The Scottish Government

Vulnerability of Scottish Seabirds to Offshore Wind Turbines

marine scotland

MacArthur Green Ltd

VULNERABILITY OF SCOTTISH SEABIRDS TO OFFSHORE WIND TURBINES

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1. INTRODUCTION

MacArthur Green has been commissioned by Marine Scotland to review the sensitivity of seabirds in Scottish waters to offshore wind farms.

The aim of this guidance note is to devise criteria for quantifying the vulnerability of Scottish seabirds to offshore wind farms. This aim has the following objectives:

1) To provide a robust method to inform project scoping, ornithological assessments and wider marine spatial planning. In particular it should assist developers and their consultants in preparing ornithological impact assessments and habitat regulations appraisals.

2) To provide guidance for statutory and non-statutory bodies to assess ornithological impact assessments against objective scientific criteria.

The primary value of this work will be to inform wider marine planning (e.g. SEAs) for future rounds of development. The use of sensitivity scores in current project level ornithological assessments, and particularly Habitats Regulations Appraisals, will be largely limited to the scoping stage. Scores will assist in the preliminary identification of species that will be sensitive to the effects assessed (collision, displacement, and to some extent, indirect effects on prey). More explicit site and population specific assessments will need to be made once baseline data are collected from specific development sites under consideration.

The key results are ranked species lists in Table 11 on page 20 (ranked species concern in relation to collision mortality impacts on populations) and in Table 12 on page 22 (ranked species concern in relation to displacement impacts on populations).

In order to meet targets for reduction in carbon dioxide emissions, development in Scottish waters of offshore wind farms is being encouraged by the Scottish and UK Governments. However, such development may potentially have adverse effects on some species of seabirds through collision, disturbance, or habitat loss.

Scotland holds internationally important populations of many seabird species (Mitchell et al. 2004; Forrester et al. 2007). Many seabirds in Scotland breed within Special Protection Areas (SPAs) and so are protected by European law, in particular the Birds Directive (2009/147/EC) under which Member States have designated SPAs for the conservation of specific Annex 1 bird species and qualifying migrant species.

This review considers impacts that offshore wind farms may have on seabirds. Our report is not trying to make any site-specific assessments, but is essentially looking at the cumulative picture; considering which Scottish seabird populations appear most vulnerable at a cumulative impacts level, considering breeding season, migration and overwintering periods.

Desholm (2009) argued that in order to prioritize bird species for assessment of the impact of mortality at wind farms, it is possible to consider just two criteria; population size and population ‘elasticity’ which is mainly determined by adult survival rate. Birds with small populations and high adult survival rates will be more severely impacted by wind farm mortality than birds with large populations and low natural survival rates. While that approach has the benefit of great simplicity, it does not take into account the fact that some kinds of birds are more, or less, likely to collide with wind turbines as a consequence of their species-specific ecology or behaviour. Nor does it take account of the possible effects of offshore wind farms on seabirds through non-lethal effects such as disturbance of flight paths or loss of foraging habitat. This review follows the approach developed by Furness and Tasker (2000), and successfully implemented for offshore wind farm hazards to seabirds in the southern North Sea, by Garthe and Hüppop (2004). In particular, the set of scoring criteria and provisional scores for seabird species, is based on evidence taken from the reviewed literature, and has been circulated to a group of appropriate experts for moderation. This ensures that the final criteria and scores have wide consensus support from stakeholders, including seabird ecologists, and conservationists. Scoring is done for breeding seabirds and for nonbreeding (wintering or passage) seabirds. The list of seabird species to be included was drawn up by SNH ornithologists, and includes true seabirds, wintering sea ducks and grebes, and the white-tailed eagle (scientific names of the study species are listed in Table 2). A few seabird species of conservation importance that occur in Scotland (such as red-breasted merganser and little gull) were omitted from the list by SNH, on the basis that they occur very infrequently, if ever, at offshore wind farms, so their populations are assumed not be at risk from offshore wind farm development. In the case of red-breasted merganser their distribution is very strictly coastal and estuarine. In the case of little gull, not only are numbers visiting Scottish marine areas very low and mainly found in estuarine areas (Forrester et al. 2007) but there are no SPA sites for this species in Scotland. Marine Scotland emphasised the need for an evidence-based approach to the assessment, and in this regard the work by Garthe and Hüppop (2004) provides the best evidence-based foundation, as their review of existing literature has not only used moderation by a panel of experts to provide a widely supported consensus, but has also been peer-reviewed, published in an internationally respected scientific journal, and widely cited subsequently. Therefore, we started with the structure established in the Garthe and Hüppop (2004) paper. We reviewed all scores allocated by Garthe and Hüppop (2004) individually. In many cases those given by Garthe and Hüppop (2004) appear to be very appropriate. Where more recent data suggest that the Garthe and Hüppop (2004) scores need modification this is clearly stated, and their scores have been modified. Where there are no new data suggesting that the Garthe and Hüppop (2004) scores are inaccurate, and where reviewers agree with those scores, they have been left as set by Garthe and Hüppop (2004). We have scored similar factors to those presented by Garthe and Hüppop (2004), but we have adjusted the factors to reflect conservation importance of seabird populations in a Scottish context, and we have altered the way in which scores have been combined to produce an overall index. Potential weaknesses in the Garthe and Hüppop (2004) approach, as identified by Desholm (2009), which include the fact that many of the different scoring factors may be correlated, are given careful consideration in the Discussion.

2. MEASURES OF CONSERVATION STATUS

The index developed by Garthe and Hüppop (2004) included nine factors, of which three represented conservation status of the species and six represented aspects of the hazard that devices represented based on aspects of the ecology of each species. A similar approach has been followed here, but to the extent possible, the conservation status factors have been selected to be specific for Scotland.

In this report, four factors are used as measures of conservation status: status in relation to the Birds Directive, proportion of the biogeographic population that occurs in Scotland, adult survival rate, and UK conservation classification. EIA requires consideration of population level impacts at a range of spatial scales. The factors used here range from UK level to Scottish level, but do not address site-specific issues or the regional scale, which are beyond the scope of this report.

2.1 Birds Directive status

Species listed in Annex 1 of the Birds Directive were given a score of 5 while species qualifying as 'Migratory species' but not on Annex 1 were scored 3 and remaining species score 1 (Table 3; scientific names of all species being considered are listed in Table 2). These scores reflect aspects of conservation importance, but are not optimal for guidance regarding consenting risk. Within this scoring factor we felt that it would be useful also to consider the proportion of the Scottish population of each species that is protected within the SPA network, a statistic of direct relevance to consenting risk. Unfortunately, such data are not readily available for Scotland. In the SPA review (Stroud et al. 2001) such a statistic is considered at a GB and biogeographic level, but those data are not calculated at a Scottish level, and are now also somewhat out of date. A useful improvement to this score may be possible if an up-to-date database of numbers of seabirds in SPAs in Scotland could be established, and kept up to date. That in itself will be a non-trivial task, but is the focus of work currently being carried out for Marine Scotland. We recommend that this factor should be replaced by the numbers in SPAs in Scotland when those data become available, in order to strengthen the relevance to consenting risk.

2.2 Proportion of biogeographic population in Scotland

The percentage of the biogeographic population (usually based on continuous distribution of the relevant subspecies, taken as the North Atlantic or European or Palearctic population as seems appropriate for particular species) occurring in Scotland was assessed from Forrester et al. (2007) where this statistic was reported, or by comparing the population estimate in Forrester et al. (2007) with the biogeographic population estimates given in del Hoyo et al. (1992, 1996) (Table 1). Threshold values for scores were selected in order to classify species into similar numbers in each category. Thus scores were allocated as: 1 for less than 1%, 2 for 1 to 4%, 3 for 5 to 9%, 4 for 10 to 19%, 5 for 20% or more. Since this metric may vary seasonally, we used the highest seasonal score for each species.

2.3 Adult survival rate

Published data on adult survival rate were used as a measure of the position of each species on the 'r-K continuum' which reflects the vulnerability of species to any increase in mortality above natural mortality (species with low adult survival rates tending to have early age of first breeding and high reproductive output and so be less vulnerable to additional mortality than the extreme 'k-selected' species). Data were taken from Garthe and Hüppop (2004) for the species listed in that paper. Where species were not listed in Garthe and Hüppop (2004), data were taken from Saether (1989), from del Hoyo et al. (1992, 1996), from Glutz von Blotzheim and Bauer (1982), from individual species studies, or estimated from data for closely related species (Table 1). Where several estimates were available, preference was given to more recent studies, and studies in the UK rather than from other parts of the world, since survival rates in populations of the same species may sometimes differ between geographical regions, as is particularly evident for example for black-legged kittiwakes in the Pacific and Atlantic (Hatch et al. 1993). For example, the estimated adult survival rate of common eiders in Denmark was 0.8 (Paludan 1962, cited in Cramp and Simmons 1977) but there is a high hunting mortality in that country. In contrast, the common eider is protected in the UK and the survival estimate of Krementz et al. 1997 of 0.895 seems more appropriate (Table 1).

Adult survival rates were classified on a 1 to 5 scale following the banding used by Garthe and Hüppop (2004): 1 (adult survival less than 0.749), 2 (adult survival 0.75-0.799), 3 (0.80-0.849), 4 (0.85-0.899), 5 (adult survival above 0.90).

Table 1. Estimates of breeding and winter (or passage) population sizes in Scotland (add data from Forrester et al. 2007), and adult survival rates of seabirds from the literature, or estimated from related species where not directly available.

Species[1]	Numbers of breeding pairs in Scotland[2]	Numbers in Scotland in winter or passage (p)	Percent of population in Scotland	Adult survival rate	Reference for adult survival rate
Greater scaup	n/a	6,000	3	0.5	Cramp & Simmons 1977
Common eider	20,000	64,500	4	0.895	Krementz et al. 1997
Long-tailed duck	n/a	15,000	1	0.72	Boyd 1962
Common scoter	n/a	27,500	3	0.773	Krementz et al. 1997
Velvet scoter	n/a	3,000	1	0.77	From related species
Common goldeneye	n/a	11,000	3	0.8	Saether 1989
Red-throated diver	1,200	3,000	10	0.84	Hemmingsson & Eriksson 2002
Black-throated diver	n/a	750	5	0.85	Nilsson 1977
Great northern diver	n/a	2,000	20	0.86	From related species
Great-crested grebe	n/a	1,200	1	0.7	Fuchs 1982
Slavonian grebe	n/a	400	5	0.65	From related species
Northern fulmar	486,000	1,000,000	15	0.986	Del Hoyo et al. 1992
Sooty shearwater	n/a	7,500 (p)	<1	0.9	From related species
Manx shearwater	126,545	200,000 (p)	34	0.9	Perrins et al. 1973
European storm-petrel	32,000	100,000 (p)	8	0.9	Scott 1970
Leach's storm-petrel	48,047	100,000 (p)	1	0.9	From related species
Northern gannet	182,511	5,000	43	0.92	Wanless et al. 2006
Great cormorant	3,600	10,000	8	0.84	Krementz et al. 1989
Shag	26,000	70,000	30	0.83	Potts et al. 1980
White-tailed eagle	32	250	<1	0.7	Cramp et al. 1980
Arctic skua	2,100	5,000 (p)	8	0.84	Del Hoyo et al. 1996
Great skua	9,650	5,000 (p)	61	0.89	Ratcliffe et al. 2002
Black-headed gull	43,200	155,500	3	0.825	Glutz von Blotzheim & Bauer 1982
Common gull	48,100	79,700	7	0.80	Glutz von Blotzheim & Bauer 1982
Lesser black-backed gull	25,000	400	12	0.93	Wanless et al. 1996
Herring gull	72,100	100,000	8	0.93	Glutz von Blotzheim & Bauer 1982
Great black-backed gull	14,800	9,000	15	0.93	Glutz von Blotzheim & Bauer 1982
Black-legged kittiwake	282,200	10,000	10	0.81	Del Hoyo et al. 1996
Little tern	331	900 (p)	3	0.75	From related species
Sandwich tern	1,100	2000 (p)	3	0.87-0.94	Robinson 2010
Common tern	4,800	10,000 (p)	4	0.88	Del Hoyo et al. 1996
Roseate tern	4	10 (p)	<1	0.87	From related species
Arctic tern	47,300	100,000 (p)	10	0.875	Del Hoyo et al. 1996

Common guillemot	799,400	760,000	25	0.885	Del Hoyo et al. 1996
Razorbill	93,300	200,000	17	0.905	Del Hoyo et al. 1996
Black guillemot	18,750	50,000	18	0.86	Petersen 1981
Little auk	n/a	10,000	<1	0.8	From related species
Atlantic puffin	493,000	20,000	14	0.95	Del Hoyo et al. 1996

1. Scientific names of species are listed in Table 2.

2. Breeding numbers are not quoted (n/a) for those species, such as common scoter and black-throated diver, where breeding birds occur only inland and not at sea, or which do not breed in Scotland.

2.4 UK threat status

This factor reflects both threat and conservation status of the species in the UK, as given by Eaton et al. (2009) ‘Birds of Conservation Concern 3’ (BOCC3). For some species, the classification in BOCC3 differs from that in the previous assessment (BOCC2), and these changes are also taken into account here, given the implications of changes in status. Scores were allocated as follows: 1 (green in BOCC2 and BOCC3), 2 (amber in BOCC2 and green in BOCC3), 3 (green in BOCC2 and amber in BOCC3), 4 (amber in BOCC3 and BOCC2), 5 (red in BOCC3) (Table 2).

Table 2. Threat status of seabirds based on BOCC2 and BOCC3 classifications

Species	Scientific name	Classification in BOCC2	Classification in BOCC3	Score
Greater scaup	*Aythya marila*	Amber	Red	5
Common eider	*Somateria mollissima*	Amber	Amber	4
Long-tailed duck	*Clangula hyemalis*	Amber	Green	2
Common scoter	*Melanitta nigra*	Red	Red	5
Velvet scoter	*Melanitta fusca*	Amber	Amber	4
Common goldeneye	*Buchephala clangula*	Amber	Amber	4
Red-throated diver	*Gavia stellata*	Amber	Amber	4
Black-throated diver	*Gavia arctica*	Amber	Amber	4
Great northern diver	*Gavia immer*	Amber	Amber	4
Great-crested grebe	*Podiceps cristatus*	Green	Green	1
Slavonian grebe	*Podiceps auritus*	Amber	Amber	4
Northern fulmar	*Fulmarus glacialis*	Amber	Amber	4
Sooty shearwater	*Puffinus griseus*	Green	Amber	3
Manx shearwater	*Puffinus puffinus*	Amber	Amber	4
European storm-petrel	*Hydrobates pelagicus*	Amber	Amber	4
Leach’s storm-petrel	*Oceanodroma leucorhoa*	Amber	Amber	4
Northern gannet	*Morus bassanus*	Amber	Amber	4
Great cormorant	*Phalacrocorax carbo*	Amber	Green	2
Shag	*Phalacrocorax aristotelis*	Amber	Amber	4
White-tailed eagle	*Haliaetus albicilla*	Red	Red	5
Arctic skua	*Stercorarius parasiticus*	Green	Red	5
Great skua	*Stercorarius skua*	Amber	Amber	4
Black-headed gull	*Larus ridibundus*	Amber	Amber	4
Common gull	*Larus canus*	Amber	Amber	4
Lesser black-backed gull	*Larus fuscus*	Amber	Amber	4
Herring gull	*Larus argentatus*	Amber	Red	5
Great black-backed gull	*Larus marinus*	Green	Amber	3

Black-legged kittiwake	*Rissa tridactyla*	Amber	Amber	4
Little tern	*Sternula albifrons*	Amber	Amber	4
Sandwich tern	*Sterna sandvicensis*	Amber	Amber	4
Common tern	*Sterna hirundo*	Green	Amber	3
Roseate tern	*Sterna dougallii*	Red	Red	5
Arctic tern	*Sterna paradisaea*	Amber	Amber	4
Common guillemot	*Uria aalge*	Amber	Amber	4
Razorbill	*Alca torda*	Amber	Amber	4
Black guillemot	*Cepphus grylle*	Amber	Amber	4
Little auk	*Alle alle*	Green	Green	1
Atlantic puffin	*Fratercula arctica*	Amber	Amber	4

Table 3. Summary scores (Importance Scores) for status and conservation concern

Species	Percent of biogeographic population score	Adult survival score	UK threat status score	Birds Directive score	Total Importance Score
Greater scaup	2	1	5	3	11
Common eider	2	4	4	3	13
Long-tailed duck	2	1	2	3	8
Common scoter	2	2	5	3	12
Velvet scoter	2	2	4	3	11
Common goldeneye	2	3	4	3	12
Red-throated diver	4	3	4	5	16
Black-throated diver	3	4	4	5	16
Great northern diver	5	4	4	5	18
Great-crested grebe	2	1	1	3	7
Slavonian grebe	3	1	4	5	13
Northern fulmar	4	5	4	3	16
Sooty shearwater	1	5	3	3	12
Manx shearwater	5	5	4	3	17
European storm-petrel	3	5	4	5	17
Leach’s storm-petrel	2	5	4	5	16
Northern gannet	5	5	4	3	17
Great cormorant	3	3	2	3	11
Shag	5	3	4	3	15
White-tailed eagle	1	1	5	5	12
Arctic skua	3	3	5	3	14
Great skua	5	4	4	3	16
Black-headed gull	2	3	4	3	12
Common gull	3	3	4	3	13
Lesser black-backed gull	4	5	4	3	16
Herring gull	3	5	5	3	16
Great black-backed gull	4	5	3	3	15
Black-legged kittiwake	4	3	4	3	14
Little tern	2	2	4	5	13
Sandwich tern	2	4	4	5	15

Common tern	2	4	3	5	14
Roseate tern	1	4	5	5	15
Arctic tern	4	4	4	5	17
Common guillemot	5	4	4	3	16
Razorbill	4	5	4	3	16
Black guillemot	4	4	4	1	13
Little auk	1	4	1	3	9
Atlantic puffin	4	5	4	3	16

Table 4. Species rankings based on conservation importance score

Species	Percent of biogeographic population score	Adult survival score	UK threat status score	Birds Directive score	Total Importance Score
Great northern diver	5	4	4	5	18
Northern gannet	5	5	4	3	17
Manx shearwater	5	5	4	3	17
European storm-petrel	3	5	4	5	17
Arctic tern	4	4	4	5	17
Lesser black-backed gull	4	5	4	3	16
Great skua	5	4	4	3	16
Black-throated diver	3	4	4	5	16
Red-throated diver	4	3	4	5	16
Razorbill	4	5	4	3	16
Atlantic puffin	4	5	4	3	16
Northern fulmar	4	5	4	3	16
Common guillemot	5	4	4	3	16
Herring gull	3	5	5	3	16
Leach’s storm-petrel	2	5	4	5	16
Shag	5	3	4	3	15
Sandwich tern	2	4	4	5	15
Great black-backed gull	4	5	3	3	15
Roseate tern	1	4	5	5	15
Common tern	2	4	3	5	14
Arctic skua	3	3	5	3	14
Black-legged kittiwake	4	3	4	3	14
Black guillemot	4	4	4	1	13
Common eider	2	4	4	3	13
Common gull	3	3	4	3	13
Little tern	2	2	4	5	13
Slavonian grebe	3	1	4	5	13
Sooty shearwater	1	5	3	3	12
Common scoter	2	2	5	3	12
Common goldeneye	2	3	4	3	12
Black-headed gull	2	3	4	3	12
White-tailed eagle	1	1	5	5	12
Greater scaup	2	1	5	3	11

Velvet scoter	2	2	4	3	11
Great cormorant	3	3	2	3	11
Little auk	1	4	1	3	9
Long-tailed duck	2	1	2	3	8
Great-crested grebe	2	1	1	3	7

3. VULNERABILITY FACTORS FOR OFFSHORE WIND FARMS

Garthe and Hüppop (2004) assigned scores for the various component factors on a scale of 1 to 5 where 5 is a strong anticipated negative impact. It is assumed that these individual factor scores can then be summed to give a total for each species that ranks species according to their vulnerability with regard to offshore wind farm developments. Six factors were scored by Garthe and Hüppop (2004), representing potential negative effects of offshore wind farms on seabirds or sensitivities of the ecology of seabird species. We have used the same six factors, but have arranged these differently to take account of a concensus view that some of the factors used by Garthe and Hüppop (2004) were of uncertain and possibly low relevance, while one (flight height) is of very high importance. These factors relate primarily to collision risks and habitat loss through avoidance. However, there are other possible impacts that are not necessarily covered by this set of factors. For example, Perrow et al. (2011) presented evidence suggesting that little tern breeding success in a colony in Norfolk may have been reduced by a shortage of young herring around Scroby Sands offshore wind farm caused by monopile installation affecting fish reproduction locally. To an extent, the high sensitivity of little tern would be indicated by our six factors because they are seabirds with a very short foraging range that utilize a very particular and restricted foraging habitat, so score as sensitive on the habitat flexibility factor, but complex and indirect ecosystem effects such as alteration of fish abundance by wind farms is something that is extremely difficult to predict. There may also be predictions that, once operational, such offshore wind farms may enhance food supplies for seabirds by acting as marine protected areas (e.g. closed to trawl fishing). Such indirect and uncertain effects are beyond the scope of this review, but should not be assumed to be negligible. The six factors included are listed in turn in the following sections (following the same sequence as originally presented in Garthe and Hüppop, 2004).

3.1 Flight manoeuvrability (Factor 1)

This factor takes into account the aerial agility of species and hence their potential to avoid collision with wind turbines at sea, although other factors such as their visual perception may also play a role in this (Martin and Shaw 2010, Martin 2011). The perception of risk, which seems to vary among species, and may possibly be as important a factor as anatomical constraints may also be relevant, but cannot readily be scored on a scale. Scores were taken from Garthe and Hüppop (2004) for those species listed in that paper, but adjusted where more recent data suggest appropriate. For additional species, scores were based on a review of the literature and on subjective judgement moderated by expert opinion. Species were classified from ‘very high flight manoeuvrability’ (score 1) to ‘very low manoeuvrability’ (score 5) (Table 5). Much of the variation in this factor among species is due simply to their anatomy (Pennycuick 1987). A large tail allows better manoeuvrability. A low wing loading allows slow flight and greater acceleration. A fast-flying species with high wing loading (heavy body mass, small wing area and short tail) is unable to manoeuvre rapidly (for example, common guillemot, great northern diver) whereas a slow flying species with a large tail area is able to be highly agile (for example Arctic tern, kittiwake). So, for example, little auk and puffin score marginally lower than razorbill and guillemot because their wing loadings are significantly lower so should make them slightly better at avoiding objects in flight. Following Garthe and Hüppop (2004), we assume that, other factors being equal, birds with low flight manoeuvrability are more likely to collide with wind turbines at offshore wind farms than are birds with high flight manoeuvrability. Nevertheless, collisions are apparently extremely rare. Petterson (2005) reported one death by collision of an eider duck out of some 2 million sea ducks that flew past an offshore wind farm in southern Kalmar Sound, Sweden. There is also a view that flight manoeuvrability may be less important in determining collision risk than had been thought, and that other aspects of avian perception may be more important. For this reason, this factor was given a lower weighting than had been the case in Garthe and Hüppop (2004), as discussed in section 3.7.

Table 5. Flight manoeuvrability scores

Species	Reference	Score
Greater scaup	Exo et al. 2003	4
Common eider	Garthe and Hüppop 2004	4
Long-tailed duck	Exo et al. 2003	3
Common scoter	Garthe and Hüppop 2004	3
Velvet scoter	Garthe and Hüppop 2004	3
Common goldeneye	Exo et al. 2003	3
Red-throated diver	Storer 1958; Garthe and Hüppop 2004	5
Black-throated diver	Storer 1958; Garthe and Hüppop 2004	5
Great northern diver	Storer 1958	5
Great-crested grebe	Garthe and Hüppop 2004	4
Slavonian grebe	Storer 1969	4
Northern fulmar	Pennycuick 1987; Garthe and Hüppop 2004	3
Sooty shearwater	Warham 1977; Spear and Ainley 1997	3
Manx shearwater	Warham 1977	3
European storm-petrel	Warham 1977	1
Leach's storm-petrel	Warham 1977; Spear and Ainley 1997	1
Northern gannet	Pennycuick 1987; Garthe and Hüppop 2004	3
Great cormorant	Garthe and Hüppop 2004; Watanabe et al. 2011	4
Shag	Pennycuick 1987	3
White-tailed eagle	http://www.youtube.com/watch?v=9srPoOU6_Z4	3
Arctic skua	Pennycuick 1987; Garthe and Hüppop 2004	1
Great skua	Pennycuick 1987; Garthe and Hüppop 2004	1
Black-headed gull	Garthe and Hüppop 2004	1
Common gull	Garthe and Hüppop 2004	1
Lesser black-backed gull	Garthe and Hüppop 2004	1
Herring gull	Pennycuick 1987; Garthe and Hüppop 2004	2
Great black-backed gull	Pennycuick 1987; Garthe and Hüppop 2004	2
Black-legged kittiwake	Pennycuick 1987; Garthe and Hüppop 2004	1
Little tern	Spear and Ainley 1997	1
Sandwich tern	Garthe and Hüppop 2004	1
Common tern	Garthe and Hüppop 2004	1
Roseate tern	Spear and Ainley 1997	1

Arctic tern	Pennycuick 1987; Garthe and Hüppop 2004	1
Common guillemot	Pennycuick 1987; Garthe and Hüppop 2004; Thaxter et al. 2010	4
Razorbill	Pennycuick 1987; Garthe and Hüppop 2004; Thaxter et al. 2010	4
Black guillemot	Similar to razorbill in physical dimensions	4
Little auk	Stempniewicz 1983	3
Atlantic puffin	Pennycuick 1987; Garthe and Hüppop 2004	3

3.2 Flight altitude (Factor 2)

This factor indicates risk of collision because seabirds that only fly very low over the water will be below the height swept by turbine blades, whereas seabirds that habitually fly high above the water are likely to be at heights that would put them at risk of collision with blades. This factor is widely considered to be of overwhelming importance in determining the risk of collision of seabirds with offshore wind turbines (Band 2011, Cook et al. 2011). While many migrating passerines fly at, or above, turbine height (Hüppop et al. 2006), Dierschke and Daniels (2003) found that over 90% of all divers, sea ducks, gulls and terns flew at below 50m above sea level, and that these birds tended to fly at lower heights under windy conditions, presumably to reduce costs of flight into headwinds (Dierschke and Daniels 2003). Flight altitude scores and data were taken from two primary sources which carried out detailed reviews: Garthe and Hüppop (2004), and Cook et al. (2011). These studies can be considered independent, as Cook et al. (2011) neither incorporated data from Garthe and Hüppop (2004) into their review, nor compared their data with the previous work. Both studies reported flight heights only for birds in flight (i.e. birds sitting on the water were not scored as zero height). There are advantages to using data such as presented by Cook et al. (2011) as these data come from offshore wind farm sites so should be appropriate for seabirds at such locations (though hardly any of their data are from Scottish marine areas). Ideally, this factor would best be presented as reported values of percentages of birds flying at blade height, without collapsing such data into scores on a 5 point scale and so, unlike Garthe and Hüppop (2004), we have followed that aim by using percentage values for each species. However, although Cook et al. (2011) provide the best available data on this topic, there are a number of problems with the Cook et al. (2011) data, as those authors themselves recognise. Most data are from observations made from boats, and probably include some, and possibly significant numbers of seabirds scared into flight in front of the boat (Camphuysen et al. 2004). Such birds tend to fly low so will bias the distribution of flight heights. Estimates of the height of flying seabirds used by Cook et al. (2011) are mostly very crude, mostly being based on estimates by observers and not on measurements. Data were also recorded not as exact heights, but as numbers of seabirds in different flight height bands, so Cook et al. (2011) fitted distributions to these data to provide model estimates, rather than reporting proportions at blade height from actual data. Some of the model fits were good, but others were not. For some species, sample sizes are very small (for example the 2% of European storm-petrels reported as flying at blade height represent one individual, given that there were data for only 52 European storm-petrels). Some reported differences between species appear to contradict what is known about those particular species. For example, the proportion flying at blade height was three times higher for black-throated divers than for red-throated divers, a difference that seems unlikely to those who know the winter behaviour of these species well. Also, model fit for black-throated diver was not very good, explaining less than half of the variation in the data set. In the case of eiders, Cook et al. (2011) chose to exclude data from three offshore wind farms where eiders were recorded flying high, in order to obtain a better model fit. Exclusion of high flying birds clearly biases the estimate of the proportion of eiders that fly at blade height, so the model estimates for this species appear to be inappropriate for assessing collision risk, at least at sites where eiders may migrate through the area. Cook et al. (2011) suggest that leaving out data for high flying eiders can be justified because eiders at those sites may be migrating, and so flying at a different height which confounded modelling. However, such an argument seems inappropriate, and also overlooks the fact that the most detailed data on eider flight height come from an offshore wind farm (excluded from the analysis) where these heights were relatively accurately measured by radar (Nysted, Denmark). All Arctic skuas and great skuas recorded by Cook et al. (2011) will have been migrating, as none of these species nest anywhere near any of the sites where their flight heights were recorded, yet their data were not excluded on the grounds of being migrants. Indeed, flight heights of skuas reported by Cook et al. (2011) are lower than the normal flight heights of skuas in areas around breeding colonies (R.W. Furness pers. obs., and preliminary data from GPS loggers deployed on great skuas by H. Wade, C. Thaxter and colleagues) suggesting that these species may fly lower over the sea when migrating than when foraging. Given the present locations of offshore wind farms around the UK, it is probable that a high proportion of many of the seabird species whose flight heights are reported in Cook et al. (2011) were migrants, and it would seem inappropriate to exclude such birds from assessment of collision risk. In cases where flight heights of seabirds have been measured by radar, the data can differ quite considerably from those reported by Cook et al. (2011) that are predominantly derived by observers viewing from boats. For example, Cook et al. (2011) report that 13% of black-headed gull flights are at blade height. However, radar studies reported a mean flight height of black-headed gulls of 29m (Day et al. 2003, Walls et al. 2004, Parnell et al. 2005), which implies a higher proportion at blade height. This discrepancy is unexplained, but it seems likely that the radar measurements of flight height are more reliable. It would be valuable to assess species risk directly from a much more complete data set on measured seabird flight heights at a variety of sites, and under different environmental conditions. We entirely agree with Cook et al. (2011) conclusion '*There is an urgent need for further research into the flight heights and avoidance rates of seabirds in relation to offshore wind farms. Ideally, this would include direct measurements of these variables through the tagging of individual birds and the monitoring of movements at a broader scale through the use of technologies such as radar*'

Where data did not match up between Garthe and Hüppop (2004) and Cook et al. (2011) (see Table 5), we estimated a value that appeared more consistent with data from closely similar species, or with other published data such as Rothery et al. (2009). For species not listed in either of the two reviews, data taken from the literature were used wherever possible to estimate an appropriate value (Table 6). Although flight altitude is clearly an extremely important factor, other local aspects of siting can also be influential at specific sites. For example, turbines placed between a common tern colony and their feeding habitat have had a high impact on a particular colony (Everaert and Stienen 2007, Stienen et al. 2008), which might not be the case where a wind farm is placed away from a mandatory flight line of birds from a specific breeding site.

Table 6. Flight height estimates

Species	Reference	Estimated % at blade height
Greater scaup	Assumed similar to other ducks	3
Common eider	Krüger and Garthe 2001; Garthe and Hüppop 2004 (score of 1); Cook et al. 2011 (estimated 2%, but note that the estimate excludes data from three wind farms where higher proportions flew at blade height). Our estimate is a compromise between these three studies.	3
Long-tailed duck	Cook et al. 2011 (estimated 0% from a small sample size from Alaska). Our estimate assumes similar to other ducks.	3
Common scoter	Krüger and Garthe 2001; Garthe and Hüppop 2004 (score of 1); Cook et al. 2011 (estimated 4.4%). Our estimate is a compromise between these studies.	3
Velvet scoter	Garthe and Hüppop 2004 (score of 1); Cook et al. 2011 (estimated 0% based on small sample size). Assumed similar to other ducks.	3
Common goldeneye	Assumed similar to other ducks	3
Red-throated diver	Krüger and Garthe 2001; Garthe and Hüppop 2004 (score of 2); Cook et al. 2011 (estimated 3.2%). Score is a compromise between conflicting data in these two studies and a view from reviewers that all divers should be same.	5
Black-throated diver	Garthe and Hüppop 2004 (score of 2); Cook et al. 2011 (estimated 10.9% but from a model with relatively poor fit (0.69) and relatively small sample size). Score is a compromise between conflicting data in these two studies and a view from reviewers that all divers should be same.	5
Great northern diver	Kerlinger 1982 (migration can occur at 1000 to 3000m heights), but score recognises view of reviewers that all divers should be same.	5
Great-crested grebe	Garthe and Hüppop 2004 (score of 2); Cook et al. 2011 (estimated 0% from relatively small sample). Value assigned is compromise between these two data sets.	4
Slavonian grebe	Assumed same as great-crested grebe	4
Northern fulmar	Garthe and Hüppop 2004 (score of 1); Cook et al. 2011 (estimated 4.88%). Our estimate is a compromise between these two studies.	5
Sooty shearwater	Assumed similar to Manx shearwater	0
Manx shearwater	Cook et al. 2011 (estimated 0.04%)	0
European storm-petrel	Cook et al. 2011 (2% based on only 52 birds recorded)	2
Leach's storm-petrel	Assumed similar to European storm-petrel	2
Northern gannet	Garthe and Hüppop 2004 (score of 3); Rothery et al. 2009 (observed 13%); Cook et al. 2011 (estimated 15.77%). Our estimate is a compromise between these studies.	16

Great cormorant	Garthe and Hüppop 2004 (score of 1). Rothery et al. 2009 (observed 13%). Our estimate is a compromise between these divergent estimates, moderated by guidance from reviewers.	4
Shag	Cook et al. 2011 (estimated 13.1% with model fit relatively poor at 0.74). 13% considered too high by several reviewers so adjusted to 5%	5
White-tailed eagle	Nygård et al. 2010 (24% of flights in study wind farm were at blade height (hub height = 70m, blade radius = 38-41m)	24
Arctic skua	Garthe and Hüppop 2004 (score of 3); Cook et al. 2011 (estimate of 3.3% flying at blade height). Observations of Arctic skuas from seawatching and from birds foraging at sea in breeding areas suggest higher flying than Cook et al 2011 model, as does G&H 2004 score. Our estimate follows Garthe and Hüppop 2004 and suggestions from reviewers more closely than the data in Cook et al. 2011.	10
Great skua	Garthe and Hüppop 2004 (score of 3); Cook et al. 2011 (estimate of 6.5% flying at blade height). Observations of great skuas from seawatching, from birds foraging at sea in breeding areas, and from deployment of GPS data loggers by H. Wade, C. Thaxter and colleagues) suggest higher flying than Cook et al. 2011 model, as does G&H 2004 score. Our estimate follows Garthe and Hüppop 2004, unpublished GPS logger data, and suggestions from reviewers more closely than the data in Cook et al. 2011.	10
Black-headed gull	Bergh et al. 2002; Scored 5 by Garthe and Hüppop 2004. Rothery et al. 2009 (4%). Cook et al. 2011 (estimated 12.7% at blade height, but model fit relatively weak at 0.76). Estimate also considers values for related gull species, and radar studies reporting a higher flight height than obtained from boat-based windfarm surveys (Cook et al. 2011)	18
Common gull	Bergh et al. 2002; Garthe and Hüppop 2004 (score of 3); Cook et al. 2011 (estimated 22.69%)	23
Lesser black-backed gull	Bergh et al. 2002; Garthe and Hüppop 2004 (score of 4); Cook et al. 2011 (estimated 27.16%)	27
Herring gull	Bergh et al. 2002; Garthe and Hüppop 2004 (score of 4); Rothery et al. 2009 (33%); Cook et al. 2011 (estimated 30.59%)	31
Great black-backed gull	Bergh et al. 2002; Scored 3 by Garthe and Hüppop 2004; Rothery et al. 2009 (44%); Cook et al. 2011 (estimated 35.05%)	35
Black-legged kittiwake	Scored 2 by Garthe and Hüppop 2004; Rothery et al. 2009 (11%); Cook et al. 2011 (estimated 16.05%)	16
Little tern	Assumed similar to other terns	7
Sandwich tern	Krüger and Garthe 2001; Bergh et al. 2002; Scored 3 by Garthe and Hüppop 2004; Rothery et al. 2009 (3%); Cook et al. 2011 (estimated 7.1%).	7
Common tern	Bergh et al. 2002; Krüger and Garthe 2001; Garthe and	7

	Hüppop 2004 (score of 2); Cook et al. 2011 (estimated 8.26%). Our estimate is a compromise between these studies.	
Roseate tern	Assumed similar to other terns	5
Arctic tern	Garthe and Hüppop 2004 (score of 1); Cook et al. 2011 (estimated 4.41%)	5
Common guillemot	Garthe and Hüppop 2004 (score of 1); Cook et al. 2011 (estimated 4.14%)	4
Razorbill	Garthe and Hüppop 2004 (score of 1); Cook et al. 2011 (estimated 6.77%). Our estimate is a compromise between these studies.	5
Black guillemot	Assumed similar to other alcids	4
Little auk	Cook et al. 2011 (estimated 4%)	4
Atlantic puffin	Garthe and Hüppop 2004 (score of 1); Cook et al. 2011 (estimated 0.02). Our estimate is a compromise between these studies.	1

3.3 Percentage of time flying (Factor 3)

This factor is considered to indicate risk of collision because seabirds that spend more time flying while at sea are more likely to be at risk of collision (all else being equal). Where available, scores were taken from Garthe and Hüppop (2004), adjusted where apprtopriate according to more recent research publications. For other species, scores were calculated from data on activity budgets following the procedure outlined by Garthe and Hüppop (2004). Species were scored 1 if 0-20% of time at sea was spent in flight, score 2 if 21-40% was spent flying, score 3 if 41-60% was spent flying, score 4 if 61-80% was spent flying, and score 5 if 81-100% was spent flying (Table 7). In the last few years, data logger information is starting to provide detailed information on at-sea activity of seabirds. For example, Kotzerka et al. (2010) reported that black-legged kittiwakes spent 35% of foraging trips engaged in sustained directional flight, and much of the remaining time in localised areas searching for food. There may be quite considerable variation in time spent flying between seasons, with breeding seabirds rearing chicks flying more than nonbreeders in winter. At present there is too little data on this to be able to provide seasonally separated scores.

Table 7. Percentage of time flying scores

Species	Reference	Score
Greater scaup	Similar to other ducks	2
Common eider	Garthe and Hüppop 2004	2
Long-tailed duck	Similar to other ducks	2
Common scoter	Garthe and Hüppop 2004	2
Velvet scoter	Garthe and Hüppop 2004	2
Common goldeneye	Similar to other ducks	2
Red-throated diver	Garthe and Hüppop 2004	2
Black-throated diver	Garthe and Hüppop 2004	3
Great northern diver	Forrester et al. 2007 (rarely flies during winter)	2
Great-crested grebe	Garthe and Hüppop 2004	3
Slavonian grebe	Cramp and Simmons 1977; Forrester et al. 2007	2
Northern fulmar	Garthe and Hüppop 2004	2

Sooty shearwater	Cramp and Simmons 1977; Forrester et al. 2007	3
Manx shearwater	Cramp and Simmons 1977; Forrester et al. 2007	3
European storm-petrel	Cramp and Simmons 1977; Forrester et al. 2007	3
Leach's storm-petrel	Cramp and Simmons 1977; Forrester et al. 2007	3
Northern gannet	Garthe and Hüppop 2004	3
Great cormorant	Garthe and Hüppop 2004; Watanabe et al. 2011 (closely related deep-diving cormorant spent only 24 minutes per day in flight)	2
Shag	Watanabe et al. 2011 (closely related deep-diving cormorant spent only 24 minutes per day in flight)	2
White-tailed eagle	Forrester et al. 2007	5
Arctic skua	Garthe and Hüppop 2004	5
Great skua	Garthe and Hüppop 2004	4
Black-headed gull	Garthe and Hüppop 2004	1
Common gull	Garthe and Hüppop 2004	2
Lesser black-backed gull	Garthe and Hüppop 2004	2
Herring gull	Garthe and Hüppop 2004	2
Great black-backed gull	Garthe and Hüppop 2004	2
Black-legged kittiwake	Garthe and Hüppop 2004	3
Little tern	Similar to other terns	5
Sandwich tern	Garthe and Hüppop 2004	5
Common tern	Garthe and Hüppop 2004	5
Roseate tern	Similar to other terns	5
Arctic tern	Garthe and Hüppop 2004	5
Common guillemot	Garthe and Hüppop 2004; Thaxter et al. 2010 (10% of foraging trip spent in flight)	1
Razorbill	Garthe and Hüppop 2004; Thaxter et al. 2010 (20% of foraging trip spent in flight)	1
Black guillemot	Del Hoyo et al. 1996; Forrester et al. 2007	1
Little auk	Del Hoyo et al. 1996; Forrester et al. 2007	1
Atlantic puffin	Garthe and Hüppop 2004	1

3.4 Nocturnal flight activity (Factor 4)

Nocturnal flight activity is difficult to score, as detailed data are not available for many species, although geolocation data logger data are starting to change this situation, though so far mainly for large Southern Ocean seabirds (Phalan et al. 2007, Mackley et al. 2010, 2011). However, similar data will soon be published for some North Atlantic seabirds including gannets (S. Garthe and colleagues) and great skuas (E. Magnusdottir and colleagues) based on geolocation data logger deployments where geographical distributions have already been reported but activity data are still being analysed (Kubetzki et al. 2009, Magnusdottir et al. 2011). According to ICES (2011) expert group on seabird ecology '*birds are somewhat less inclined to avoid turbines at night*'. In contrast, according to Anon (2006), '*extended periods of infra-red monitoring at night using TADS at Nysted provided unexpected evidence that no movements of birds were detected below 120m during the hours of darkness, even during periods of heavy [seabird] migration*'.

We used scores published in Garthe and Hüppop (2004) for the species where these were available (Table 8), so followed the score values established in that study. Score 1 (hardly any flight activity at night) to score 5 (much flight activity at night). We used published data where possible, and information (often qualitative rather than quantitative) from individual species studies or from handbooks (Glutz von Blotzheim and Bauer (1982), Cramp and Simmons (1983), del Hoyo et al. (1992, 1996). Classifications were also moderated by experts. It is possible that, in the near future, collection of quantitative data on time spent in flight from geolocation data loggers (for example based on salt-water switch recording time spent with the logger immersed in seawater) will allow this scoring to be converted into a quantitative scale rather than the present qualitative one.

Garthe and Hüppop (1996) reported that in the southern North Sea, lesser black-backed gulls frequently forage at fishing vessels during the night, and that great black-backed gulls, herring gulls and black-legged kittiwakes will also forage at fishing vessels at night. However, Kotzerka et al. (2010) reported from GPS tracking data that black-legged kittiwake foraging trips mainly occurred during daylight, and that while some birds appeared to undertake foraging trips that lasted overnight, their travel speeds indicated that they were mostly inactive during the night. So it is possible that nocturnal foraging in gulls is mainly limited to situations where the birds are unable to obtain adequate resources during daylight. Similarly, geolocation data loggers indicate that breeding gannets rarely fly during hours of darkness, but do so slightly more during their migration period (Garthe and colleagues, MS in review). Greater scaups are ‘mainly night-active making regular feeding flights to the sea in the evening and returning at dawn’ (Nilsson 1970). During the breeding season, red-throated diver foraging flights occurred during daylight but extended into twilight in the two weeks following hatching of chicks (Reimchen and Douglas 1984). Divers apparently rarely fly during darkness. As with Factor 3, there may be seasonal variation in these scores, possibly with seabirds flying more in dark conditions while rearing chicks, or during the shortest days of winter, but there are no suitable data on this.

Table 8. Nocturnal flight activity scores

Species	Reference	Score
Greater scaup	Nilsson 1970 (mainly night-active making regular feeding flights to the sea in the evening and returning at dawn)	5
Common eider	Garthe and Hüppop 2004	3
Long-tailed duck	Similar to scoters	3
Common scoter	Garthe and Hüppop 2004	3
Velvet scoter	Garthe and Hüppop 2004	3
Common goldeneye	Similar to scoters	3
Red-throated diver	Garthe and Hüppop 2004; Reimchen and Douglas 1984 (rarely fly at dusk except when rearing chicks, and do not fly at night)	1
Black-throated diver	Garthe and Hüppop 2004	1
Great northern diver	Similar to other divers	1
Great-crested grebe	Garthe and Hüppop 2004	2
Slavonian grebe	Similar to great-crested grebe	2
Northern fulmar	Garthe and Hüppop 2004	4
Sooty shearwater	Cramp and Simmons 1977; del Hoyo et al. 1992	3
Manx shearwater	Cramp and Simmons 1977; del Hoyo et al. 1992	3
European storm-petrel	Albores-Barajas et al. 2011 (while nesting undertook short nocturnal trips from colony to feed)	4

Leach's storm-petrel	Cramp and Simmons 1977; del Hoyo et al. 1992	4
Northern gannet	Garthe and Hüppop 2004; Garthe et al. MS in review	2
Great cormorant	Cramp and Simmons 1977; del Hoyo et al. 1992	1
Shag	Cramp and Simmons 1977; del Hoyo et al. 1992	1
White-tailed eagle	Willgohs 1961 in Krone et al. 2009 (generally diurnal)	1
Arctic skua	Garthe and Hüppop 2004	1
Great skua	Garthe and Hüppop 2004; Magnusdottir et al. unpubl. data	1
Black-headed gull	Garthe and Hüppop 2004	2
Common gull	Garthe and Hüppop 2004	3
Lesser black-backed gull	Garthe and Hüppop 2004; Garthe and Hüppop 1996 (regularly fly behind fishing vessels at night)	3
Herring gull	Garthe and Hüppop 2004; Garthe and Hüppop 1996 (sometimes fly behind fishing vessels at night)	3
Great black-backed gull	Garthe and Hüppop 2004; Garthe and Hüppop 1996 (sometimes fly behind fishing vessels at night)	3
Black-legged kittiwake	Garthe and Hüppop 2004; Kotzerka et al. 2010 (rarely fly at night); Garthe and Hüppop 1996 (sometimes fly behind fishing vessels at night)	3
Little tern	Perrow et al. 2006 (diurnal foraging)	1
Sandwich tern	Pearson 1968; Garthe and Hüppop 2004	1
Common tern	Pearson 1968; Garthe and Hüppop 2004	1
Roseate tern	Pearson 1968	1
Arctic tern	Pearson 1968; Garthe and Hüppop 2004	1
Common guillemot	Garthe and Hüppop 2004	2
Razorbill	Garthe and Hüppop 2004	1
Black guillemot	Similar to other alcids	1
Little auk	Similar to other alcids	1
Atlantic puffin	Garthe and Hüppop 2004	1

3.5 Disturbance by wind farm structures, ship and helicopter traffic (Factor 5)

Seabird species vary in their reactions to offshore wind turbines, ship and helicopter traffic such as occurs during maintenance of offshore wind farm turbines. Where possible, scores presented by Garthe and Hüppop (2004) were used, adjusted where appropriate where more recent studies have been published. A literature search was carried out focused on disturbance sensitivity of seabird species, and scores allocated to species were moderated by experts. Scoring categories were: 1 (hardly any escape behaviour and a very short flight distance when approached), to 5 (strong escape behaviour, at a large response distance). Although disturbance distances have often been reported as relatively short (Barrett and Vader 1984, Evans and Nettleship 1985, Carney and Sydeman 1999, Thayer et al. 1999, Rojek et al. 2007, Garthe and Hüppop 2004), alcids (e.g. common guillemots, razorbills, puffins) can sometimes be disturbed by boats hundreds of metres away (Ronconi and Clair 2002, Bellefleur et al. 2009). Divers are especially sensitive to approaching boats and may dive or fly off when vessels are more than 1000m away (Schwemmer et al. 2011, Topping and Petersen 2011). Among the sea ducks, scoters are particularly vulnerable to being disturbed by boats (Kaiser et al. 2006, Schwemmer et al. 2011). Greater scaup dive or hide when low-flying helicopters approach (Austin et al. 2000), and are disturbed by passing ships up to 400m away (Platteeuw and Beekman 1994). Common eider had a 208m median flush distance from ships, but with no reaction from some flocks on the water (Schwemmer et al. 2011).

Long-tailed ducks had a 293m median flush distance from ships (Schwemmer et al. 2011). In contrast, common scoter had a 804m median flush distance from ships, and a maximum flush distance of 3.2km (Schwemmer et al. 2011). Kaiser et al. (2006) reported that common scoter had flush distances of 1000-2000m, somewhat longer distances than reported by Schwemmer et al. (2011). Goldeneyes fly from ships passing at 500-1000m away (Platteeuw and Beekman 1994). Terns can be followed at a moderate distance by a small inflatable boat without apparently causing significant disturbance (Perrow et al. 2011), while some seabirds such as fulmars and shearwaters, appear to show little or no disturbance response to boats, and little response to aircraft. While it is clear that some seabirds do strongly avoid wind turbines at sea, recent work modeling the cumulative impact of disturbance by wind turbines suggests that the impact of these through increased travel distances and habitat loss is trivial, even for species that show especially strong avoidance behaviour, such as red-throated divers (Topping and Petersen 2011).

Table 9. Disturbance scores

Species	Reference	Score
Greater scaup	Platteeuw and Beekman 1994 (fly from boats up to 400m away)	4
Common eider	Garthe and Hüppop 2004; Schwemmer et al. 2011 (208m median flush distance from ships, but with no reaction from some flocks on the water)	3
Long-tailed duck	Schwemmer et al. 2011 (293m median flush distance from ships)	3
Common scoter	Garthe and Hüppop 2004; Kaiser et al. 2006 (flush distances of 1000-2000m); Schwemmer et al. 2011 (fly from boats over 1000m away)	5
Velvet scoter	Garthe and Hüppop 2004	5
Common goldeneye	Platteeuw and Beekman 1994 (fly from ships passing at 500-1000m away)	4
Red-throated diver	Schwemmer et al. 2011; Topping and Petersen 2011 (fly from boats more than 1000m away)	5
Black-throated diver	Schwemmer et al. 2011; Topping and Petersen 2011 (fly from boats more than 1000m away)	5
Great northern diver	Schwemmer et al. 2011; Topping and Petersen 2011 (fly from boats more than 1000m away)	5
Great-crested grebe	Garthe and Hüppop 2004	3
Slavonian grebe	Similar to great-crested grebe	3
Northern fulmar	Garthe and Hüppop 2004	1
Sooty shearwater	Cramp and Simmons 1977; del Hoyo et al. 1992	1
Manx shearwater	Cramp and Simmons 1977; del Hoyo et al. 1992	1
European storm-petrel	Cramp and Simmons 1977; del Hoyo et al. 1992	1
Leach’s storm-petrel	Cramp and Simmons 1977; del Hoyo et al. 1992	1
Northern gannet	Garthe and Hüppop 2004	2
Great cormorant	Garthe and Hüppop 2004	4
Shag	Cramp and Simmons 1977; del Hoyo et al. 1992	3
White-tailed eagle	Nygård et al. 2010 (Study by Hoel 2009 suggest eagles use	1

	the air space inside and outside wind farm area similarly)	
Arctic skua	Garthe and Hüppop 2004	1
Great skua	Garthe and Hüppop 2004	1
Black-headed gull	Garthe and Hüppop 2004	2
Common gull	Garthe and Hüppop 2004	2
Lesser black-backed gull	Garthe and Hüppop 2004; but note possible gain from perching on structures	2
Herring gull	Garthe and Hüppop 2004; but note possible gain from perching on structures	2
Great black-backed gull	Garthe and Hüppop 2004; but note possible gain from perching on structures	2
Black-legged kittiwake	Garthe and Hüppop 2004; but note possible gain from perching on structures	2
Little tern	Perrow et al. 2006, 2011a,b	2
Sandwich tern	Garthe and Hüppop 2004; Perrow et al. 2011b	2
Common tern	Garthe and Hüppop 2004; Perrow et al. 2011b	2
Roseate tern	Perrow et al. 2011b	2
Arctic tern	Garthe and Hüppop 2004; Perrow et al. 2011b	2
Common guillemot	Barrett and Vader 1984; Evans and Nettleship 1985; Carney and Sydeman 1999; Thayer et al. 1999; Rojek et al. 2007; Garthe and Hüppop 2004; Ronconi and Clair 2002; Bellefleur et al. 2009 (fly from approaching boats hundreds of m away)	3
Razorbill	Barrett and Vader 1984; Evans and Nettleship 1985; Carney and Sydeman 1999; Garthe and Hüppop 2004; Ronconi and Clair 2002; Bellefleur et al. 2009 (fly from approaching boats hundreds of m away)	3
Black guillemot	Barrett and Vader 1984; Evans and Nettleship 1985; Carney and Sydeman 1999; Ronconi and Clair 2002; Bellefleur et al. 2009 (fly from approaching boats hundreds of m away)	3
Little auk	Cramp and Simmons 1980; Evans and Nettleship 1985; del Hoyo et al. 1996	2
Atlantic puffin	Barrett and Vader 1984; Evans and Nettleship 1985; Carney and Sydeman 1999; Garthe and Hüppop 2004	2

3.6 Flexibility in habitat use (Factor 6)

Seabirds vary in the range of habitats they use, and whether they use these as specialists or generalists. Habitats at sea include a range of different oceanographic conditions, for example relating to water masses and frontal systems. This score classifies species into categories from 1 (use a wide range of habitats over a large area, and usually with a relatively wide range of foods) to 5 (specialise in using a very limited and predominantly inshore habitat, and generally with a narrow focus on a particular food). Species scoring low tend to forage over large marine areas with little association with particular marine features. Species scoring high tend to feed on very specific habitat features, such as shallow banks with bivalve communities, or kelp beds. Where available, scores presented by Garthe and Hüppop (2004) were used. Scores for other species were based on foraging ecology described in single species studies in the literature, or from standard handbook descriptions.

Literature indicates many cases of species showing limited flexibility in feeding habitat. For example, greater scaup switch feeding sites and species according to prey availability (Nilsson 1970), but need shallow water areas for foraging, as do common goldeneyes (Jones and Drobney 1986). Common eiders, long-tailed ducks and common scoters are dependent on shallow feeding grounds with shellfish banks (Garthe 2006). Long-tailed ducks are dependent on shallow feeding grounds with shellfish banks (Garthe 2006). Red-throated diver wintering range was considered on the basis of diet studies to be restricted to nearshore, shallow marine waters (Guse et al. 2009). However, Garthe (2006) concluded from at-sea surveys that red-throated divers are not dependent on shallow feeding grounds as they are not restricted to shellfish banks, and they are not restricted to nearshore waters in the German sector of the North Sea (Garthe 2006). The same applies to black-throated divers in winter (Garthe 2006). Both species apparently avoid shipping lanes as they appear not to habituate to disturbance from ships (Schwemmer et al. 2011).

Table 10. Flexibility in habitat use by seabirds scores

Species	Reference	Score
Greater scaup	Nilsson 1970 (able to switch feeding sites and species according to prey availability, but limited to very specific habitat); Jones and Drobney 1986 (need shallow water areas); Forrester et al. 2007 (winters in sheltered sea lochs and firths, brackish coastal lagoons and freshwater lochs close to the coast where molluscs are available in shallow water - much less than 10m deep)	4
Common eider	Garthe and Hüppop 2004 gave score 4; Garthe 2006 (dependent on shallow feeding grounds with shellfish banks); Forrester et al. 2007 (almost entirely coastal, mainly in sheltered and shallow bays where blue mussel beds are present)	4
Long-tailed duck	Garthe 2006 (dependent on shallow feeding grounds with shellfish banks); Forrester et al. 2007 (mainly along sheltered coasts, usually with sandy substrates)	4
Common scoter	Garthe and Hüppop 2004 gave score 4; Garthe 2006 (dependent on shallow feeding grounds with shellfish banks); Forrester et al. 2007 (shallow sea with soft substrates, where molluscs are available in depths 10-20m)	4
Velvet scoter	Garthe and Hüppop 2004 gave score 4; Forrester et al. 2007 (exclusively at sea, from close inshore to well offshore, in both sheltered estuaries and off exposed coasts, commonly feeding in depths of ca 15m but capable of diving to 30m which can enable birds to spend time over underwater banks far enough offshore to be invisible from land) This suggests a lower score than given by Garthe and Hüppop 2004 since habitat use by this species seems to be wider than in common scoter, for example.	3
Common goldeneye	Jones and Drobney 1986 (need shallow water areas); Forrester et al. 2007 (freshwater lochs, rivers, coastal lagoons, estuarines and open coast, but in marine areas needs molluscs or crustaceans in shallow water, often aggregates around sewage outfalls)	4

Red-throated diver	Garthe and Hüppop 2004 gave score 4; Guse et al. 2009 (wintering range restricted to nearshore, shallow marine waters – shown by diet); Garthe 2006 (not dependent on shallow feeding grounds as they are not restricted to shellfish banks - not restricted to nearshore waters Germany); Forrester et al. 2007 (prefers inshore waters often with some shelter, most regularly being found in sounds and wide sandy bays)	4
Black-throated diver	Garthe and Hüppop 2004 gave score 4; Garthe 2006 (not dependent on shallow feeding grounds as they're not restricted to shellfish banks - not restricted to nearshore waters Germany); Forrester et al. 2007 (inshore coastal waters, favouring certain widely scattered relatively shallow and predominantly sandy-bottomed sites)	4
Great northern diver	Forrester et al. 2007 (coastal marine waters, found in sheltered sandy bays, but equally at home around stormy headlands, often as much as 10km offshore, coming closer to shore during periods of bad weather), so lower score than for other diver species seems probably appropriate; reviewers suggested a score of 4 for this species might be appropriate.	3
Great-crested grebe	Garthe and Hüppop 2004 gave score 4; Forrester et al. 2007 (some stay on breeding freshwaters, but most move to sheltered estuaries for winter)	4
Slavonian grebe	Forrester et al. 2007 (sheltered shallow coastal waters, especially estuaries and bays)	4
Northern fulmar	Garthe and Hüppop 2004 gave score 1; Forrester et al. 2007 (oceanic, preferred marine habitat around Scotland is the shelf-break areas to the north and west, although very large numbers can occur near trawler fleets elsewhere over the continental shelf)	1
Sooty shearwater	Forrester et al. 2007 (oceanic, generally prefers cold pelagic waters)	1
Manx shearwater	Forrester et al. 2007 (pelagic although mainly over continental shelf; range over most of the North Atlantic continental shelf in summer)	1
European storm-petrel	Forrester et al. 2007 (pelagic, generally found over the continental shelf)	1
Leach's storm-petrel	Forrester et al. 2007 (oceanic, found above and beyond the shelf break over deep water)	1
Northern gannet	Garthe and Hüppop 2004 gave score 1; Forrester et al. 2007 (oceanic, pelagic but mainly inshore over continental shelf)	1
Great cormorant	Garthe and Hüppop 2004 gave score 3; Forrester et al. 2007 (may visit a variety of freshwater habitats, in winter distributed more evenly around coasts, especially sea lochs, estuaries and firths)	3
Shag	Watanuki et al. 2008 ('flexible foraging strategy' – use of both sandy and rocky areas); Wanless et al. 1991b (recorded feeding between 1-60m and over many sediment categories (rock, sand, gravel, mud) – generally avoided deep and muddy sediment areas. Mostly inshore but within that area	3

	the species is fairly plastic in its requirements)	
White-tailed eagle	Forrester et al. 2007 (both inland and coastal habitats, including estuaries, moorland, agricultural land, marshes and lochs, and rocky shore coasts)	2
Arctic skua	Garthe and Hüppop 2004 gave score 2; Forrester et al. 2007 (coastal shelf seas)	2
Great skua	Garthe and Hüppop 2004 gave score 2; Forrester et al. 2007 (shallow seas over continental shelf, large numbers associating with fishing vessels)	2
Black-headed gull	Garthe and Hüppop 2004 gave score 2; Forrester et al. 2007 (coastal and inland in winter, including beaches, estuarine mudflats, inland on grass and freshly ploughed land, refuse tips, lochs and estuaries)	2
Common gull	Garthe and Hüppop 2004 gave score 2; Forrester et al. 2007 (coastal and inland in winter, feeding on farmland, playing fields, estuaries and at sea)	2
Lesser black-backed gull	Garthe and Hüppop 2004 gave score 1; Forrester et al. 2007 (feeds in a range of habitats in coastal areas, and in agricultural areas, and extensive use is made of refuse tips and other sources of human waste; generally uses more marine areas than herring gull)	1
Herring gull	Garthe and Hüppop 2004 gave score 1; Forrester et al. 2007 (diet is catholic, taking live marine and terrestrial prey and scavenging. Forages around ships in inshore areas, on shoaling fish, in the intertidal zone, in agricultural areas, on refuse and in streets)	1
Great black-backed gull	Garthe and Hüppop 2004 gave score 2; Forrester et al. 2007 (forages at sea and on estuaries, beaches and rocky coasts and on islands that often hold seabird colonies. Less common inland than other large gulls)	2
Black-legged kittiwake	Garthe and Hüppop 2004 gave score 2; Kotzerka et al. 2010 (birds foraged over the continental shelf within the 200m depth contour. Some evidence they may forage over deep water areas. Likely to be seasonal changes) Forrester et al. 2007 (extremely pelagic)	2
Little tern	Forrester et al. 2007 (extremely coastal, usually sheltered shallow marine or estuarine feeding areas)	4
Sandwich tern	Garthe and Hüppop 2004 gave score 3; Forrester et al. 2007 (inshore waters on all coasts, but particularly those with shallow water and sandy bottoms such as estuaries)	3
Common tern	Garthe and Hüppop 2004 gave score 3; Forrester et al. 2007 (in Scotland mainly in estuaries, some on sea lochs and more open but sheltered coasts, few inland on rivers and lochs)	3
Roseate tern	Forrester et al. 2007 (the most marine of the *Sterna* terns, but in Scotland mostly occurs in Firth of Forth estuary)	3
Arctic tern	Garthe and Hüppop 2004 gave score 3; Forrester et al. 2007 (coastal marine)	3
Common guillemot	Garthe and Hüppop 2004 gave score 3; Forrester et al. 2007 (typically feeds offshore with inshore and pelagic feeding less common)	3

Razorbill	Garthe and Hüppop 2004 gave score 3; Forrester et al. 2007 (found in a wide range of marine habitats but generally in shallow sea)	3
Black guillemot	Forrester et al. 2007 (exclusively coastal, usually feeds inshore, close to breeding sites, often associating with kelp beds)	4
Little auk	Forrester et al. 2007 (an oceanic plankton feeder, occurring mainly offshore)	2
Atlantic puffin	Garthe and Hüppop 2004 gave score 3; Forrester et al. 2007 (feeds far from the coast and is pelagic in winter)	3

3.7 Species index values for collision concern and displacement concern

Garthe and Hüppop (2004) computed a risk index that summed the first four factor scores and divided the sum by four, and multiplied that by the sum of factor scores five and six, divided by two. This recognised that the first four factors all relate to flight ability and flight behaviour, while factors five and six relate to habitat use and susceptibility to disturbance. Thus their index combines both collision risk and disturbance/habitat loss considerations into a single score, which is potentially confusing.

An alternative approach is to score separately for collision concern and for disturbance/habitat displacement concern. We take that new approach here.

For collision risk, it seems appropriate to give a high weighting to the flight altitude (percent flying at blade height), and low weightings to manoeuverability, percent of time flying, and nocturnal flight activity (again differing from the approach in Garthe and Hüppop 2004). So our index multiplies the percentage flying at blade height by the mean of the other three factors, and multiplies the resulting value by the conservation importance score (Table 11). Flight altitude score ranges from 0 to 35, the mean of the other three factors ranges from 1.3 to 3.7 (within a theoretically possible range of 1 to 5), and the conservation importance score from 7 to 18 (within a theoretically possible range of 4 to 20). It would be possible to rescale these scores in some way to adjust weighting of the three components in the overall index. We considered this possibility carefully, and while there is an attraction to rescaling to give equal weight to the behavioural component and the conservation importance component, we felt that the higher weighting to flight altitude was entirely appropriate in view of the crucial importance of this in determining potential collision risk. This approach is consistent with feedback from reviewers who overwhelmingly felt that it was appropriate to upweight flight height influence in this index. Exploratory rescaling to give equal weight to flight height and conservation importance had only a small influence on the ranking of species, so the index is relatively robust to the detailed weighting given to these two components.

For disturbance/habitat displacement our index multiplies the disturbance score by the habitat loss score, and multiplies the resulting value by the conservation importance score. The disturbance score multiplied by the habitat loss score varies from 1 to 20. Thus the risk factor varies over a similar range to the variation in conservation importance score, giving these two components similar weighting in the overall index. The total has then been divided by 10, to recognise that the disturbance/displacement impact on populations is likely to be considerably less than a direct mortality impact such as from collisions and therefore the two scales should not be compared in a quantitative way but only in terms of the species ranking within one scale (Table 12).

Table 11. Species concern in the context of collision impacts: percent flying at blade height x 1/3(manoeuverability score + % time flying score + nocturnal flight score) x conservation importance score (ranked by index value).

Species	Flight height % at blade height	Flight agility	% of time flying	Night flight	Conservation importance score	Total risk score
Great black-backed gull	35	2	2	3	15	1225
Herring gull	31	2	2	3	16	1157
Lesser black-backed gull	27	1	2	3	16	864
White-tailed eagle	24	3	5	1	12	864
Northern gannet	16	3	3	2	17	725
Common gull	23	1	2	3	13	598
Black-legged kittiwake	16	1	3	3	14	523
Arctic skua	10	1	5	1	14	327
Great skua	10	1	4	1	16	320
Black-headed gull	18	1	1	2	12	288
Sandwich tern	7	1	5	1	15	245
Black-throated diver	5	5	3	1	16	240
Great northern diver	5	5	2	1	18	240
Northern fulmar	5	3	2	4	16	240
Common tern	7	1	5	1	14	229
Red-throated diver	5	5	2	1	16	213
Little tern	7	1	5	1	13	212
Arctic tern	5	1	5	1	17	198
Roseate tern	5	1	5	1	15	175
Razorbill	5	4	1	1	16	160
Shag	5	3	2	1	15	150
Common guillemot	4	4	1	2	16	149
Slavonian grebe	4	4	2	2	13	139
Greater scaup	3	4	2	5	11	121
Common eider	3	4	2	3	13	117
Black guillemot	4	4	1	1	13	104
Great cormorant	4	4	2	1	11	103
Common goldeneye	3	3	2	3	12	96
Common scoter	3	3	2	3	12	96
European storm-petrel	2	1	3	4	17	91
Velvet scoter	3	3	2	3	11	88
Leach’s storm-petrel	2	1	3	4	16	85
Great-crested grebe	4	4	3	2	7	84
Long-tailed duck	3	3	2	3	8	64
Little auk	4	3	1	1	9	60
Atlantic puffin	1	3	1	1	16	27

Manx shearwater	0	3	3	3	17	0
Sooty shearwater	0	3	3	3	12	0

Table 12. Species concern in the context of disturbance and/or displacement from habitat (Disturbance score x Habitat flexibility score x Conservation Importance score)/10 (Ranked by index value)

Species	Disturbance by ship and helicopter traffic	Habitat use flexibility	Conservation importance score	Species concern index value
Black-throated diver	5	4	16	32
Red-throated diver	5	4	16	32
Great northern diver	5	3	18	27
Common scoter	5	4	12	24
Common goldeneye	4	4	12	19
Greater scaup	4	4	11	18
Velvet scoter	5	3	11	16
Common eider	3	4	13	16
Black guillemot	3	4	13	16
Slavonian grebe	3	4	13	16
Common guillemot	3	3	16	14
Razorbill	3	3	16	14
Shag	3	3	15	14
Great cormorant	4	3	11	13
Little tern	2	4	13	10
Arctic tern	2	3	17	10
Atlantic puffin	2	3	16	10
Long-tailed duck	3	4	8	10
Roseate tern	2	3	15	9
Sandwich tern	2	3	15	9
Common tern	2	3	14	8
Great-crested grebe	3	4	7	8
Great black-backed gull	2	2	15	6
Black-legged kittiwake	2	2	14	6
Common gull	2	2	13	5
Black-headed gull	2	2	12	5
Little auk	2	2	9	4
Northern gannet	2	1	17	3
Herring gull	2	1	16	3
Great skua	1	2	16	3
Lesser black-backed gull	2	1	16	3
Arctic skua	1	2	14	3
White-tailed eagle	1	2	12	2
Manx shearwater	1	1	17	2
European storm-petrel	1	1	17	2
Leach’s storm-petrel	1	1	16	2
Northern fulmar	1	1	16	2
Sooty shearwater	1	1	12	1

4. DISCUSSION

The key results are ranked species lists in Table 11 (ranked species concern in relation to collision mortality impacts on populations) and in Table 12 (ranked species concern in relation to displacement impacts on populations).

A draft version of the factors and species-scores was sent to seabird experts for comment. Most reviewers suggested no change to the factors used, and no change to most scores. Most reviewers felt that one or two out of the 228 scores should be adjusted, so agreed with more than 99% of the scores. Two scores were identified that were consistently questioned by reviewers and the scores for these species were altered to bring them in line with this consensus opinion. So the scores presented in the current document have broad agreement from a diverse group of relevant European seabird experts. However, there is uncertainty in the scoring, and in the relevance of particular factors. In particular, there was a broad consensus among reviewers that flight height was considerably more important than any of the other factors in assessment of collision risk, and that this factor should also be weighted higher than the conservation importance score. After discussions, and comments from reviewers, we decided to move away from the formula used by Garthe and Hüppop (2004) to recognise firstly that there is broad support for the view that collision concern should be considered separately from displacement concern, as the rankings of species on these two features are very different. Secondly, flight height is generally considered to be the key factor in the assessment of collision concern, and there are some mixed views among experts over the relative importance of manoeuvrability, percent of time flying, and amount of nocturnal flight in affecting collision risk. Our use of two separate indices and the downweighting of the last three factors recognises this. This approach also seems more appropriate now than it was when Garthe and Hüppop (2004) prepared their paper, because there are now considerably more detailed data on seabird flight height from the work of Cook et al. (2011). Nevertheless, it is clear that there is an urgent need for more accurate flight height data and a better understanding of how flight height varies according to environmental conditions.

Desholm (2009) not only suggested that empirical evidence did not strongly support the idea that seabirds that fly at night are at higher risk of collision with offshore wind turbines, but also suggested that a suitable index ranking species by level of concern could be constructed from just two factors; conservation concern expressed as the proportion of the biogeographic population passing through the area of risk, and the importance of adult survival rate in determining population trend (technically expressed as ‘elasticity’ but essentially recognising that additional mortality of long-lived birds will have a greater impact on their population than the same level of additional mortality affecting birds with a naturally low adult survival rate since that tends to be balanced by high reproductive output in species with low adult survival). Desholm (2009) showed that this very simple and statistically robust model worked well for a range of migrant bird species from coal tits to eider ducks passing an offshore wind farm in the Baltic Sea. However, that range of species extends from very short-lived birds (some small passerines are fortunate to live to be one year old, but may rear ten or more chicks) to very long-lived birds such as most seabirds (which typically live tens of years and in many cases do not even start to breed until several years old and rarely rear more than one chick per pair). In our analysis we are dealing mainly with species at the long-lived end of this spectrum of life histories and so the simple model focusing on adult survival rate becomes less useful as there is relatively little variation in this among most seabird species. In addition, it seems lower risk of collision than seabirds that fly at higher altitudes.

So the simple model proposed by Desholm (2009) while suitable for broadly ranking birds of all kinds and concluding that seabird populations are of high concern whereas small passerine populations are not, does not perform well when comparing between seabird species of similar demography but differing in ecology and behaviour.

A factor that has been raised as possibly affecting collision risk for seabirds is weather conditions such as fog or heavy rain, which may obscure turbines. Such effects might over-ride any species-specific differences in vulnerability. In reviewing the results of studies at demonstration offshore wind farms in Denmark, Fox et al. (2006) stated "*Waterbird migration typically reduces substantially or ceases during periods of poor visibility and indeed during the observations reported here, the arrival of fog and active rain associated with frontal systems invariably resulted in the cessation of active migration that had been observed during previous periods of good visibility. We must stress that these responses are those by waterbirds generally and at Nysted by common eiders in particular*" and "*There has been a general concern world-wide that even if there are few collisions under normal conditions, bird populations may be affected by catastrophic mortality events on rare occasions when visibility is impaired by fog or other adverse weather conditions. The observations at Nysted that waterbirds tend not to fly in the area off the turbines at night, or under adverse weather conditions (as found elsewhere; Petterson 2005) suggest that collision risk is not likely to be high even under conditions when the turbines are less visible*". These observations suggest that catastrophic mortality incidents caused by adverse weather conditions are less likely at offshore wind farms than has been suggested by some. Similarly, seabirds that fly at night might be more at risk of collision on darker nights or during adverse weather. However, even the most highly adapted seabirds to nocturnal flight activity (for example white-chinned petrels *Procellaria aequinoctialis*) show greatly reduced flight activity at night when there is no moonlight available to guide them (Mackley et al. 2011).

With considerable research effort being put into studying the behaviour of seabirds at sea, and new developments such as use of data loggers to measure flight heights of individual seabirds throughout the breeding season or overwinter, it will be possible to revise the scoring in the light of more detailed data. In particular, there is a need for more accurate data on seabird flight heights while at sea. The influences of local conditions and environmental variation on this parameter also need to be better understood. For example, seabirds searching for fishing vessels may be able to do so more successfully if they fly high so can see greater distances (Skov and Durinck 2001, Furness et al. 2007), whereas seabirds that are commuting to a specific foraging site (such as a sand bank with sandeels, or a predictable frontal region with aggregations of zooplankton) should fly low over the sea surface to minimise travel costs and time (Pennycuick 1987), especially if flying into a headwind (Dierschke and Daniels 2003). So birds of the same species may behave differently if utilizing different feeding opportunities. Similarly, although divers tend to fly relatively low over the sea when moving between feeding sites at sea, divers flying from a nest site to the sea come off the land at a greater height, and often come off land over cliff coastline (M. Heubeck in litt.). In such cases their flight height in the initial part of the foraging trip is dictated by land topography, and so varies by location. In this context, we note that most of the data used by Cook et al. (2011) come from offshore wind farm sites in the southern UK or from overseas, and very little from Scottish waters.

There were some discrepancies between the published data on flight heights of seabirds in Garthe and Hüppop (2004) and in Cook et al. (2011), and these often differed from data for the same species of seabirds at a 'coastal' offshore wind farm near Blyth (Rothery et al. 2009). Where these discrepancies occurred we made a judgement as to the appropriate score for the species with regard to scores allocated to similar species as well as to the apparent 'outlier' nature of particular data.

This clearly points to a need to obtain larger and more accurate data sets on seabird flight heights, and to be cautious about the ranking of seabird species presented in Table 11. However, we suggest that species with high scores in Table 11 should be given particular concern in relation to offshore wind developments. This table identifies gulls, white-tailed eagles, gannets, skuas and divers as being the groups whose populations are most at risk in a Scottish context. Many seabird species rarely fly at turbine blade height, and so appear to have negligible risk of population level impacts from collision mortality, though it would be desirable to have more data on flight heights to allow this inference to be converted into a confident conclusion that might permit species to be scoped out of assessments. These include sea ducks, alcids, storm-petrels and shearwaters (Table 11). The low risk for these species is consistent with data from long-established offshore wind farms (ICES 2011).

According to ICES (2011) '*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*'.

This is consistent with data from Swedish and Danish offshore wind farms. Petterson (2005) recorded only one collision of a sea duck from about 2 million migrating past a Swedish offshore wind farm, while Fox et al. (2006) used radar studies at Nysted to predict a collision rate of 0.02% (i.e. a 99.98% avoidance rate) for 235,000 common eiders migrating past that site, and observed no collisions by infra-red monitoring (of a single turbine). Fox et al. (2006) did observe significant displacement, of scoters in the short term, and of divers without any evidence of habituation. Lindeboom et al. (2011), studying ecological changes at an offshore wind farm in the Netherlands, reported '*gannets, scoters, auks and divers showed strong avoidance behaviour in their flight pattern in the vicinity of the farm*' and '*gulls, cormorants and terns did not avoid the farm and used it for foraging*'. There is clearly a need for a better understanding of the extent to which displacement of seabirds from wind farms does occur, and what population-level effects, if any, arise from this. Meanwhile, in the absence of such research to date, indirect assessments are all that is available to regulators, developers and consultants. In assessing potential importance of displacement for different seabird species (Table 12), although there was strong consensus among reviewers for the scores used, this consensus may be more a result of uncertainty than confident agreement, and so the ranking of species needs to be treated with caution. However, we suggest that species with scores over 15 (divers, scoters, goldeneye, scaup, eider, black guillemot, Slavonian grebe) should be considered as focal species for concern about potential displacement effects, while species with scores below 8 (fulmar, storm-petrels, shearwaters, gulls, skuas, gannet, little auk, and white-tailed eagle) seem very unlikely to be affected by displacement.

In scoping potential areas for offshore wind farm development in Scottish waters, Davies and Watret (2011) considered constraints implied by seabird SPAs, and the distribution at sea of seabirds as indicated by the European Seabirds at Sea database. These data were combined with the flight height data presented by Cook et al. (2011) to assess numbers of seabirds flying at collision height risk in different parts of the Scottish marine area. The development of sensitivity scoring and conservation importance scoring for individual species of seabirds may help to refine such assessment of environmental constraints by allowing a focus on the seabird species of greatest concern. This would most usefully be combined with mapping of the distribution of seabird SPAs and the numbers of each species protected at these sites. Thus, in addition to improving knowledge of flight heights and the implications of these for collision risk, a useful improvement to the conservation importance score may be possible if an up-to-date database of numbers of seabirds in SPAs in Scotland could be established, and kept up to date, allowing better understanding of the consenting risk for specific developments.

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