technical Report No. 85, Pinngortitaleriffik, Greenland Institute of Natural Re- sources.

Nordic Council of Ministers. 2010. Action Plan for Seabirds in Western Nordic Ar- eas. Report from a workshop in Malmo, Sweden, 4-5 May 2010.

Petersen, Æ. 2002. Fugladauði í veiðar-færum í sjó við Ísland. Náttúrufræðingur-inn 71: 52–61.

Pierce, G.J., Dyson, J., Kelly, E., Eggleton, J.D., Whomersley, P., Young, I.A.G., San-tos, M.B., Wang, J.J. & Spencer, N.J. (2002), Results of a short study on by- catches and discards in pelagic fisheries in Scotland (UK). Aquatic Living Resources 15: 327–334.

Ramos R., Militão T., González-Solís J., Ruiz J., 2009, Moulting strategies of a long-distance migratory seabird, the Mediterranean Cory's shearwater Calonectris diomedea diomedea. Ibis 151: 151–159.

Tasker, M.L., Camphuysen, C.J., Cooper, J., Garthe, S., Montevecchi, W.A. & Bla- ber, S.J.M. 2000. The impacts of fishing on marine birds. ICES Journal of Marine Science 57: 531-547.

Valeiras J, Caminas JA (2003) The incidental capture of seabirds by Spanish drifting longline fisheries in the western Mediterranean Sea. Scientia Marina 67:65-68

Wagner, E. L., Boersma, P. D. (2011). Effects of Fisheries on Seabird Community Ecology. Reviews in Fisheries Science, 19(3), 157–167. doi:10.1080/10641262.2011.562568

Warden, M. 2010. Bycatch of wintering common and red-throated loons in gillnets off the USA Atlantic coast 1996-2007. Aquatic Biology 10: 167-180.

Warden, M.L. 2010. Bycatch of wintering common and red-throated loons in gillnets off the USA Atlantic coast, 1996-2007. Aquatic Biology 10:167-180

Watkins, B.P., Petersen, S.L. & Ryan, P.G. 2008. Interactions between seabirds and deep-water hake trawl gear: an assessment of impacts in South African waters. Animal Conservation 11: 247–254.

Žydelis, R., Bellebaum, J., Österblom, H., Vetemaa, M., Schirmeister, B., Stip-niece, A., Dagys, M., van Eerden, M. & Garthe, S. (2009). Bycatch in gillnet fisheries - An overlooked threat to waterbird populations. Biological Conservation, 142(7), 1269–1281. doi:10.1016/j.biocon.2009.02.025

8 Effects of Wet Renewable Energy on Seabirds

8.1 Summary

There is increasing need for renewable energy sources, and the marine environment has been identified as a potential source (Grecian *et al.* 2010). Elsewhere in this report we discuss the potential impacts of wind energy upon seabirds; here we consider how installations for energy derived from waves and tidal currents may impact marine birds. A recent review article (Grecian *et al.* 2010) identifies potential risks of wave and tidal energy installations and suggests means for identifying appropriate sites and collecting data for assessment of those sites.

Installations to harness tidal energy use large underwater rotors with blades

At first glance it would appear that wave- and tidal-energy installations would have a relatively minor impact on birds, at least compared with that of wind turbines. Nevertheless, diving birds could potentially be harmed by the rather slowly (15 rpm) rotating blades of tidal-propelled rotors.

8.2 References

Grecian, W.J., R. Inger, M.J. Atrill, S. Bearhop, B.J. Godley, M.J. Witt, S.C. Votier. 2010. Potential impacts of wave powered marine renewable energy installations on marine birds. Ibis 152: 683-697.

Annex 1: List of participants

Name	Address	Phone/Fax	Email
Richard R. Veit	Biology Dept., CSI/CUNY, 2800 Victory Blvd., Staten Island, NY 10314 USA	718-982-4144 718-982-3852	Veitrr2003@yahoo.com
Tycho Anker-Nilssen	Norwegian Institute for Nature Research (NINA), Tungasletta 2, NO-7485 Trondheim, Norway		Tycho.Anker-Nilssen@nina.no
Robert T. Barrett	Zoology Department Tromsø Museum, University of Tromsø, N-9037 Tromsø, Norway.	Tel: +47 77645013; fax: +47 77645520	rob.barrett@tmu.uit.no
James B. Reid	Joint Nature Conservation Committee, Dunnet House, 7 Thistle Place, Aberdeen AB10 1UZ, Scotland, UK.		jim.reid@jncc.gov.uk
C.J. "Kees" Camphuysen	Netherlands Institute for Sea Research, PO Box 59, 1790 AB Den Burg, Texel, The Netherlands		Kees.Camphuysen@nioz.nl
Ivan Ramirez	SPEA-Sociedade Portuguesa para o Estudo das Aves, Avenida da Liberdade No. 105 2 Esq., PT – 1250-140 Lisboa, Portugal.		ivan.ramirez@spea.pt;
Vitor H. Paiva	Inst. of Marine Research (IMAR/CMA), Dept of Life Sciences, Univ. of Coimbra, Apartado 3046, PT – 3001-401 Coimbra, Portugal.		(vitorpaiva@ci.uc.pt)

Gina Shield (by correspondence)	NOAA/NMFS Northeast Fisheries Science Center, Woods Hole, MA 02543	gina.shield@noaa.gov
Francis Daunt (by correspondence)	ERC Centre for Ecology and Hydrology, Hill of Brathens, Banchory, Aberdeenshire, AB31 4BW, UK	frada@ceh.ac.uk
Morten Frederiksen (by correspondence)	National Environmental Research Institute, Department of Arctic Environment, University of Aarhus, Frederiksborgvej 399, DK-4000 Roskilde, Denmark	mfr@dmu.dk

Annex 2: List of Scientific Names

Scientific names

African penguin *Speniscus demersus*

Atlantic puffin *Fratercula arctica*

Audouin's gull *Larus audouinii*

Black Scoter *Melanitta nigra*

Black-footed albatross *Phoebastria nigripes*

Black-legged kittiwake *Rissa tridactyla*

Brown booby *Sula leucogaster*

Brünnich's guillemots *Uria lomvia*

Cape gannet *Morus capensis*

Common Eider *Somateria mollissima*

Common guillemot *Uria aalge*

Common loon *Gavia immer*

Common tern *Sterna hirundo*

Cook's petrel *Pterodroma cookii*

Cory's shearwater *Calonectris diomedea*

Flesh-footed shearwater *Puffinus carneipes*

Gentoo penguin *Pygoscelis papua*

Great Shearwater *Puffinus gravis*

Great Skua *Catharacta skua*

Herring gull *Larus argenteus*

Ivory gull *Pagophila eburnean*

Laysan albatross *Phoebastria immutabilis*

Lesser black-backed gull *Larus fuscus*

Little auk (Dovekie) *Alle alle*

Manx shearwater *Puffinus puffinus*

Masked booby *Sula dactylatra*

Northern fulmar *Fulmarus glacialis*

Northern gannet *Morus bassanus*

Pelagic cormorant *Phalacrocorax pelagicus*

Razorbill *Alca torda*

Red-footed booby *Sula sula*

Red-throated Loon *Gavia stellata*

Roseate tern *Sterna dougalii*

Sandwich Tern *Sterna sandvicensis*

Sooty Shearwater *Puffinus griseus*

South polar skua *Catharacta maccormicki*

Surf Scoter *Melanitta perspicillata*

White-winged Scoter *Melanitta fusca*

Annex 3: WGSE draft resolution for the next meeting

The **Working Group on Seabird Ecology** (WGSE), chaired by Richard Veit, USA, will meet in Montpelier, France, DATE October 2012 (to be announced) to:

a) Evaluate ecological facilitation ("local enhancement") among seabirds, and among seabirds, cetaceans and pelagic fishes, and its importance to seabird conservation in the North Atlantic;

b) Review datastudies on effects of wet renewable energy developments on seabirds;

c) Assess the efficacy of MPAs for seabirds, particularly in the context of climate change, and explore how to assess sufficiency of an MPA network for seabirds;

d) Data collection and storage for seabird recommendations (OSPAR 4-2012):

i. To provide advice on suitable arrangements (including format) for data collection and storage resulting from the implementation of OSPAR Recommendations 2011/1-7 on seabirds, taking into account existing data collection arrangements and compatibility with current developments under MSFD implementation (the group will work intersessionally/ by correspondence on data collection through spring/summer 2012);

e) Ecological quality objective for seabird populations (OSPAR 6-2012):

i. To update the value of the draft EcoQO indicator on Seabird Population Trends in OSPAR Region III (Celtic Seas) and make any relevant recommendations;

ii. To consider whether or not the target thresholds [both a) the target for a species-specific trend in abundance (e.g. 70% or more of the baseline); and b) the target for the proportion of species meeting species-specific targets (e.g. 75% or more)] used in the EcoQO would be indicative of a seabird community that is at GES.

WGSE will report provisionally by 20 November 2012 and will submit the annual report by 15 December 2012 (via SSGEF) for the attention of SCICOM and ACOM.

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	ToR a) There is increasing need for evaluation of foraging choices made by and used by seabirds and is o relevance to our recent previous work on seabirds and svhooling fishes, tracking and interactions of birds with windfarms. ToR b) We began study of wet renewable energy at OSPARS request in 2011, and were unable to adequately address the question, in part due to limited data being available. We expect that adequate data will be available by next year. The drive to meet energy requirements increasingly from renewable sources is now seeing the deployment of devices aimed to harness wave and tidal power. The potential effects of these on birds at sea is not known so again WGSE considers it worthwhile to review the efficacy of methods now being proposed to assess the possible effects on bird ecology at sea. ToR c) This is an issue of worldwide importance and immediate relevance, on which WGSE has worked previously. There are substantial new data now

	available to enable assessment of efficacy of MPAs. ToR d) This is an OSPAR request aiming to facilitate data collection, storage and reporting on the seabirds EcoQO also in relation to the MSFD implementation. (OSPAR 4-2012). ToR e) This is an update of the 2008 advice to OSPAR on Region III. It should be considered if the EcoQO targets correspond to the GES under the MSFD and can be used as MSFD indicators (OSPAR 6-2012).
Resource requirements	Facilities for WGSE to work in Montpelier 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	Routine office and other support usually available from ICES HQ when meeting remotely.
Financial	
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, Northwest Atlantic Seabird Cooperative

Annex 4: WGSE provisional report March 2011

Executive summary

The Working Group on Seabird Ecology met "virtually" over WebEx with Richard Veit as Chair based in Staten Island, New York from 29 March to 1 April 2011. Four representatives from three countries (Norway, Denmark, USA) participated by WebEx and three other countries (UK, Spain , Canada) participated through correspondence.

During the March meeting we gathered recent data on bycatch, including significant updates from non-EU North Atlantic waters, and summarize them here as an update to Tables presented in the WGSE report from 2008. Updates on data and indications of newly organized observer programs are the main progress we have found in action on the seabird bycatch issue. We also organized what information is available on indirect impacts of fisheries upon seabirds. Our conclusion is that fisheries impacts on prey species, and direct physical impact on seabird habitats (such as dredges inflicting damage on mussel or scallop beds), are the main issues of concern to seabirds, though we have few or no new data to support or quantify these relationships. Our main findings on bycatch and indirect impacts from fisheries are that we have summarized the data available and have clearly identified points to address at our upcoming November meeting.

1. Introduction

1.1. Participation

The following members of WGSE participated in the meeting, all using WebEx:

Tycho Anker-Nilssen	Norway
Morten Frederiksen	Denmark
Gina Shield	USA
Richard Veit (Chair)	USA

1.2. Terms of Reference

At our last meeting in Copenhagen (March 2010), we decided to shift the timing of our regular annual meeting to fall rather than spring. Therefore our annual meeting will be at Funchal, Madeira in early November 2011. Thus the purpose of this virtual meeting was to address the status of some ongoing concerns, and to assess the status of others in preparation for our regular meeting in the fall.

At this meeting, we **i)** reviewed progress towards a Community Plan of Action to reduce seabird bycatch in fisheries in EU waters; **ii)** summarized new knowledge on indirect effects of fisheries on seabirds; and **iii)** considered the status of data collection on EcoQO's in OSPAR Regions II and III, so that we may effectively summarize these at the fall meeting.

2. Update on Bycatch of Seabirds in Fisheries

2.1. Bycatch in EU water

BirdLife International (2009) produced a proposal for an Action Plan for the EU to reduce the bycatch of seabirds in fisheries. Our task is to assess to what extent this plan has been carried forward. The proposal produced the following components to such an Action Plan:

1) Extend the IPOA-Seabirds to other relevant fishing gear including trawls and gillnets
2) Uptake of seabird measures by RFMOs/RFMAs3
3) Defining an incidental catch problem
4) Mitigation measures and related standards
5) Mitigation research
6) Education, training and outreach
7) Observer programmes
8) Seabird incidental catch reduction objectives
9) Monitoring and reporting framework for NPOA-Seabirds and regional plans
10) Periodic performance review

What we can report on at this time is that there have been improvements and adjustments made to observer programs, and these programs have produced some new data for the Mediterranean. While, as we reported in 2008 (WGSE 2008), the data here are very rough estimates and should only be used to suggest rough order-of-magnitude mortality rates. For determining which species of birds we should be concerned about, they are useful.

In EU waters, the data available so far indicate that the areas of strongest concern are in the Mediterranean, where the critically endangered Balearic Shearwater is being killed by the hundreds each year in the pelagic longline fishery (Garcia-Barcelona *et al.* 2010). Thousands of threatened Cory's Shearwaters are also being killed.

2.2. Bycatch Elsewhere in North Atlantic

Elsewhere in the North Atlantic, increasingly detailed and sophisticated data have been produced for SW Greenland (Merkell 2011) and USA waters (Shields, unpublished; Tables 1.2 and 1.3). There are several messages from these data pertinent to the EU. First, broadscale observer programs are feasible. Second, while we have no other data on mortality against which to test these observer-based data, at least the rank-ordering of species by abundance are consistent with previous predictions about what species should be most susceptible (e.g. Tasker *et al*. 2000). Third, gillnet fisheries seem to be by far the most damaging and are responsible for the bulk of mortality off Greenland (Eiders and murres) and off the USA (Great Shearwaters and Red-throated.

3. Indirect Impacts of Fisheries upon Seabirds

The effects of fisheries on seabird populations can be summarized into four categories:

1) Bycatch of fishing operations
2) Overharvesting of seabird food
3) Effects of discard on the seabird populations
4) Ecosystem effects

As far as bycatch is concerned, the group recognized two different fisheries of special importance: (1) the long-line fisheries (the main impact in the region discussed within the scope of this report is probably on the fulmar); and (2) bycatch in gillnets, especially bottom-set ones. The lumpsucker gill-net fishery was specifically noted as this fishery is of short time duration but can have a large impact on certain seabird populations (Nordic Council of Ministers, 2010).

From the list above, we agreed in conversation during the meeting that the three most important indirect of fisheries upon seabird populations are harvesting of seabird food, the provision of discards, and the damage done to marine habitats by dredges and trawls. A thorough evaluation of analyses done to date of the impacts of these factors on seabirds will be conducted at the fall meeting. For now, our group has reached agreement that the above activities are those that bear the closest scrutiny.

3.1. Depletion of prey stocks

Many seabird prey species, such as sand eels, herring, pilchards and sprat are fished commercially, so that fishing pressure can deplete seabird prey directly. Furthermore, fishery on one species can result in the increase of another competitor that is in turn prey for seabirds. Finally, fishery on larger ground fish such as cod or haddock can result in an increase of those species upon which such groundfish feed. All these foodweb relationships are complex and it is difficult to attribute population changes to any one factor with confidence; nevertheless it must be true that mortality of seabird prey due to fisheries impacts populations of seabirds.

3.2. Discards

Many seabirds have benefitted from fish discarded from commercial operations. Those that have likely been impacted the most are those that ordinarily scavenge to a certain extent anyway, such as fulmars, shearwaters, skuas and gulls. Potentially increases of scavengers feeding upon discards (e.g. gulls, skuas) can have negative impacts upon species that share breeding sites and are subject to mortality or displacement (e.g. auks, terns).

3.3. Physical degradation

Fishery operations that use dredges and otter trawls can scour the ocean floor and have profound impacts on the biota there. Such activities inevitably impact marine communities and probably affect seabirds, though it is undoubtedly difficult to untangle the specific links between fishing activity and seabird impact.

4. EcoQOs for OSPAR I and II

This topic will be addressed at the Fall meeting in Madeira. The Chair will begin assembling the pertinent information so that this Term of Reference may be addressed at that time.

Table 1.1a. Estimated annual bycatch of seabirds in ICES regions. Data from WGSE (2008), updated with Zydelis (2009) and Garcia-Barcelona (2010).

	ICES REGION									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Species										
Divers			500-1000	300						
Northern Fulmar		—			43 000	12000				
Great Shearwater							48000			
Sooty Shearwater						1600				
Balearic Shearwater										
Yelkouan Shearwater										
Cory's Shearwater										
Shearwater, spp									>4000	
European Shag										
Great Cormorant			9000		1000s					
Northern Gannet								Mod-high	>3000	
Common Eider			300-400		1000s					
Great Skua										
Lesser Black-backed Gull										
Great Black-backed Gull						1200				
Herring Gull										
Audouin's Gull										
Mediterranean Gull										
Yellow-legged Gull										
Black-legged Kittiwake						5000				
Sandwich Tern									750	
Black Tern										
Common Guillemot			500-6500	1200	1000s	1600				
Razorbill				1200	1000s	750			130	

Table 1.1b. Estimated seabird bycatch in the Mediterranean. Data from WGSE (2008) and from Garcia-Barcelona (2010).

MEDITERRANEAN			
	I	II	III
Balearic Shearwater	100s+		
Cory's Shearwater	1000s	1000s	1000s
Yelkouan Shearwater	100s	100s	100s
European Shag	10s		
Great Cormorant		10s	
Northern Gannet	100s	10s	
Great Skua	<10s		
Audouin's Gull	10s-100s	10s	10s
Mediterranean Gull	10s	10s	
Black-headed Gull	10s		
Yellow-legged Gull	10s	100s	100s
Black-legged Kittiwake	10s		
Sandwich Tern		10s	
Black Tern		10s	

Table 1.2. Bycatch of seabirds off North America and Greenland. Data from Gina Shields, NOAA, Woods Hole, USA.

SPECIES	Number	Percent of Total Bycatch	Estimated Annual Bycatch	SW Greenland
Red-throated Loon	1	0.002	1000–2000[a]	
Northern Fulmar	14	0.02	10s–100s	
Great Shearwater	565	85	1500–12 000	
Sooty Shearwater	10	0.02	10s–2000	
Storm-Petrel, Wilson's and unidentified	2	.003	6–40	
Cormorant, unidentified	1	0.002	3–20	
Northern Gannet	12	0.018	36–2000	
Common Eider	2	0.003	6–40	6000–20 000
Great Black-backed Gull	11	0.017	30–2000	
Herring Gull	18	0.027	50–4000	
Gull, spp.	11	0.017	30–2000	
Guillemot, mainly Common	6	0.009	20–120	600–2000
Total	665	100	3000–13 000	

[a] from Warden (2010)

Table 1.3. Observer coverage for fisheries off North America. Data from Gina Shields, NOAA Woods Hole, MA, USA.

	Total Seadays	Approx % coverage	Total No. seabird takes
Fishery			
Northeast and Mid-Atlantic Bottom Otter Trawl	6610	5–30%	38
Northeast Bottom Longline	267	30%	9
Northeast and MidAtlantic Gillnet	2819	5–30%	589
Herring Purse Seine	93	20%	2
Scallop Dredge	2388	10%	9
Herring/Mackerel Midwater and Pelagic Paired Trawl	856	20–50%	18
Pelagic Longline*		9%	

5. References

BirdLife International. 2009. European Community Plan of Action (ECPOA) for reducing incidental bycatch of seabirds in fisheries. Proposal by BirdLife International, September 2009.

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

Christensen-Dalsgaard, S., Fangel, K., Dervo, B.K., and Anker-Nilssen, T. 2008. Bifangst av sjøfugl i norske fiskerier - eksisterende kunnskab og forslag til kartleggingsprosjekt. Norsk Institutt for Naturforskning, Trondheim, NINA Rapport 382. 62 pp.

Dunn, E. & Steel, C. 2001. The impact of longline fishing on seabirds in the north-east Atlantic: recommendations for reducing mortality. Unpublished report to RSPB, NOF, JNCC and BirdLife International. 108 pp.

Garcia-Barcelona, S., Ortiz de Urbina, J.M., de la Serna, J.M., Alot, E., and Macias, D. 2010. Seabird bycatch in Spanish Mediterranean large pelagic longline fisheries, 200-2008. Aquatic Living Resources

Kies, B. & Tomek, T. 1990. Bird mortality in fishing nets in the Gulf of Gdansk, Polish Baltic Coast. Pelagicus 5: 23-27.

Merkel, F.R. 2011. Gillnet bycatch of seabirds in Southwest Greenland, 2003 - 2008. Technical Report No. 85, Pinngortitaleriffik, Greenland Institute of Natural Resources.

Nordic Council of Ministers. 2010. Action Plan for Seabirds in Western Nordic Areas. Report from a workshop in Malmo, Sweden, 4-5 May 2010.

Petersen, Æ. 2002. Fugladauði í veiðar-færum í sjó við Ísland. Náttúrufræðingur-inn 71: 52–61.

Warden, M.L. 2010. Bycatch of wintering common and red-throated loons in gillnets off the USA Atlantic coast, 1996-2007. Aquatic Biology 10:167-180

Lewison, R.L., Crowder, L.B., Read, A.J. & Freeman, S.A. 2004. Understand-ing impacts of fisheries bycatch on marine megafauna. Trends in Ecology & Evolution 19: 598-604.

Melvin, E.F., Parrish, J.K. & Conquest, L.L. 1999. Novel tools to reduce sea-bird bycatch in coastal gillnet fisheries. Conservation Biology 13: 1386-1397.

Pierce, G.J., Dyson, J., Kelly, E., Eggleton, J.D., Whomersley, P., Young, I.A.G., San-tos, M.B., Wang, J.J. & Spencer, N.J. (2002), Results of a short study on by-catches and discards in pelagic fisheries in Scotland (UK). Aquatic Living Resources 15: 327–334.

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

Warden, M. 2010. Bycatch of wintering common and red-throated loons in gillnets off the USA Atlantic coast 1996-2007. Aquatic Biology 10: 167-180.

Watkins, B.P., Petersen, S.L. & Ryan, P.G. 2008. Interactions between seabirds and deep-water hake trawl gear: an assessment of impacts in South African waters. Ani-mal Conservation 11: 247–254.

Žydelis, R., Bellebaum, J., Österblom, H., Vetemaa, M., Schirmeister, B., Stip-niece, A., Dagys, M., van Eerden, M. & Garthe, S. 2009. Bycatch in gillnet fisheries - An overlooked threat to waterbird populations. Biological Conservation 142: 1269-1281.

Annex 5: Seabird Review Group (SRG) Technical minutes

Comments on Section 3 of Working Group on Seabird Ecology (WGSE) Report 2011: Report of the Working Group on Seabird Ecology

Seabird Review Group dealing with EcoQO for seabird populations in Region II – OSPAR 2011/3 –

a) to review and make recommendations on a draft Ecological Quality Objective (EcoQO) on Seabird Population Trends in OSPAR Region II (Greater North Sea) (to be developed in the course of 2010), the processes that have derived it and that could be used to update values on the EcoQO indicator. The review should include (but not be limited to):

  i. the degree to which appropriate and available data have been used; and

  ii. the reliability that OSPAR might place on values derived from the EcoQO indicator;

b) to provide an updated assessment of the seabird population trends in OSPAR Region III in relation to the draft EcoQO indicator on Seabird Population Trends in OSPAR Region III (Celtic Seas) and make any relevant recommendations.

Review of: Section 3 of WGSE Report 2011: Report of the Working Group on Seabird Ecology (WGSE), 1–4 November 2011, Madeira, Portugal

Reviewers: Nicole LeBoeuf (Chair), Henrik Österblom, and Henrik Skov

The WGSE was asked to review progress with the draft EcoQO for seabird population trends in OSPAR II (Greater North Sea), including assessing the degree to which appropriate and available data had been used and the reliability that OSPAR might place on the values derived from the EcoQO. WGSE was also asked to make recommendations on the processes used to derive the EcoQO and for its future updating. The RG was asked to review Section 3 of WGSE Report 2011: Report of the Working Group on Seabird Ecology (WGSE), 1–4 November 2011, Madeira, Portugal and to provide its comments to the Seabird Advice Drafting Group for consideration at its meeting to be held 24–25 January 2012.

Reviewer Comments

Over the past ten years, WGSE has been developing an EcoQO for the status of breeding populations of seabirds with the aim of adoption by OSPAR for the entire OSPAR area. The Seabird EcoQO has been demonstrated using data from OSPAR Region III (ICES 2008), and the adoption of an EcoQO for Region II would represent a scientifically important component to include in OSPAR work and one of likely high general public interest

The report from WGSE gives the results of trend assessments for 16 seabird species for the Greater North Sea for the 20-year period 1991–2010. To be able to complete these assessments intersessionally despite data delays is a significant achievement, and the Reviewers believe that the work of the WGSE has now further strengthened the promise of full adoption by OSPAR. As such, this report provides an important step towards developing EcoQOs for the region and the working group should be commended for completing the report intersessionally despite delays in data provided.

That said, the Reviewers note the fact that the robustness of the reported trends has not been assessed, and that the lack of sensitivity tests of the statistical methods applied are reasons for concern. Both should be resolved before further progress can be made with the Seabird EcoQO. Further work is also required to elaborate species-specific baselines and interpretation models in relation to food webs in order to document to what extent the Seabird EcoQO is an appropriate indicator in assessing and achieving Good Environmental Status as part of measures to be implemented under the EC Marine Strategy Framework Directive.

Specifically, based upon a review of this document, the Reviewers note that the data used for the trend analyses are, despite the exclusion of some species, a comprehensive extract of regional monitoring data from all North Sea countries. The Reviewers believe that the report would gain from adding more information about monitoring sites and count methods. Relevant information (proportion of regional population in sample) is provided in ICES WGSE Report 2010, but it would be valuable to also include information on geographical positions (maps) of locations surveyed and methods used for respective survey.

The Reviewers also note that the trend analyses were undertaken using log-linear models in the software TRIM. Judged from the report TRIM was chosen due to time constraints despite it being referred to as inappropriate in ICES WGSE 2010 (page 9, section 2.2.2), and the report recommends the implementation of the Thomas method used for the assessments for OSPAR Region III (ICES 2010). The Thomas method would allow for imputation across missing counts and for incorporation of both whole colony counts and plot counts, even when they exist for the same colony in the same year. This recommendation should be emphasized, as the two methods produce very different trends from the same data; the main difference being that confidence intervals are estimated empirically by bootstrapping in the Thomas method, resulting in much wider intervals. The evaluation of seabird trends in OSPAR Region III was entirely based on the mean values using the Thomas method, yet if the confidence intervals had been used to assess the EcoQO then only one species (as opposed to six species when using the mean value) would show as not achieving its lower target.

Unfortunately, the use of the TRIM software, raises the question of the reliability of the results of the EcoQO. The Reviewers believe that it should be a priority for ICES to compare the statistical trend models used in TRIM and by the Thomas method with a range of other statistical methods which allow for imputation, smoothing and integration of data sources with different levels of uncertainty. Examples could be Generalised Additive Models, Trendspotter and Bayesian time series models. Comparative tests would be useful to show the robustness of the trends and associated confidence intervals estimated with the applied method. Further scrutiny of the statistical framework also seems warranted given the general lack of consensus on statistical methods for determination of population trends and the variability of results produced by different methods.

Additionally, one Reviewer suggested that it would be worthwhile to compare the differences in output and conclusions (as a sensitivity analysis) between the TRIM method and "wizard" approach as there appear to be some differences in trends for several of the species included (by visually comparing the graphs for the different species in ICES WGSE 2010 and 2011).

The Reviewers noted that a uniform baseline year (2000) was chosen for all seabird species assessed and concur with the Working Group that species-specific baselines should be elaborated, e.g. by performing sensitivity tests. If it is possible using this analysis to use species specific reference points, the Reviewers anticipate clear differences between timing of anthropogenic impacts are stated in ICES WGSE 2010.

In addition to the recommendations for updating related to the statistical treatment of data, work is needed to develop interpretation models for the Seabird EcoQO. In relation to the qualitative descriptors being drawn up for the Marine Strategy Framework Directive (MSFD) by ICES, the Seabird EcoQO has been recommended as part of the food web indicators. Despite the fact that the evaluations of the Seabird EcoQO suggest that it is scientifically sound and performs well with certain limitations, the application of the indicator on the basis of breeding populations alone might be worth further consideration.

Further, since a large proportion of breeding seabirds feed themselves and their chicks on prey taken primarily in coastal waters (e.g. cormorants and shags, gannets, skuas, terns, gulls and auks) the EcoQO based entirely on data from breeding colonies may fail to provide useful information to feed into the general system of food web indicators envisaged under the MSFD. The Reviewers believe that central to this question is the issue of scale-dependency in the response of seabirds to prey. Recent model results concerning interactions between wintering seabirds and fish in the North Sea actually suggest that the strongest responses by seabirds to the variability in prey stocks are found at a large spatial scale (Fauchald *et al.* 2011). The Reviewers recommend that ICES assess the spatial hierarchy of seabird-fish interactions during the breeding season.

ICES emphasizes the importance of the ecosystem approach and is the main host for data on fish stock dynamics of relevance for several of the seabirds included. As such, the Reviewers suggest that the analysis would benefit from including information regarding relevant fish stock trends when prey species and their dynamics are known (or at least reference to ICES documents where they can be found). A future ambition of the Working Group could be to advise on precautionary guiding principles for harvest of fish stocks that are also prey to seabird species. A first attempt to arrive at such a precautionary principle was published December 2011 in Science (Cury *et al.* 2011).

Fauchald, P., Skov, H., Skern-Mauritzen, M., Hausner, V.H., Johns, D. and Tveraa, T. 2011. Scale-dependent response diversity of seabirds to prey in the North Sea. Ecology 92, 228–239.

Philippe M. Cury, Ian L. Boyd, Sylvain Bonhommeau, Tycho Anker-Nilssen, Robert J.M. Crawford, Robert W. Furness, James A. Mills, Eugene J. Murphy, Henrik Österblom, Michelle Paleczny, John F. Piatt, Jean-Paul Roux, Lynne Shannon and William J. Sydeman. Global seabird response to forage fish depletion — one-third for the birds". Science 23 Dec 2011, Vol. 334, Issue 6063.