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Contents

Executive summary 3

1 **Introduction** 4

2 **Local Enhancement among Seabirds and Other Marine Predators and its Consequences for Conservation** 4

2.1 Definitions 5

2.2 Evidence of Local Enhancement and Facilitation 5

2.3 Costs and Benefits of Foraging Associations 7

2.4 Coevolution: Variation between species 7

2.5 Conservation applications 8

2.6 References 8

3 **Modelling the At Sea Distribution of Seabirds: Predicting Locations of Hotspots** 12

3.1 Types of Bird Data 13

3.2 Survey Design 13

3.3 Types of Models 13

3.4 Inclusion of Environmental Data 14

3.5 Behavioural Classes of Birds 14

3.6 Aggregations of Birds 14

3.7 Definitions of "Persistent" and "Hotspot" 15

3.8 Conclusions and Recommendations 15

3.9 References 15

4 **Recommend priority areas of study to determine the consequences to seabirds of landing obligations/discard bans** 16

4.1 Priority areas for study 17

4.1.1 Population ecology 17

4.1.2 Nonbreeding season 18

4.1.3 Diet 18

4.2 Conclusion 19

4.3 Summary of Recommendations 19

4.4 References 20

Executive summary

Between 2012 and 2013, the ICES Working Group on Seabird Ecology effectively divided into two separate groups: the "Bird Expert Group of the OSPAR Intersessional Correspondence Group on Coordination of Biodiversity Assessment and Monitoring (ICG-COBAM)" and the ICES "Working Group on Seabird Ecology". The first of these was formed to deal with applied issues, especially the development and implementation of "EcoQ0s" while the second has the task of writing about more "pure science" topics. It is our intention to form a joint ICES/OSPAR group in future years whose goal it will be to address both applied and pure research. For now, this report will include only the work of the ICES WGSE; the results of the OSPAR group will appear separately.

We addressed three terms of reference, on Local Enhancement and Facilitation, on use of Mathematical Models to portray spatial distribution of seabirds, and on recent changes on European law regarding discards by commercial fishing vessels.

The resolution to form the Joint ICES/OSPAR Group will be added at a later stage.

1 Introduction

The Group met simultaneously with the OSPAR ICG- COBAM, chaired by Ian Mitchell. We acknowledge the assistance and helpful conversations with the members of that group. We anticipate that future meeting will be concurrent with both groups so as to continue this important interaction.

Terms of Reference for the meeting

a) Review data and publications on "Local Enhancement" and "Facilitation" among seabirds and other marine predators to assess possible impact of these behaviours upon conservation policy;
b) Review utility and accuracy of "Habitat Models" of birds at sea for the construction of Marine Protected Areas;
c) Recommend priority areas of study to determine the consequences to seabirds of landing obligations/discard bans;
d) Work with ICG-COBAM (Seabirds) Group to update information on EcoQOs for ICES Regions II and III;
e) Work with ICG-COBAM (Seabirds) Group to consider a future joint ICES-OSPAR group structure and make recommendations.

2 Local Enhancement among Seabirds and Other Marine Predators and its Consequences for Conservation

There is increasing recognition of the importance "Positive Interactions" among species in structuring communities (Stachowicz 2001, Bruno *et al.* 2003). For seabirds, an important kind of positive interaction is the use of birds of the same species, birds of other species, and other marine predators such as cetaceans, seals and fishes as cues to the presence of food. The process by which a single bird uses, say, a feeding flock of birds as a cue to the presence of prey is called "Local Enhancement" or "Facilitation". There are subtly different uses of each of these terms, but the issue we address here is whether the feeding success, and therefore presumably the fitness, of individual seabirds, is increased due to the actions of other individuals of either the same or different species. If this contention is true, then it implies that conservation of any one species of seabird must take into consideration the status and possible conservation of those species that the focal species uses as a cue while foraging. For example, conservation of Great Shearwaters, which often feed over tuna schools, should take in to consideration conservation of tuna.

Managers of marine resources and conservation biologists share an interest in predicting the distribution of seabirds, and in particular establishing what factors are most influential in attracting birds. There has been varying success, or often surprising failure, in relating seabirds to their food or other resources (Shealer 2002). One factor that is certainly important but rather poorly emphasized is the attraction of birds to each other, and the attraction of birds to other marine predators such as cetaceans and predatory fishes. The gap has been identified as being the behaviour of the birds (Camphuysen *et al.* 2012). There is need for greater focus on feeding behaviour, and a greater understanding of requirements for successful foraging. In particular, how does enhancement affect the energetics of seabirds provisioning young? And what is required for recruitment and does enhancement dramatically improve survival probabilities of some species in the first years of life? It is counterintuitive that seabirds would benefit in foraging associations with competitors, and it may be that such associations are not always profitable. However such foraging associations are ubiquitous, sometimes involving enormous numbers of individual seabirds. Here we consider how local enhancement and facilitation among seabirds and other marine predators is of fundamental importance in understanding survival and reproductive success and distribution at sea.

2.1 Definitions

Seabirds use cues from other individuals, conspecifics or other taxa whether seabirds, fish or marine mammals, to detect food (Nevitt and Veit 1999, Grünbaum and Veit 2003, Silverman *et al.* 2004). This process is often called "Local Enhancement" but the same term may refer to birds cooperating in the herding of prey in addition to simply passively providing cues to the presence of prey. The term "Facilitation" refers to a cooperation among species in which only one of the species receives direct benefit (Stachowicz 2001). It is unclear for most seabird aggregations whether one or more species participating in the interaction derive benefit. There are important implications; detection of prey may be positively density dependent through local enhancement (e.g. birds aggregate to high bird density because that high density indicates increased prey abundance; Grünbaum and Veit, 2003). In addition to serving as cues to the presence of prey, some marine predators such as dolphins, seals and tunas and other fishes, drive prey such as schooling fishes and zooplankton to the surface so that they become more readily available to birds (Harrison *et al.* 1991; ICES 2010).

2.2 Evidence of Local Enhancement and Facilitation

Seabirds occur in different types of feeding associations, reflecting prey availability and the nature of inter-specific relationships. These inter-specific associations have been described and the likely benefits explored in a number of papers (e.g. Ashmole 1971, Pierotti 1988, Camphuysen and Webb 1999). The patterns appear to vary between polar and tropical regions, and between near shore and offshore habitat, reflecting the constraints on foraging in different marine environments and adaptive responses.

Tropical oceans

In tropical oceans seabirds have varied adaptive interspecific relationships with other seabird species, with predatory fish such as tuna, and with cetaceans (Au and Pitman 1986 Ballance *et al.* 1997, Hodges and Woehler 1994, LeCorre and Jaquemet 2005, Vaughan *et al.* 2007). In the eastern tropical Pacific the ''tuna-dolphin-seabird assemblage'' is a conspiculus feature of the marine community, in which a large diversity of seabirds associate with yellowfin tuna (*Thunnus albacares*), spotted and spinner dolphins (Ballance *et al.* 2006). Breeding success and fitness of many aerial tropical species such as sooty tern, almost certainly depend on their association with tuna schools, which drive schooling baitfish to the surface where they can be accessed by the birds (Table 1).

The open ocean of the tropics may offer particular challenges for aerial predators; hydrographic features do not function to concentrate prey in the same way as on the continental shelf, and the spatial predictability of prey is lower than in high latitude waters. The capacity of aerial predators to see each other and interpret the behaviour of conspecifics and other seabirds is potentially important in providing cues. The diversity of highly aerial tropical seabirds suggests that there may be an advantage to the efficient coverage of large distances to locate feeding events. The disadvantage is that many tropical species are limited in their prey capture to the very surface of the sea. It is a reasonable hypothesis that for many species there is a high level of dependency on other species which function to drive prey to the surface.

In the sometimes enormous and species rich mixed species associations in tropical waters (Au and Pitman 1986) the participants may differ in the benefits, indeed may not always benefit. However the associations reported in the literature indicate that seabirds benefit from associating with cetaceans in particular, using them both in locating prey and making it available at the surface. Shearwaters were observed deliberately joining non-feeding dolphins; once feeding dolphin and tuna association drove bait fish into a dense ball and held them near the surface where they were available to the birds (Martin 1986).

Polar waters

Abundant seabirds and cetaceans have been associated with hotspots in Arctic and Antarctic seas. Species rich persistent concentrations of top predators were found associated with ecologically important ocean features such as the Antarctic Circumpolar Current by Santora and Veit (2013), but also in persistent associations indicative of local enhancement (Harrison *et al.* 1991). Black-browed albatrosses are unambiguous leaders in mixed-species flocks feeding on Antarctic krill, around South Georgia (Harrison *et al.* 1991), interactions with a small group of other species suggesting co-evolved species affiliations. The importance of local enhancement will not necessarily be great, for example at high densities Grünbaum and Veit (2013) found little effect.

However facilitation might be very important at high prey densities (Hunt *et al.* 1988). Schneider *et al.* (1990) identified the importance of the interaction between hydrography and local enhancement as the result of species associations; they found kittiwakes feeding near auks – on the dead and disoriented euphausiids accumulating in fine-scale convergences near a sub-surface feeding frenzy.

North Atlantic

Associations of seabirds, and seabirds with cetaceans, are a feature within EU waters, sometimes creating large aggregations: gannets and other seabirds with dolphins, Cory's shearwaters with migrating fin whales in the Bay of Biscay. These mixed-species associations are more common in some sea areas than others – for example gannet associations with marine mammals are more typical off offshore areas (Camphuysen *et al.* 2012, Camphuysen and Webb, 1999). Bellier *et al.* (2005) tested patterns of aggregation in gannets in the Bay of Biscay and found evidence for local enhancement. They found that aggregations formed primarily in areas of high gannet density, consistent with findings of Grünbaum and Veit (2003).

As for other species dependent on the surface waters, gannets are first using a marine habitat, but then strongly associated with other species which serve as facilitators, driving prey toward the surface, into reach. They associate with cetaceans, particularly dolphins, in the productive waters of the Gulf of St. Lawrence; in an analysis of the relative importance of various drivers, cetacean abundance was most important, indicating local enhancement and facilitation is important for foraging gannets (Guse 2013). As in the tropical Pacific and polar oceans, gannets foraging in North Atlantic waters have a hierarchical search pattern: they occupy physical environment defined by the ocean currents and oceanographic features such as hydrographic frontal systems, and they use local enhancement to detect prey patches (Bellier *et al.* 2005, Guse 2013). Aggregations in European waters occur at several spatial scales.

Strong tidal fronts are found around European coasts, and species converging on these good foraging areas may also be benefitting from local enhancement, as described above in the Bering Sea. At a tidal front in the Irish Sea surface-feeding species (mostly kittiwakes) were found feeding in surface convergences on the accumulating debris resulting from a subsurface feeding frenzy by Manx Shearwaters (*Puffinus puffinus*), guillemots (*Uria aalge*) and razorbills (*Alca torda;* Durazo *et al.* 1998).

2.3 Costs and Benefits of Foraging Associations

The drivers generating the positive interactions between species result in a gradient of possible interactions (Bronstein 1994, Stachowicz 2001), with mutualism at one extreme and competition and a failure to tap resources is at the other extreme. Clearly seabirds that join a feeding flock may experience increased competition with members of that flock, conspecific or otherwise, than they would while feeding alone, apart from any flock. At the same time it seems inescapable that this increased competition is more than counteracted by the increased food intake occurring in the flock. Quantifying this balance of increased competition versus increased food intake is logistically difficult, even if using photography or video. Events simply transpire too fast.

An open area for research is to determine by how much a bird's fitness increases through local enhancement, or at least how food capture rate depends on density of competitors. Since large feeding flocks seem to last longer than smaller flocks (pers. obs, Harrison *et al.* 1991), prey capture probably increases over some range of flock sizes. If this is true, then certainly population growth rates of seabirds that depend on finding feeding flocks to find sufficient food need to be linked to the presence, frequency and size of those flocks. Irons (1998) found that breeding kittiwakes returned to the same feeding areas, and selectively joined flocks in preferred feeding areas – with preference shown for large flocks, which were typically associations with diving seabirds such as murres.

2.4 Coevolution: Variation between species

Considerable interest exists in the evolution of mixed-species foraging associations and their importance in influencing the spatial structure of species within communities (Goodale *et al.* 2010) and the interspecific associations in marine environments may have greater importance than has been recognized. However there is the repeated contention that in the marine environment, seabird flocks are temporary feeding associations – not highly evolved associations (e.g. Munn and Terborgh 1979). This does not identify the strength of some of the relationships between marine species in foraging associations. There are indeed simple transient foraging flocks of seabirds, but also mixed-species foraging flocks in which species show strong interspecific affinities (e.g. Pitman and Ballance 1992). Murphy (1936) observed that in the Southern Ocean the procellariids are more frequently in mixed-species associations than apart from them. There are interdependencies that reflect differing flight dynamics, diving abilities and sensory capacities. Differences exist between species in their ability to find prey either directly (e.g. olfactory capability across different spatial scales; Nevitt 2000) or indirectly (e.g. observation of other predators; Harrison *et al.* 1991). Mixed-species seabird flocks vary in complexity and the spectrum of interspecific relationships represented has been understated in the literature (Harrison and Whitehouse 2011).

Evidence from Matley *et al.* 2012 illustrates how such differences in detection of prey may result in patterns frequently seen such that it is difficult to associate predators with prey distributions; in this study of the behaviour of seabirds feeding on Arctic cod, schools of fish were a good predictor of fulmar distribution but not black-legged kittiwakes. The former is a procellariid with prey detection primarily by olfactory senses, while the kittiwakes are visual, and benefit from local enhancement and facilitation (Schneider *et al.* 1990, Irons 1998).

2.5 Conservation applications

The broad taxonomic and geographical ubiquity of local enhancement provides a compelling argument for a more ecosystem-level approach to protecting marine habitats. Ecosystem management depends on understanding the importance of such processes; the loss of biodiversity, and so the simplification of marine communities, may be the greatest threat to marine ecosystems (Stachowicz 2001). If seabirds are worth protecting, then certainly other animals that contribute to their acquisition of resources require protection as well. If gannets depend on dolphins to find food, then a conservation plan for gannets ought to include dolphins. Furthermore for seabirds that rely mainly on others of their own species as cues to food, then a decline in that species may trigger a rapid, nonlinear crash as the species decline below some threshold where they are no longer useful to one another as cues.

We need additional data on interactions among seabirds, other seabirds and other predators. Understanding patterns in the aggregation of birds – important implications for designation of protected areas, and management of species - particularly management of populations for recovery.

It is convincing that populations of cetaceans are important for foraging seabirds; their demise has represented degradation of their foraging environment. In locations such as Northern European waters there are many species which once would have been important in the marine ecosystem as facilitators that are now missing. The recovery of great whales regionally in European waters will be a significant development improving foraging opportunities of species such as gannets and various procellariids.

Aggregations of seabirds occur at a number of spatial scales, indicating the scale of their oceanic habitat, and then within that aggregations forming as the result of local enhancement and facilitation. In the case of the first, it is within our power to establish habitat associations, and define the habitat of a species of seabird at sea. However local enhancement and facilitation is the product of the communities, the characteristic combination of species and their relative abundances. The importance of interspecific interdependencies represents and obstacle to our ability to define at sea areas important for seabirds. The importance of local enhancement and facilitation varies between species, and in some cases may be a fundamental characteristic of the species foraging ecology. Understanding this is important for protecting these species.

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Table 1. Interspecific associations and apparent Local Enhancement/Facilitation.

SPECIES ASSOCIATION [1]	LOCATION (REGION/HABITAT)	LOCAL ENHANCEMENT/FACILITATION[2]	SOURCE
Sula spp., wedge-tailed shearwater (*Puffinus pacificus*), spotted dolphin *(Stenella attenuata)*, spinner dolphin (S. longirostris), yellow-finned tuna (*Thunnus albacares*)	Tropical Pacific/ open ocean	1, 2	Au and Pitman 1986
Parkinson's petrel (*Procellaria parkinsoni*), melon-headed whale (*Peponocephala electra*), false killer whale (*Pseudorca crassidens*)	Tropical Pacific/ open ocean	1, 2, 3	Pitman and Ballance 1992
Wedgetailed shearwaters (*Puffinus pacificus)* and brown noddies (*Anous stolidus)* Skipjack tuna *(Katsuwonus pelamis)*	Tropical Pacific/ open ocean	1, 2	Hebshi *et al.* 2008
Cory's shearwaters (*Calonectris diomedea*), great shearwater (*Puffinus gravis*), Atlantic spotted dolphin (*Stenella frontalis*)	Tropical Atlantic/ Azores – open ocean	1, 2, 3	Martin 1986
Cory's shearwaters (*Calonectris diomedea*), dolphins (*Delphinus* and *Stenella spp) and* tuna (*Thunnus* spp)	Tropical Atlantic/ Azores - open ocean	1, 2	Clua and Grosvalet 2001
Black-browed albatross (*Deomedea melanophris*), Antarctic fur seals (*Arctocephalus gazella*), macaroni penguins (*Eudyptes chrysolophus*), *Pachyptila* spp.	Antarctic/ shelf South Georgia	1, 2, 3	Harrison *et al.* 1991
Black-legged kittiwakes, *Aethia* spp., *Uria* spp.	North Pacific/ Bering Sea - shelf	2, 3	Hunt *et al.* 1988

Black-legged kittiwakes (*Rissa tridactyla*), *Uria* spp	North Pacific/ Bering Sea - shelf	2, 3	Schneider *et al.* (1990)
Black-legged kittiwakes, Manx shearwater (*Puffinus puffinus*), guillemot (*Uria aalge*)	North Atlantic/ Irish Sea	2, 3	Durazo *et al.* (1998)
Gannet (*Sula bassana*), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), harbour porpoise (*Phoca vitulina*), minke whale (*Balaenoptera acutorostrata)*	North Atlantic/ Gulf St Lawrence	1, 2	Guse 2013
Black-legged kittiwake, Northern fulmar (*Fulmarus glacialis*), red phalarope (*Phalaropus fulicara*), thick-billed murre (*Uria lomvia*), California grey whale (*Eschrichius robustus*)	North Pacific/ Bering Sea - shelf	3	Grebmeir & Harrison, 1992; Obst & Hunt 1990
Glaucous-winged gull (*Larus glaucenscens*), Rhincerous auklet (*Cerorhinca monocerata*)	North Pacific, continental shelf	1, 2	Grover and Olla 1983
Leach's storm petrel (*Oceanodroma leucorhoa*). Manx shearwater, pilot whale (*Globicephala melas*), bottlenose dolphins (*Tursiops truncatus*)	NE North Atlantic open ocean	1, 2, 3	Skov *et al.* 1995
Black-legged kittiwakes, northern gannets, minke whales (*Balaenoptera acutorostrata*)		1 ,2, 3	Camphuysen and Webb 1999
Wilson's Storm-petrels *Oceanites oceanicus* , Rough-toothed Dolphins *Steno bredanensis*	Brazil – coastal waters	3	Olmos *et al.* 2013

[1] **Species frequently observed together, at core of interspecific association, not a full list of documented attendants**

[2] **Apparent basis of association (1 = inter-specific association aid participant(s) in location of prey patch; 2= prey made available at the surface by diving species; 3 = waste or fragmented prey made available by messy eater)**

3 Modelling the At Sea Distribution of Seabirds: Predicting Locations of Hotspots

Recent mathematical models of seabird distribution do a fairly poor job of indicating areas of persistent seabird aggregation, which is exactly what they are attempting to predict. We offer some nonparametric approaches that may be more informative. The overall goal is to identify those parts of the ocean that are persistently important to birds. The words "persistent" and "important" need to be defined precisely, but this is not difficult (Santora and Veit 2013).

Identification of parts of the ocean that are more important to seabirds than are others has recently achieved paramount importance because of the need for development of offshore areas for wind, tidal and wave energy, and fossil fuel extraction (Desholm and Kahlert 2005; WGSE 2011). Areas that are especially important to seabirds are often referred to as "Hotspots" (Piatt *et al.* 2006, Hurlbert and Jetz 2007, Santora and Veit 2013, Hazen *et al.* 2013) and a large effort has been devoted to identifying such Hotspots with the idea that wind turbines or oil drilling platforms should not be built in those areas because of the potential damage to birds.

A principal method to identify seabird Hotspots is to build a statistical model of spatial data on seabirds, for which the data have been collected from ships and airplanes (Oppell *et al.* 2012, Menza *et al.* 2012, Clarke *et al.* 2003). Most recent models have been in the broad category of "regression", "GLM" or "GAM" and include data on birds plus environmental information. The latter are often obtained remotely, and are often long-term averages rather than values collected during the cruise on which the data on birds have been collected. The output of such models is a map of modelled seabird abundance. This chapter evaluates the accuracy of these maps and consequently their reliability and usefulness in the planning for offshore energy installations and the design of Marine Protected Areas.

3.1 Types of Bird Data

Surveys of birds have been conducted from both ships and airplanes. Generally it is important to include some sort of "distance sampling" but in practice, improvement in accounting for missed birds is counteracted by missing additional birds while estimating distances. Provided birds are searched for using binoculars, differences between "Line Transects", which use distance sampling and "Strip Transects" which don not, ranges from the order of 5% (pers. obs. unpublished) to 80%, depending on species (Ronconi and Burger 2009). Distance sampling is especially difficult to implement during aircraft surveys because of the speed with which the plane travels and consequently the short time available to count birds.

Many of the critiques applied to Strip Transects have been acknowledged not to apply particularly well to shipboard surveys of birds (Clarke *et al.* 2003).

3.2 Survey Design

Most recent surveys have used modified "Distance Sampling" or a combination of Strip and Line Transects (Tasker *et al.* 1984) in which distances and angles to birds are collected when bird density permits, and dropped when densities are so high that substantial birds would be missed when spending time to collect them.

3.3 Types of Models

The aim of modelling distributions of birds is to estimate their abundance in each part of the ocean surveyed, given incomplete data. It is only possible to sample a fraction, often a small fraction, of the available habitat. Therefore, the general approach is to construct a model that determines the best predictors of seabird numbers in the areas that are sampled, and then to predict abundance of birds in areas not surveyed. This approach, while perfectly logical, has some serious pitfalls.

Most models of the basic regression or "General Linear Model" framework, e.g.:

Bird Abundance = $\beta_1X_1 + \beta_2X_2 + \ldots\ldots\beta_nX_n + \ldots\varepsilon$ (1)

But also include "General Additive Models" in which the relationships among the dependent and independent variables are estimated using regression techniques to estimate slopes at many points along each X-Y line. For all such models, critical points for those on seabird abundance include choice of what environmental data to use, how to deal with large aggregations and consequent peculiar statistical distribution of bird abundance data, and method of dealing with birds unidentified to species.

3.4 Inclusion of Environmental Data

Most datasets on pelagic birds, whether collected from ship or airplane, are not accompanied by environmental data. Therefore, most models of seabird abundance have used remotely sensed data (e.g. satellite-based colour images of phytoplankton concentration as a proxy for primary productivity) or data collected from other ships. Often the environmental data used are long-term average values, rather than the value at the time and place where the bird data were collected. Since aggregations of birds are ephemeral, the environmental factors leading to formation of aggregations of seabirds ought to be collected as closely as possible in time to the time the aggregations are found.

3.5 Behavioural Classes of Birds

Output from models is strongly affected by behaviour of birds recorded. If one includes all birds seen during a survey within a model, a great deal of noise is generated by birds that are flying from one place to another. By comparison, if one includes only birds that are feeding within a model, then the output from that model is much more likely to reflect the habitat preference of those birds. Similarly, including only birds sitting on the water is likely to be an improvement over use of all birds, regardless of behaviour.

3.6 Aggregations of Birds

Statistical distributions of bird abundance are peculiar and very right-skewed with a very long "tail". This is because birds at sea are very highly aggregated (variance – to mean ratios often in the 10^2–10^4 range, or vastly larger than for Poisson distribution, for example) as very large clusters of birds are often separated by large tracts of ocean where no birds are present. Statisticians have always had great difficulty dealing with such data, and there is no known statistical distribution that fits them. Progress has recently been made using joint probability distributions, in which abundance data are divided in two components – one which specifies the number of samples with zero birds, and the other that specified the shape of the distribution of the cells with > 0 birds. There are even three part distributions, in which there are two components as described above, plus a third component that specifies and exact proability of encountering a very large aggregation, where "very large" is defined in terms of some multiple of mean abundance (e.g. 100 times the mean abundance).

Still, with all these improvements, there is the problem of predictability of bird abundance since there are relatively few very large aggregations. Some nonparametric models of "Hotspots" (Santora and Veit 2013) help to address this specific point and may provide for a framework for identifying Hotspots, despite the limitations of models discussed above.

3.7 Definitions of "Persistent" and "Hotspot"

Some places harbour aggregations of birds that never appear a second time. Other places are known places of seabird aggregation that are visited often by birds (and consequently birders) because large aggregations of birds often appear. The goal of the kind of modelling we are talking about is to quantify the persistence of such locations. Santora and Veit (2013) overlayed a grid over the area sampled, calculated mean abundance for each of the squares within the grid, and then for each of the squares asked what proportion of the time the square was sampled did it have abundance that exceeded the mean over all squares by 2 s.d. units. Those squares that did meet this criterion > 50% of the times sampled were defined as Hotspots.

Using this method, definitions of "Persistent" and "Hotspot" emerge that are appropriate to the particular geographical area surveyed. A Hotspot in a polar region will contain more birds than one in the tropics.

3.8 Conclusions and Recommendations

1) Care must be taken to retain all very large aggregations of birds and not remove these as "outliers". All very large aggregations should be included, regardless of behaviour.
2) As closely as possible, data on seabird abundance should be modelled with simultaneously collected environmental data. If this is not possible, maps of raw data (not modelled data) may be preferable.
3) The most direct link to seabirds is the food they eat, so the most important environmental data to include within a model is simultaneously collected data on zooplankton abundance by echosounder.

All data collected from ships and aircraft should include behavioural code for each bird or flock of birds. Models should consider using only birds recorded as "feeding", or behaving in a way as to suggest feeding (e.g. sitting on the water), when making predictions about hotspots.

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4 Recommend priority areas of study to determine the consequences to seabirds of landing obligations/discard bans

The imminent changes in fisheries as part of the reform of the CFP (CEU 2012) will remove a major source of prey for scavenging seabirds. The changes in the landing obligations will be step-wise, with an end to pelagic discards as of 2014, and of demersal discards by 2016. There will continue to be some waste available via fishing vessels, including some discards (5% permitted, although what this will represent in practice is unclear). The consequences for seabirds are uncertain, but for some species are likely to be considerable.

Bicknell *et al.* (2013) have identified the potential consequences for seabird communities in the EU, and based on this comprehensive review we will make specific recommendations for priority areas for study. There is great value in initiating research immediately in order to set a baseline. Study of the changes must be cognizant that changing fisheries policies are likely to have consequences which vary regionally and according to taxa of seabird.

Seabird species vary in their use of discards, with some species not using them at all, and others opportunist scavengers in inflated populations as the result of dependency on fisheries. In some cases the conservation status of threatened species is positively affected by food available from fisheries (Louzao *et al.* 2006).

Bicknell *et al.* (2013) identify three categories of bird using discards (Figure 1). The generalist omnivores (large gulls and skuas) merit study because they may be expected to shift from a diet dominated by discards to feeding substantially upon other smaller seabirds that may be conservation priorities. The generalist piscivores (gannets, fulmars, Balearic and Cory's shearwaters) will likely vary in their response to the discard ban; a better understanding of their population responses is important as they are the group most likely to experience precipitous declines regionally. Finally, there may be impacts on specialist piscivores (Sandwich terns, common terns and kittiwakes), not because of their dependency on discards but because of likely changes in the marine community (Tasker *et al.* 2000). There are certain to be changes in the behaviour, distribution and abundance of seabirds – interspecific competition for prey may increase with deleterious effects on a range of seabird species. There are also likely to be local or regional changes in the marine community such that the availability of forage fish changes, potentially benefitting some seabird species (Bicknell *et al.* 2013).

4.1 Priority areas for study

4.1.1 Population ecology

Gaps in knowledge have been identified by Bicknell *et al.* (2013) which provide guidance for priority areas of study. One central issue is the need to understand population and demographic changes at colonies. Three types of data should be collected as a priority as part of existing populations monitoring: regional variation in breeding success, recruitment, and mortality. Long-term seabird monitoring is important, in order to understand change in context and take remedial action when appropriate, and is necessary to provide the statistical power required to control for other confounding environmental factors (Bicknell *et al.* 2013; Table 2). While there is no question that better fisheries management is a good thing for the marine ecosystem, these species will be impacted. As we learn how their populations are affected by the changes, we need to realign our expectations of their population sizes, and set in place new realistic goals for their conservation.

Given the magnitude of this change in fisheries policy, and potential for ecosystem wide changes, we recommend reporting seabird demographic change according to ICES fisheries statistical areas. The implementation of the new discard policy will not come into force uniformly across sea areas, and it is desirable if data on regional seabird colonies can be related to information on obligatory landings – a measure of food lost to scavengers. The compilation of data will include Norwegian waters, interesting because of the much earlier discard ban and this region. The ban on cod discards went into effect in 1987, and the full ban on discards was implemented on 1 January 2009 (Bjarne Schultz pers comm.). Throughout European waters the nature of the fisheries (pelagic vs. demersal), the total fishing effort, and the seabird community present (pelagic vs. nearshore) will have been important determinants of the availability of discards and the array of dependent scavengers. An important area for study will be relating the fisheries region with the populations of birds, and documenting the change among the scavengers. The effectiveness of this approach depends on the collection of data by regions documenting the implementation of the new landing obligations/ discard ban. Supplementary information on the disposal of offal and legal discards from the fishing fleet would be valuable. The differences between regions in the response of seabird populations will be of great interest in understanding where and how marine communities are changing.

4.1.2 Nonbreeding season

One important gap in knowledge is the extent to which scavenging seabird species use discards in the nonbreeding season and the extent to which discards contribute to winter survival of adults and to recruitment. Discards provide an easy source of food to birds during the winter, and in their first years of life (Bicknell *et al.* 2013). Survival of young gulls and gannets is likely to be increased as the result of waste from fishing vessels. The impacts will be in the availability and quality of food, but also distribution of birds will be affected (Bartumeus *et al.* 2010). All three categories of species are predicted to change their distribution at sea as a consequence of the discard ban, both because of the lost food resource, and the consequent regional change in abundance of small forage fish (Bicknell *et al.* 2013). The outcome will depend upon the extent to which the discard ban is put in force, and the other fisheries waste that continues to be available to birds (e.g. offal).

The following are specific recommended areas of study:

- The distribution of birds at sea in the non-breeding season, with particular focus on foraging surrounding fishing vessels (e.g. Camphuysen and Garthe 1997, Votier *et al.* 2013).
- Regional winter mortality events, evidence of starvation/body condition of birds in winter (Camphuysen and Heubeck 2001).
- Evidence of changing migration routes in migratory species – and potential for vulnerability of early life stages (e.g. Péron and Grémillet 2013, Catry *et al.* 2011).

The methods used in the studies referred to above include innovative approaches to difficult questions – whether bird-borne cameras (Votier *et al.* 2013), or the stable isotopes which have provided new insights to the movements of migrant seabird species (Péron and Grémillet 2013, Catry *et al.* 2011). The generalist piscivores which are the subject of these studies might reasonably be expected to respond to the loss of discards in their diet by catching fish, and the application of these relatively new techniques to test this idea, and should represent a priority for research.

4.1.3 Diet

A priority for research is the systematic study of diet across a range of species in the three categories illustrated in Figure 1. A recent review of the methodological approaches to research into diet provides a basis for the systematic study, across the ICES fisheries statistical areas, and appropriate for the various species of seabird (Barrett *et al.* 2007).

Many of the species which benefit from discards are opportunistic species, which switch between prey types depending on availability. In some cases the loss of discards could create acute problems; great skuas switch between discards and seabirds, chicks taken from the nest (Miles 2013). Their impact on protected species could be considerable. This pattern could also be seen in large gull species, which may switch to eating more seabirds, their chicks and eggs. Focus on diet of skuas and large gulls, and comparisons of their breeding performance regionally should be a priority area of research.

The following are required:

- Meta-analysis of diet studies of seabird species thought to depend largely on discards to seek species-specific , temporal and regional differences in such dependencies, to be able to predict where birds might be most affected.
- Inventory of the seabird colonies which may be vulnerable to the changed availability to discards to 'generalist piscivores' (Figure 1), and study into appropriate remedial action.
- Study of the growth rates and condition of young birds – comparing those fed discards and those fed forage fish (testing junk food hypothesis; Wanless *et al.* 2005).

Techniques also exist for automating the study of diet – with stable isotope analysis a way of studying tropic flow. Nitrogen isotopes are a means of establishing how high up the food chain birds feed (Barrett *et al.* 2007). With clippings from feathers, the isotope signature of chicks would indicate the 'part of the food chain' used in their production. Other predictions could relate to 'tropic flow' – for example fulmars shifting to prey lower on the food chain, feeding more on zooplankton. Presently fatty acid analysis, DNA finger-printing and stable isotope analysis are all increasingly useful, sometimes in combinations, in order to provide indications of population level shifts in diet (Iverson *et al.* 2007, Karnovsky *et al.* 2012, Deagle *et al.* 2007, Jaeger and Cherel 2011).

4.2 Conclusion

Bicknell *et al.* (2013) conclude that research should focus on understanding changes in the foraging behaviour of opportunistic seabirds as a consequence of the discard ban – but also as a consequence of changing natural fish prey availability which is likely to change with EU fisheries reform. At present it is difficult to predict the magnitude of the impact of the new landing obligations/ discard ban. Changes in policy on discards may have a striking impact on some species, those with inflated populations, but we predict further impacts on the wider seabird community, with potential benefits to some species. Monitoring seabird populations is important and also potentially valuable as an indicator of environmental changes.

4.3 Summary of Recommendations

1) Continue collecting data on abundance for birds of the three major groups (large scavengers, gannets and shearwaters, terns and kittiwakes) such that predictions of increased or decreased abundance following discard ban can be tested.

2) Ensure support for population monitoring studies providing data on regional variation in breeding success, recruitment and mortality (reporting seabird demographic change according to ICES fisheries statistical areas).

3) Studies required of the distribution of birds at sea in the non-breeding season, with particular focus on foraging surrounding fishing vessels; studies of at sea movements of migrant seabirds required to detect changes as the result of changing fisheries practices, and assess vulnerability.

4) Ensure support to long term monitoring of winter mortality events, evidence of starvation/body condition of birds in winter.

5) Meta-analysis of diet studies of seabird species thought to depend largely on discards to seek species-specific, temporal and regional differences in such dependencies, to be able to predict where birds might be most affected.

6) Inventory of the seabird colonies which may be vulnerable to the changed availability to discards to 'generalist piscivores' and studies into appropriate remedial action.

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Table 2. Discard use by seabirds in the EU. Seabird taxa known to regularly follow fishing vessels and extensively consume fishery discards. Also included are minimum estimated European or EU population sizes along with proportion of the global estimate (Bicknell *et al.* 2013).

Breeding taxa		European population (breeding pairs)/ % of global population (minimum estimates)
NE Atlantic		
Black-legged kittiwake	*Rissa tridactyla*	2 410 673 / 48†
Herring gull	*Larus argentatus*	705 000 / 64†
Lesser black-backed gull	*Larus fuscus*	264 975 / 99†
Great black-backed gull	*Larus marinus*	100 000 / 58†
Great skua	*Stercorarius skua*	15 990 / 99†
Northern gannet	*Morus bassanus*	309 559 / 79†
Northern fulmar	*Fulmarus glacialis*	2 326 208 / 43†
Mediterranean		
Audouin's gull	*Larus audouinii*	13 246 / 96‡
Yellow-legged gull	*Larus michahellis*	340 910 / 90‡
Balearic shearwater	*Puffinus mauretanicus*	9000 / 100‡
Cory's shearwater	*Calonectris diomedea diomedea*	138 500 / 100‡
Common tern	*Sterna hirundo*	220 000 / 48†
Sandwich tern	*Sterna sandvicensis*	69 000 / 43†

***From the peer-reviewed literature (see text for references).**

†European populations and % estimate from Mitchell *et al.* (2004).

‡EU populations and % estimate from Snow & Perrins (1998).

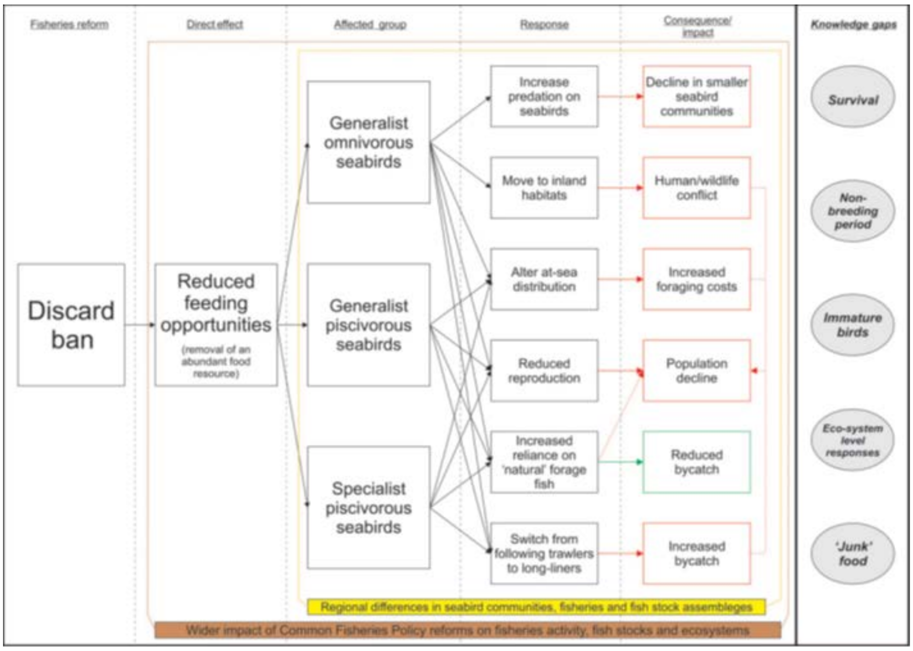

Figure 1. Potential effects of discard reform on seabird communities. Red boxes and arrows = negative consequence/impact, green boxes and arrows = positive consequence/impact, and dashed red line/arrows = possible effect dependent on natural fish stocks and severity of linked consequence. Yellow dotted line = encircles the factors that may vary regionally, and brown dotted line = encircles the factors that may be influenced by the wider impact of the Common Fisheries Policy reform (reproduced from Bicknell *et al.* 2013).

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