BTO Research Report No. 669

Collision, Displacement and Barrier Effect Concept Note

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Report of work carried out by the British Trust for Ornithology
on behalf of Natural England

June 2015

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Registered Charity No. 216652

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EXECUTIVE SUMMARY

1. Offshore wind farms (OWFs) may potentially affect birds in a number of ways, most notably through: i) collisions with turbines; ii) displacement of birds due to effective loss of habitat; and iii) barrier effects where the wind farm creates an obstacle to regular movements to and from breeding colonies or migration. These effects have usually been considered separately in Environmental Impact Assessments (EIAs). There is a need to consider whether the multiple impacts from these different effects in combination may be significant.

2. This summary concept note outlines the issues associated with and options for integrating the impacts associated with collision, displacement and barrier effects associated with OWFs in a statistically and ecologically appropriate way. The extent to which barrier effects have been differentiated from displacement effects is questionable, however, as both are manifested as a reduction in the number of birds in flight within the wind farm.

3. An initial overview is provided of key reviews which have assessed the sensitivities or vulnerabilities of species to the likely effects of OWFs. This information has then been used to derive a list of key species where two or more effects could operate together and therefore where multiple impacts need to be considered in combination. Displacement, barrier and collision effects have often not been considered in combination because the species considered at greatest risk from collision have generally been considered to be of low risk from displacement and vice versa. Based on the methodology outlined above, none of the species considered here required the effects of wind farms to be combined. Caution is urged, however, with using this approach as the basis for making the decision as to whether effects should be combined or not and a watching brief needs to be maintained on the evidence base

4. A further review briefly summarises how collision, displacement and barrier effects have been assessed and treated by different OWF project applications for these species in the UK. Four main approaches appear to have been taken:

   i. Mortalities calculated separately for both collision and displacement – effects not combined;

   ii. Mortalities calculated separately for both collision and displacement – effects combined by simple addition of predicted losses;

   iii. Mortalities calculated separately for both collision and displacement – effects combined and displacement considered as the population lost in the long-term due to the effective loss of habitat;

   iv. Mortality calculated for collision and reduced productivity assumed to be the result of displacement – effects combined.

5. Before the effects of wind farms on bird populations can be combined, it is important to consider the processes by which displacement/barrier effects and collision may impact populations, i.e. which components of the population may be affected and how. With respect to displacement/barrier effects, impacts might occur through: increased chick mortality (observed as a decrease in productivity through reduced provisioning), increased juvenile mortality, increased immature mortality (i.e. of pre-breeding birds), increased adult mortality (of breeders and/or non-breeders) and breeding adults becoming non-breeders.

With respect to collision, impacts might occur through: increased chick mortality (indirect but could arise through the loss of a parent), increased juvenile mortality, increased immature mortality and increased adult mortality.

6. Potential alternative methodologies for combining the impacts associated with collision, displacement and barrier effects into a single integrated metric of impact are based on two broad approaches. Given the practical difficulties in distinguishing between displacement and barrier effects in the field, we focus our discussion on displacement/barriers effects collectively and how they may be combined with collision.

i. The first approach, hereafter referred to as **Additive Mortality**, is a simple addition, for each relevant age class, of the estimated annual (or seasonal) mortality arising from displacement/barrier effects and the predicted annual (or seasonal) mortality arising from collisions, as derived from Collision Risk Models (CRMs), to give a total mortality rate.

ii. The second approach is hereafter referred to as **Displacement/Barrier Effect Corrected Additive Mortality.** Here a revised annual (or seasonal) collision rate is calculated, for each relevant age class, based on the number of birds available to collide with turbines following displacement or barrier effects. This value is then combined with an estimate of the annual (or seasonal) mortality arising from displacement/barrier effects for each relevant age class, to give a total mortality rate.

If the effect of displacement is simply considered by estimating the proportion of displaced birds that might be expected to be lost in the long-term, i.e. as Displacement as Habitat Loss (Busch *et al.* 2015), then a Displacement/Barrier Effect Corrected Additive Mortality approach would effectively be taken, but, having accounted for the assumed population loss, the only ongoing impacts on demographic rates would be through collision.

7. The key aim of our work here is to consider the process of combining effects of wind farms rather than focus on potential modelling frameworks which could be used thereafter to investigate the population level consequences (i.e. changes in population size) resulting from the development over its operational lifetime. Hence, it is not part of our brief to review the range of population models available and comment on their suitability. Nor can we provide guidance as to whether sufficient empirical data exist to test the predictions of these population models.

Note, however, for any population modelling framework used, consideration would have to be given to as to whether density dependent processes were operating.

8. Careful consideration should be given as to whether the assumptions regarding the processes by which displacement/barrier effects, in particular, may impact populations can be justified given the limitations of the data available and evidence base.

1. BACKGROUND

Offshore wind farms (OWFs) may potentially affect birds in a number of ways, most notably:

- Collision with turbine blades and ancillary structures (moving and stationary);
- Displacement of birds due to effective loss of suitable feeding habitat; and
- Barrier effects where the wind farm creates an obstacle to regular movements (for example, to and from breeding colonies) or migration.

These different effects may impact populations in different ways.

In Environmental Impact Assessments (EIAs) of the potential effects of OWFs, collision impacts are assumed to represent an immediate, direct mortality event which can be calculated as an annual (or seasonal) predicted number of birds killed. Mortality through collisions may also potentially have a knock-on impact through resultant decreases in a species breeding productivity as mediated through reduced provisioning of the young, although this is seldom considered. In contrast, displacement, [disturbance] and barrier effects are harder to quantify directly as they manifest themselves in terms of impacts on daily time and energy budgets, that ultimately may reduce the demographic fitness, i.e. survival rates and breeding productivity, of the birds diverted or displaced from 'source' areas as well as potentially impacting on birds in areas that displaced birds move to, if, for example, densities of birds are increased in these 'sink' areas. To date, EIAs have tended to assume that both collision and displacement effects are manifested as mortality effects.

Studies of the impacts of the displacement associated with habitat loss or change on the breeding productivity or survival of individuals and thus on populations as a whole are few. Burton *et al.* (2006) reported how the body condition and survival rates of common redshank *Tringa totanus* were impacted following their displacement by a loss of intertidal habitat. However, similar studies of the impacts of habitat loss in the marine environment are lacking. In actuality, the survival of birds displaced through loss of habitat will depend on how close alternative areas are to carrying capacity and thus whether they are able to support increased densities. If areas elsewhere do exist but are limited in quality or extent, and/or already occupied, then increasing pressure on those areas could lead to increased competition for resources (Goss-Custard 1985, Goss-Custard *et al.* 2002). Such competition will increase as the availability of alternate habitat below carrying capacity decreases with cumulative development.

In EIAs of the potential effects of OWFs, there is thus uncertainty as to whether the effect of displacement should be considered simply by estimating the proportion of displaced birds that might be expected to be lost from the population in the long-term, due to the effective loss of habitat associated with this effect, or by estimating the annual (or seasonal) impacts on demographic processes, i.e. survival and productivity, that would lead to this reduction in population size. Typically, only impacts on annual (or seasonal) mortality have been considered (e.g. through a matrix approach, as outlined in existing guidance: Natural England / JNCC 2012). It has come to our attention, however, that within the industry, the term 'one-off loss' in relation to displacement has come in usage. What we mean here is a population loss which occurs as a result of a loss in foraging area, through changes in demographic rates until a new equilibrium is reached. While the changes that lead to this loss occur over the long-term, rather than as a one-off event, they are not ongoing throughout the lifetime of the wind farm development. The consideration of displacement as a direct population loss has more recently been termed as Displacement as Habitat Loss (Busch *et al.* 2015).

The potential impacts associated with barrier effects are often treated in a qualitative way, due to the difficulty of translating increases in flight distances into estimates of increases in energy expenditure and ultimately impacts on breeding productivity or survival.

Given these difficulties, the potential impacts of collision, displacement and barrier effects are thus typically treated as separate and discrete impacts that may operate on receptor populations and it is not clear how these should be combined.

A further reason that displacement, barrier and collision have not been considered in combination is that species considered at greatest risk from collision have generally been considered to be of low risk from displacement and vice versa (e.g. see Furness *et al.* 2013). So typically in the assessment of impacts it has been assumed that auks and divers will be sensitive to displacement impacts, but due to their low flight heights they will not be at high risk of collision. Conversely species such as northern gannet *Morus bassanus* and gulls, including black-legged kittiwake *Rissa tridactyla*, will be more at risk from collision impacts as a result of their flight behaviour, but less sensitive to disturbance and displacement effects. In fact, some gull species may show a lack of response or may even be attracted to turbine structures. Bird's responses to the effects of wind farms may also vary according to a range of factors relating not only to birds themselves (e.g. age class, status) but as a consequence of the season being considered and the relative location of the wind farm (e.g. with respect to key foraging areas or migration routes).

However, there are some species, that include northern gannet and black-legged kittiwake, for which assessments have considered both these impacts, albeit usually separately without attempting (in most cases) to assess whether these impacts associated with these effects could be significant in combination.

For species where collision mortality is not considered a significant risk (e.g. auk species), there is still a need to consider how to combine assessments of population impacts resulting from displacement of birds from within a wind farm footprint with population impacts arising from barrier effects on birds intending to forage in areas beyond the wind farm.

2. AIM AND OBJECTIVES

The Marine Renewables Ornithology Group (MROG) which is made up of Statutory Nature Conservation Bodies (SNCBs: JNCC, NE, SNH, NIEA and NRW), Marine Scotland Science (MSS) and the Royal Society for the Protection of Birds (RSPB), ran a workshop in May 2015 which aimed to provide an expert review of existing and new evidence for displacement impacts to seabirds from offshore renewables projects. It considered current assessment approaches, both within the UK and abroad, and provided best practice advice on assessment methods for the future, with the aim of developing a more co-ordinated UK assessment approach industry-wide.

To assist in the planning of this workshop, a series of concept notes were prepared to set out the background and develop thinking around the key issues that will be covered at the workshop. The concept notes formed the basis of pre-workshop documentation and were used to set the scene for the workshop discussion.

The aim of this project is to produce a concept note outlining the issues associated with and options for integrating the impacts associated with collision, displacement and barrier effects associated with OWFs in a statistically and ecologically appropriate way. The project has four main objectives:

i. To summarise the evidence for collision, displacement and barrier effects across a range of seabird species in order to derive a list of key species where two or more effects could operate together and therefore where multiple impacts need to be considered cumulatively.

ii. To collate information and review how collision, displacement and barrier effects have been assessed collectively by different OWF project applications in the UK (and in other European countries if possible) for northern gannet, black-legged kittiwake and terns as a priority and other species if data exist.

iii. To derive and present potential alternative methodologies for combining the impacts associated with collision, displacement and barrier effects into a single integrated metric of impact.

iv. To identify key evidence gaps in our understanding of the combined effects of collision, displacement and barrier effects and suggest what post-consent monitoring would most effectively address the lack of information on those critical assumptions underpinning the methodologies presented by this project.

3. RESULTS

3.1 OBJECTIVE 1. To summarise the evidence for collision, displacement and barrier effects across a range of seabird species in order to derive a list of key species where two or more effects could operate together and therefore where multiple impacts need to be considered cumulatively

Post-construction monitoring of the impacts associated with collision, displacement and barrier effects was recently reviewed in MMO (2014). At present, the evidence base for these effects remains limited, although new studies and improved study design should improve this situation. As such, rather than attempting to provide a complete review of existing evidence, this summary references key reviews which have carried out assessments of the sensitivities or vulnerabilities of species to the likely effects of OWFs. Broadly these have assessed the likely sensitivity of species to particular effects based on a combination of: (i) a range of behavioural traits which have been evaluated in a quantitative manner e.g. in relation to collision, flight height, % time in flight (as derived from extensive literature searches and in some cases checked with known experts); and (ii) their relative conservation status (incorporating life history characteristics).

The most recent review was that of Bradbury *et al.* (2014) which derived both numerical and categorical scores for the relative vulnerability of species to the separate effects of collision and disturbance/displacement. This work was an update of Furness *et al.* (2013) using information which had become available since that paper was published (hence some of the minor differences in final scores: see Tables A and B in the Appendices). Furness *et al.* (2013) was considered to be an update of Garthe and Hüppop (2004), which produced a Species Sensitivity Index (SSI) for both collision and displacement collectively, for a Scottish context and is not discussed further here. Langston (2010) has been the only study to separately propose sensitivity scores (using the categorical scores of low, medium or high) for collision, displacement and barrier effects and was based heavily on scores derived from on Garthe and Hüppop (2004) and King *et al.* (2009). Additional supporting information for this current project has also been extracted from Furness (2013) which looked at the evidence for displacement or attraction for six wind farm sites within Europe. Similarly the review work of Cook *et al.* (2014) is referenced in relation to the evidence for both displacement/attraction and barrier effects for five key species: northern gannet, black-legged kittiwake, lesser black-backed gull *Larus fuscus*, herring gull *Larus argentatus* and great black-backed gull *Larus marinus*.

The final recommended scores for collision risk and displacement were based on Bradbury *et al.* (2014). It was decided, however, to remove the conservation score from the final population vulnerability scores for both effects as it was deemed more appropriate to have scoring systems based solely on flight characteristics and overall species ecology respectively. New numerical scores for vulnerability to collision and displacement were then calculated, which were latterly converted into a categorical score ranging from 1 to 5 (very low, low, medium, high and very high) and 1 to 4 for collision and displacement respectively (see Tables A and B in the Appendix). In the absence of any information on barrier effects from either Bradbury *et al.* (2014) and Furness *et al.* (2013), we have reverted to Langston (2010) which produced a categorical score ranging from 1 to 2 (low and medium) for this particular effect (see Table C respectively in Appendix 1). The final scores for each effect are presented in Table 1 in order to be able to assess where two or more effects could operate together and therefore where multiple impacts might need to be considered cumulatively.

Based on the methodology outlined above, none of the species considered here required the effects of wind farms to be combined. Caution is urged, however, with using this approach as the basis for making the decision as to whether effects should be combined or not and a watching brief needs to be maintained on the evidence base. For example, whilst the northern gannet may score extremely low for vulnerability to displacement, empirical data indicates that they may exhibit strong displacement effects (see Cook *et al.* 2014 for review of current evidence). Consequently some EIAs have considered whether these effects could be significant in combination for northern gannet (see objective 2). For many gull species (e.g. lesser black-backed, herring and greater black-backed gull), the evidence with respect to displacement/attraction, as derived from post-construction monitoring reports, is also equivocal with some studies suggesting evidence for attraction, others evidence for displacement, and others no significant response (Furness 2013; Cook *et al.* 2014). However, should a potential change in numbers be predicted, given their high sensitivity to collision, there may be need to consider effects in combination for northern gannet, all gulls, as well as skuas and terns.

Table 1. Summary of all final collision, displacement and barrier effect risk scores as derived from Tables A, B and C in the Appendix 1. Scores for collision and displacement (sic) are derived from Bradbury *et al.* 2014 (although they refer to the latter as displacement/disturbance) but have been adjusted to remove the conservation scores. Scoring for barrier effects was based on categorical data from Langston (2010) as this was the only source of information available (yellow cell =low score (1), orange cells = medium (2). Use of hyphen indicates lack of data available.

	Final Collision Risk Score		**Final Displacement score**		**Final barrier score**
Species	**Numerical (Conservation Score removed)**	**Categorical (Conservation Score removed**	**Numerical (Conservation Score removed)**	**Categorical (Conservation Score removed)**	
Greater scaup	**11**	**	**16**	****	
Common eider	**6**	**	**12**	***	
Long-tailed duck	**0**	*	**12**	***	
Common scoter	**8**	**	**20**	****	
Velvet scoter	**8**	**	**15**	***	
Common goldeneye	**13**	**	**16**	****	
Red-breasted merganser	**13**	**	**12**	***	
Goosander	**13**	**	**16**	****	-
Red-throated diver	**13**	**	**20**	****	
Black-throated diver	**15**	**	**20**	****	
Great northern diver	**13**	**	**15**	***	
White-billed diver	**13**	**	**20**	****	-
Northern fulmar	**3**	*	**1**	*	
Cory's shearwater	**0**	*	**1**	*	-
Great shearwater	**0**	*	**1**	*	-
Sooty shearwater	**0**	*	**1**	*	-
Manx shearwater	**0**	*	**1**	*	
Balearic shearwater	**0**	*	**1**	*	
Wilson's storm-petrel	**0**	*	**1**	*	-
European storm-petrel	**5**	*	**1**	*	
Leach's storm-petrel	**5**	*	**1**	*	
Northern gannet	**32**	****	**2**	*	
Great cormorant	**19**	***	**12**	***	
Shag	**16**	***	**9**	**	
Great crested grebe	**6**	**	**12**	***	-

	Final Collision Risk Score		Final Displacement score		Final barrier score
Species	**Numerical (Conservation Score removed)**	**Categorical (Conservation Score removed**	**Numerical (Conservation Score removed)**	**Categorical (Conservation Score removed)**	
Slavonian grebe	**5**	*	**12**	***	-
Red-necked phalarope	**17**	***	**2**	*	-
Grey phalarope	**17**	***	**2**	*	-
Pomarine skua	**23**	***	**2**	*	
Arctic skua	**23**	***	**2**	*	
Long-tailed skua	**23**	***	**2**	*	
Great skua	**20**	***	**2**	*	
Sabine's Gull	**33**	****	**6**	**	-
Black-legged kittiwake	**35**	****	**4**	*	
Black-headed gull	**27**	****	**4**	*	
Little gull	**30**	****	**3**	*	
Mediterranean gull	**42**	****	**4**	*	
Common gull	**50**	****	**4**	*	
Lesser black-backed gull	**60**	*****	**2**	*	
Herring gull	**82**	*****	**2**	*	
Iceland gull	**82**	*****	**2**	*	
Glaucous gull	**82**	*****	**2**	*	
Great black-backed gull	**82**	*****	**4**	*	
Little tern	**23**	***	**8**	**	
Black tern	**20**	***	**6**	**	-
Sandwich tern	**23**	***	**6**	**	
Common tern	**23**	***	**6**	**	
Roseate tern	**19**	***	**6**	**	
Arctic tern	**12**	**	**6**	**	
Common guillemot	**2**	*	**9**	**	
Razorbill	**1**	*	**9**	**	
Black guillemot	**1**	*	**12**	***	
Little auk	**1**	*	**4**	*	
Atlantic puffin	**1**	*	**6**	**	

3.2 OBJECTIVE 2. To collate information and review how collision, displacement and barrier effects have been assessed collectively by different OWF project applications in the UK (and in other European countries if possible) for northern gannet, black-legged kittiwake and terns as a priority and other species if data exist

Assessment of effects

Estimates of collision-related mortality in EIAs have tended to be estimated using the Band Collision Risk Model (CRM) (Band *et al.* 2007 or its update for use in a marine context, Band 2012). Whereas the impacts associated with displacement have been estimated for the purposes of EIAs using a simple matrix table - whereby a range of displacement rates are cross-tabulated with mortality rates. The Interim Advice Note provided by NE & JNCC (2012) states that susceptibility to disturbance scores (in relation to ships and helicopters) can be used to provide an initial indication of potential displacement levels that may be exhibited by each species where more specific evidence on displacement levels is lacking (citing Furness and Wade 2012, which was the commissioned report which gave rise to Furness *et al.* 2013; an update currently being developed by the SNCBs will use Bradbury *et al.* 2014). Similarly, the habitat use flexibility (or habitat specialisation) score may also give an initial indication of the likelihood that mortality will arise from displacement. In neither instance are specific values for displacement or mortality linked to the disturbance or habitat sensitivity scores provided in the Interim Advice Note. Barrier effects have been assessed less consistently in EIAs. While some assessments have considered how the increase in flight distances associated with the barrier effects presented by OWFs might be associated with increased energy expenditure (Speakman *et al.* 2009, Masden *et al.* 2009), the consequences for this for fitness (body condition, breeding productivity, survival) are not readily determined (although see Searle *et al.* 2014 which looked at the impacts of displacement and barrier effects on survival and productivity).

Collectively barrier effects and displacement effects are referred to as macro-avoidance (see section 5.1 of Cook *et al.* 2014 for further details, but note that the term macro-response is used in preference to describe the response of birds to the presence of the wind farms outside its perimeter, thereby also including possible attraction effects). Whilst the exact relationship between macro avoidance and collision rates is unknown, it is intuitive that the higher the macro-avoidance rates in response to a wind farm, the lower will be the numbers of birds at risk of collision with wind turbines – potentially resulting in a reduced number of birds being killed. Similarly, where birds are attracted to a wind farm, it is intuitive that more birds would be at risk of collision.

Effects of OWFs at a population level

To date there has been a lack of empirical evidence on the effects of OWFs at the population level. Hence the following section is largely based on theoretical discussion or at best on the outputs of predictive modelling, which remain untested to date.

The extent to which collision mortality may be important for a population depends not only on the absolute number affected but also on the relative proportions of juvenile birds, immature birds, non-breeding adults and breeding adults involved. Collision mortality may also potentially impact on populations through knock-on effects on breeding productivity.

Displacement effects for breeding seabirds are more likely to be observed as changes in productivity as opposed to survival rates. Seabirds experiencing challenging conditions are more likely to abandon the current breeding attempt before compromising their own survival (Furness 2013), although it is likely that they may enter the wintering period in poor body condition and hence may still subject to higher mortality effects. Although such effects are likely to be more pronounced for breeding adults, non-breeding and immature birds may also subject to them when attending the colony in the breeding season. There could be scope, however, for displacement effects to have direct consequences for wintering birds which are displaced from high quality habitat and forcing them to redistribute into much poorer quality habitat resulting in poorer body condition leading to lower over-winter survival rates or potentially reduced breeding success in the subsequent year. Displacement of birds from poor quality habitat is less likely to have such consequences at the population level, however (Furness 2013). Birds which are displaced to other areas are also likely to have an impact of the birds already present in their least preferred habitat through increased competition. To date the effects of displacement have been mostly assumed to be mediated through reduction in survival (see Interim Guidance Note, NE & JNCC 2012), although there have been recent examples of work where effects on breeding productivity were also modelled (e.g. Searle *et al.* 2014).

Barrier effects are less likely to be an issue for migrating birds since the energetic costs associated with diverting around a wind farm are likely to be relatively small in the context of total distance travelled (Masden *et al.* 2009). In contrast, the increased cost of repeated diversions around a wind farm made by breeding birds moving between their nests and foraging areas may be more substantial (see Masden *et al.* 2010). Yet barrier effects for migrating birds as opposed to breeding birds have tended to be the main focus to date (e.g. Desholm & Kahlert 2005). However, the extent to which barrier and displacement effects have been differentiated between in the field is highly debatable as both are manifested as a reduction of birds within the wind farm (Cook *et al.* 2014). Hence it is likely that barrier effects during the breeding season have been inadvertently observed as part of displacement studies and may have already been accounted for.

Approaches used to date to combine effects in order to derive a population level effect

The following is not a meant to be a comprehensive review of all sites in the UK which have assessed collision, displacement and barrier effects collectively. Rather we have used examples to demonstrate the range of possible approaches that have been taken to date. We have based this section on comments provided by the Marine Renewables Ornithological Group (MROG) in response to a request made by Natural England. Broadly speaking, most interest has tended to focus on the possibility of combining the effects of displacement and collision with no consideration of barrier effects. This may in part reflect the lack of Likely Significant Effects (LSEs) predicted in Habitats Regulations Assessments (HRAs) for the latter effect or that studies to date have not attempted to separate barrier and displacement effects (see above).

i. *Mortalities calculated separately for both collision and displacement – effects not combined*

CASE STUDY: Northern gannet in relation to the Hornsea OWF Project One[1] (July 2013). It was argued by the applicant that while collision and displacement impacts could both result in mortalities for the species due to the interaction between the two impacts, as well as questions about whether displacement should be treated as an annual effect, it was not appropriate to simply add the numbers of predicted mortalities derived for displacement and collision, and an overall impact could not be determined.

[1] http://infrastructure.planningportal.gov.uk/wp-content/ipc/uploads/projects/EN010033/2.%20Post-Submission/Application%20Documents/Reports/12.6%20Habitats%20Regulation%20Assessment.pdf

ii. *Mortalities calculated separately for both collision and displacement – effects combined by simple addition of predicted losses*

CASE STUDY: Northern gannet in relation to the Navitus Bay Wind Park (April 2014)[2]. The mortality losses for collision and displacement were treated as additive losses.

iii. *Mortalities calculated separately for both collision and displacement – effects combined and displacement considered as the population lost in the long-term due to the effective loss of habitat.*

CASE STUDY: Northern gannet in relation to the Dogger Bank Creyke Beck OWF projects[3]. In the EIA and HRA undertaken for the Dogger Bank Creyke Beck OWF projects, the effect of displacement was considered by estimating the proportion of displaced birds that might be expected to be lost in the long-term, i.e. as Displacement as Habitat Loss (Busch *et al.* 2015). The assessment of annual collision undertaken in the HRA for northern gannet thus considered whether a revised population figure that reflected this population loss would lead to a change in the conclusions of the assessment. In practice, as the reduction in the population due to displacement was predicted to be small, the conclusions to the HRA would have been unchanged and thus this approach was not taken through in the assessment.

iv. *Mortality calculated for collision and reduced breeding productivity assumed to be the result of displacement – effects combined.*

CASE STUDY: herring gull, great black-backed gull, common guillemot *Uria aalge*, razorbill *Alca torda* and Atlantic puffin *Fratercula arctica* at MORL and BOWL OWFs. A 'common currency' was developed in order for collision and displacement effects to be considered together. Displacement effects were modelled solely through impacts on breeding productivity whereby each displaced bird was assumed to represent a separate pair and that 100% of displaced birds failed to breed successfully. The displacement rates were set at two fixed rates for all species. Collision mortality across all age classes and for all breeding adults only (excluding sabbaticals) were calculated and the effects of collisions were also apportioned into summer and wintering periods. PBR and ABC methods were then used to determine acceptable and precautionary effect thresholds taking into account these additional losses in mortality and reduced breeding productivity as a consequence of the OWF developments.

3.3 OBJECTIVE 3: Derive and present potential alternative methodologies for combining the effects of collision, displacement and barrier mortality into a single integrated metric of impact

In this section, we outline a broad approach that could be considered for combining displacement, barrier and collision effects into a single metric. Given the practical difficulties in distinguishing

[2] http://infrastructure.planningportal.gov.uk/wp-content/ipc/uploads/projects/EN010024/2.%20Post-Submission/Application%20Documents/Reports/5.3%20Habitat%20Regulations%20Assessment%20Screening%20Report.pdf

[3] http://infrastructure.planningportal.gov.uk/wp-content/ipc/uploads/projects/EN010021/2.%20Post-Submission/Representations/ExA%20Questions/19-05-2014%20%20-%20ExA%20Second%20Written%20Questions/Natural%20England%20Response%20to%20Second%20Written%20Questions.pdf

between displacement and barrier effects in the field, we focus our discussion on displacement/barriers effects collectively and how they may be combined with collision.

Stage 1. Decide which demographic rate is likely to be affected by which effect and to what extent

Before the effects of wind farms on bird populations can be combined, it is important to consider the processes by which displacement/barrier effects and collision may impact populations, i.e. which components of the population may be affected and how. With respect to displacement/barrier effects, a range of impacts might occur:

- **Increased chick mortality** (due to reduced provisioning resulting in lower productivity);
- **Increased juvenile mortality**;
- **Increased immature mortality** (i.e. of pre-breeding birds);
- **Increased adult mortality** (of breeders and/or non-breeders) arising from a poorer body condition (an increase in mortality is considered most likely to occur in the winter: Furness 2013; Searle *et al*. 2014);
- **Breeding adults becoming non-breeders** (birds don't actually die but will no longer contribute to the breeding population resulting in lower overall productivity and thus recruitment rates).

At this stage, it is not possible to take into account carry over effects e.g. displacement effects in the winter of adults could be manifested as birds being in poorer body condition at the start of the breeding season and hence future breeding success could be impacted.

With respect to collision, impacts might occur through:

- **Increased chick mortality** (indirect but could arise through the loss of a parent);
- **Increased juvenile mortality**;
- **Increased immature mortality** (i.e. of pre-breeding birds);
- **Increased adult mortality** (of breeders and/or non-breeders).

It is thus necessary to decide which how different components (e.g. age classes) of the population might be impacted by each effect (see Table 2). In addition consideration will need to be given as to how the scale of changes in demographic rates might be determined. This might be through a matrix approach, as outlined in existing guidance in relation to adult mortality but could be adapted to include additional age classes (Natural England / JNCC 2012) or informed by relevant studies (e.g. Searle *et al.* 2014), but is likely to also depend significantly upon expert opinion.

Table 2. Potential age-related demographic impacts needing to be considered in combination.

Impact	**Displacement/barrier effect**	**Collision**
Increased chick mortality	Y	Y[1]
Increased juvenile mortality	Y	Y
Increased immature mortality	Y	Y
Increased adult mortality	Y	Y
Breeding adults stop breeding[2]	Y	-

[1] Increased chick mortality could occur indirectly through the loss of a parent.

[2] While in this case, no mortality would be assumed to arise as a result of displacement, it is assumed that displaced birds would forego breeding in the year(s) concerned. The decrease in the size of the breeding population would thus have to be taken into account in population modelling. Non-breeders could, however, potentially re-enter the breeding population at a later stage should the conditions change.

Stage two. Selection from two possible options for combining collision, displacement and barrier effects into a single metric*.*

In terms of combining effects, there are two broad approaches, which are described below and summarised in Table 3:

i) The first approach, hereafter referred to as **Additive Mortality**, is a simple addition, for each relevant age class, of the estimated annual (or seasonal) mortality arising from displacement/barrier effects and the predicted annual (or seasonal) mortality arising from collisions, as derived from Collision Risk Models (CRMs), to give a total mortality rate (Eq. 1).

$$\sum combined\ impacts\ = \sum\ collision\ mortality + \sum displacement/barrier\ effects\ mortality$$

[Equation 1]

ii) The second approach, hereafter referred to as **Displacement/Barrier Effect Corrected Additive Mortality** takes into account the proportion of the population which exhibit displacement or barrier effects, resulting in lower densities of birds within the footprint of the wind farm. Due to the reduced abundance of birds, the predicted number of estimated collisions is proportionally reduced. Consideration is needed as to whether avoidance rates used in such an approach are therefore appropriate, since they incorporate macro-avoidance of the wind farm and thus may already reflect displacement (e.g. Cook *et al.* 2014)[4]. Any avoidance rates used in collision risk modelling may need to be adjusted accordingly, although at present there is a lack of empirical data to inform any changes to values used.

Here a revised annual (or seasonal) collision rate is calculated, for each relevant age class, based on the number of birds available to collide with turbines following displacement or barrier effects. This value is then combined with an estimate of the annual (or seasonal) mortality arising from displacement/barrier effects for each relevant age class, to give a total mortality rate (Eq. 2).

$$\sum combined\ impacts\ = \sum\ corrected\ collision\ mortality + \sum displacement/barrier\ effects\ mortality$$

[Equation 2]

Careful consideration should be given as to whether the assumptions regarding the processes by which displacement/barrier effects, in particular, may impact populations can be justified given the limitations of the data available and evidence base.

[4] Theoretically overall avoidance rate is calculated as:

$A_{rate} = 1 – [(1 - A_{micro})\ X\ (1-A_{meso})\ X\ (1 - A_{macro})]$

but given the lack of data on the meso and micro scales, the following formula is more appropriate:

$A_{rate} = 1 – [(1 – A_{within})\ X\ (1 - A_{macro})]$

Table 3. Possible approaches for combining impacts of collision, displacement and barrier effects into a single integrated metric of impact.

Option	Approach	Limitations of approach
Additive Mortality	Addition of mortality from displacement/barrier effects and collisions	As birds which are displaced will not also be at risk of collision, consideration is needed as to whether the macro-response component of the avoidance rates used in CRM tallies with the displacement rate assumed
Displacement/Barrier Effect Corrected Additive Mortality	Addition of mortality from displacement/barrier effects and corrected collisions, accounting for reduced population in wind farm due to displacement/barrier effects	Consideration needed as to whether avoidance rates are appropriate, since they incorporate macro-avoidance of the wind farm and thus may already reflect displacement

Stage 3. Choose the appropriate population modelling framework

The key aim of our work here is to consider the process of combining effects of wind farms rather than focus on potential modelling frameworks which could be used thereafter to investigate the population level consequences (i.e. changes in population size) resulting from the development over its operational lifetime. Hence, it is not part of our brief to review the range of population models available, e.g. Population Viability Analysis (PVA), Potential Biological Removal (PBR), Acceptable Biological Change (ABC) or Individual Based Models (IBMs), and comment on their suitability. Nor can we provide guidance as to whether there is sufficient empirical data which exists which can be used to test the predictions of these population models.

Further considerations

None of approaches described above differentiate between displacement effects having an ongoing impact rather than acting on demographic rates until a new equilibrium is reached over the long-term.

For any population modelling framework used, consideration would thus also have to be given to as to whether density dependent processes were operating, such that the impacts of displacement on demographic rates – i.e. the proportion of birds incurring increased mortality or reduced productivity – reduce over time as population size decreases towards the carrying capacity of the habitat that birds are displaced to.

If the effect of displacement is simply considered by estimating the proportion of displaced birds that might be expected to be lost in the long-term, i.e. as Displacement as Habitat Loss (Busch *et al.* 2015), then a Displacement/Barrier Effect Corrected Additive Mortality approach would effectively be taken, but, having accounted for the assumed population loss, the only ongoing impacts on demographic rates would be through collision.

3.4 OBJECTIVE 4: To identify key evidence gaps in our understanding of the combined effects of collision, displacement and barrier effects and suggest what post-consent monitoring would most effectively address the lack of information on those critical assumptions underpinning the methodologies presented by this project

In outlining potential approaches for combining the potential impacts associated with collision, displacement and barrier effects, the existing evidence gaps associated with these effects need to be recognised. Here we briefly summarise the key limitations in the current knowledge base relating to each of these potential effects of OWFs before then considering the issues relating to how these might be combined.

Collision

- There is a complete lack of empirical data of actual collisions collected at OWFs. This has led to a reliance on information from coastal sites where corpses can be collected (Cook *et al.* 2014), despite concerns as to its applicability, e.g. emerging evidence that flight heights and thus risk of collision are likely to vary between land and sea (see Corman & Garthe 2014, Ross-Smith *et al.* in prep). The absence of empirical data from OWFs reflects the limitations of current technology and the absence of a need to monitor collisions from many licence conditions. A current Offshore Renewables Joint Industry Programme (ORJIP) project aims to provide information on collision rates of key seabird species at OWFs and thus help validate avoidance rates used for these species in CRMs (Davies *et al.* 2013).

Displacement

- Overall there is limited empirical data, from UK OWFs in particular, on displacement rates and the spatial extent to which displacement effects occur. This reflects a combination of: i) poor survey design, in terms of both spatial and temporal coverage which limits the ability to be able to detect change; ii) the limitations associated with the use of the Before-After-Control-Impact (BACI) approach, as the extent to which control sites can be considered being independent (e.g. they have often been located immediately next to the wind farm) or even comparable in terms of biological and physical features, may be highly questionable; and iii) the lack of or inadequate statistical analyses used. These issues have led to recommendations that a Before-After-Gradient (BAG) design would be far more appropriate, and should be used in conjunction with density surface modelling approaches (MMO 2014, Mackenzie *et al.* 2013). The latter has the benefit of modelling important environmental covariates which allows better site characterisation. It has also been advocated that power analyses might be used on pre-construction data in order to be able to ascertain on a site-by-site basis what the size of the survey area should be (MMO 2014).

Barrier effects

- There is a general lack of empirical data to date on barrier effects and from the UK in particular (MMO 2014). This reflects a combination of: i) inappropriate methodology (e.g. boat surveys or watches from fixed points); and ii) the limitations of radar techniques (e.g. in terms of species identification), although radar has been used very successfully during mass migration events when focussing on key (larger) seabird or waterbird species.

Lack of evidence for population level consequences

- For all effects there is considerable uncertainty over how the effects of wind farms relate to key demographic rates, i.e. survival or breeding productivity, that determine population size and trends. In combination with the knowledge gaps associated with each of the effects outlined above, this uncertainty reflects a combination of : i) a lack of long-term monitoring carried out at colonies; ii) insufficient information on the connectivity of seabird colonies to OWFs – this has particular relevance for the HRAs required in relation to Special Protection Areas (SPAs) designated under the EC Birds Directive; and (iii) lack of information of migration routes, which is important in assessing barrier and collision effects in particular.

Combining collision risk with other wind farm effects which alter the numbers of birds within the wind farm

- In terms of combining effects, it is of the highest priority to better understand displacement/attraction and barrier effects, and the relationship between these, which ultimately alter the number of birds within the wind farm, and the actual number of birds which might be killed through collisions. A key aspect to this is the need to better understand the demographic processes through which displacement and barrier effects might impact populations.

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APPENDIX 1

Table A. Summary of collision risk scores (numerical and categorical) as extracted from three key reviews: Langston (2010), Furness *et al.* (2013) and Bradbury *et al.* (2014). The Final Collision Risk Score is based on Bradbury *et al.* (2014); further details are given in the footnotes. Grey cells indicate a lack of available data.

Species	**Langston (2010) COLLISION RISK SCORE[1]**	**Furness *et al.* (2013) COLLISION RISK SCORE[2]**						**Bradbury *et al.* (2014) COLLSION RISK SCORE[2]**									**Final Collision Risk score[6]**
		a	**b**	**c**	**d**	**e**	**Final e Score**	**a**	**b**	**c**	**d**	**e**	**Final score (as published)**	**Category (as published)[3]**	**Final score – no conservation score[4]**	**Category - no conservation score[5]**	
Greater scaup	*	3	2	4	5	11	121	3	4	2	5	10	110	L	**11**	L	**
Common eider	*	3	4	2	3	13	117	2	4	2	3	12	72	L	**6**	L	**
Long-tailed duck	*	3	3	2	3	8	64	0	3	2	3	7	0	VL	**0**	VL	*
Common scoter	*	3	3	2	3	12	96	3	3	2	3	12	96	L	**8**	L	**
Velvet scoter	*	3	3	2	3	11	88	3	3	2	3	11	88	L	**8**	L	**
Common goldeneye	*	3	3	2	3	12	96	5	3	2	3	11	147	L	**13**	L	**
Red-breasted merganser	*							5	4	2	2	8	107	L	**13**	L	**
Goosander								5	4	2	2	9	120	L	**13**	L	**
Red-throated diver	*	5	5	2	1	16	213	5	5	2	1	16	213	M	**13**	L	**
Black-throated diver	*	5	5	3	1	16	240	5	5	3	1	15	225	M	**15**	L	**
Great northern diver	*	5	5	2	1	18	240	5	5	2	1	15	200	M	**13**	L	**
White-billed diver								5	5	2	1	7	93	L	**13**	L	**
Northern fulmar	*	1	3	2	4	16	48	1	3	2	4	13	39	VL	**3**	VL	*
Cory's shearwater	*							0	3	3	3	12	0	VL	**0**	VL	*
Great shearwater	*							0	3	3	3	8	0	VL	**0**	VL	*

Species	Langston (2010) COLLISION RISK SCORE[1]	Furness *et al.* (2013) COLLISION RISK SCORE[2]						Bradbury *et al.* (2014) COLLSION RISK SCORE[2]									Final Collision Risk score[6]
		a	**b**	**c**	**d**	**e**	**Final e Score**	**a**	**b**	**c**	**d**	**e**	**Final score (as published)**	**Category (as published)[3]**	**Final score – no conservation score[4]**	**Category - no conservation score[5]**	
Sooty Shearwater	*	0	3	3	3	12	0	0	3	3	3	13	0	VL	**0**	VL	*
Manx shearwater	*	0	3	3	3	17	0	0	3	3	3	13	0	VL	**0**	VL	*
Balearic shearwater	*							0	3	3	3	17	0	VL	**0**	VL	*
Wilson's storm-petrel								0	1	3	4	7	0	VL	**0**	VL	*
European storm-petrel	*	2	1	3	4	17	91	2	1	3	4	14	75	L	**5**	VL	*
Leach's storm-petrel	*	2	1	3	4	16	85	2	1	3	4	14	75	L	**5**	VL	*
Northern gannet	**	16	3	3	2	17	725	12	3	3	2	16	512	H	**32**	H	****
Great cormorant	**	4	4	2	1	11	103	8	4	2	1	10	187	L	**19**	M	***
Shag	*	5	3	2	1	15	150	8	3	2	1	13	208	M	**16**	M	***
Great crested grebe		4	4	3	2	7	84	2	4	3	2	7	42	VL	**6**	L	**
Slavonian grebe	*	4	4	2	2	13	139	2	4	2	2	13	69	L	**5**	VL	*
Red-necked phalarope								10	1	2	2	12	200	M	**17**	M	***
Grey phalarope								10	1	2	2	4	67	L	**17**	L	***
Pomarine skua	**							10	1	5	1	8	187	L	**23**	M	***
Arctic skua	**	10	1	5	1	14	327	10	1	5	1	14	327	M	**23**	M	***
Long-tailed skua	**	n/a	n/a	n/a	n/a	n/a	n/a	10	1	5	1	7	163	L	**23**	M	***
Great skua	**	10	1	4	1	16	320	10	1	4	1	16	320	M	**20**	M	***
Sabine's gull								20	1	2	2	6	200	M	**33**	H	****
Black-legged kittiwake	**	16	1	3	3	14	523	15	1	3	3	12	420	H	**35**	H	****
Black-headed gull	*	18	1	1	2	12	288	20	1	1	2	15	400	M	**27**	H	****

Species	Langston (2010) COLLISION RISK SCORE[1]	Furness *et al.* (2013) COLLISION RISK SCORE[2]						Bradbury *et al.* (2014) COLLSION RISK SCORE[2]									Final Collision Risk score[6]
		a	b	c	d	e	Final e Score	a	b	c	d	e	Final score (as published)	Category (as published)[3]	Final score – no conservation score[4]	Category - no conservation score[5]	
Little gull	*							15	1	3	2	13	390	M	**30**	H	****
Mediterranean gull	**							25	1	2	2	13	542	H	**42**	H	****
Common gull	*	23	1	2	3	13	598	25	1	2	3	15	750	H	**50**	H	****
Lesser black-backed gull	**	30	1	2	3	16	960	30	1	2	3	16	960	VH	**60**	VH	*****
Herring gull	**	35	2	2	3	16	1307	35	2	2	3	18	1470	VH	**82**	VH	*****
Iceland gull	**							35	2	2	3	10	817	H	**82**	VH	*****
Glaucous gull	**							35	2	2	3	10	817	H	**82**	VH	*****
Great black-backed gull	**	35	2	2	3	15	1225	35	2	2	3	14	1143	VH	**82**	VH	*****
Little tern	*	7	1	5	1	13	212	10	1	5	1	16	373	M	**23**	M	***
Black tern								10	1	4	1	13	260	M	**20**	M	***
Sandwich tern	**	7	1	5	1	15	245	10	1	5	1	17	397	M	**23**	M	***
Common tern	**	7	1	5	1	14	229	10	1	5	1	14	327	M	**23**	M	***
Roseate tern	**							8	1	5	1	16	299	M	**19**	M	***
Arctic tern	**	5	1	5	1	17	198	5	1	5	1	14	163	L	**12**	L	**
Common guillemot	*	1	4	1	2	16	37	1	4	1	2	14	33	VL	**2**	VL	*
Razorbill	*	1	4	1	1	16	32	0.5	4	1	1	14	14	VL	**1**	VL	*
Black guillemot	*	1	4	1	1	13	26	0.5	4	1	1	10	10	VL	**1**	VL	*
Little auk	*	1	3	1	1	9	15	0.5	3	1	1	9	8	VL	**1**	VL	*
Atlantic puffin	*	1	3	1	1	16	27	0.5	3	1	1	14	12	VL	**1**	VL	*

[1] Note that Langston (2010) did not score collision risk as high for seabird species.

[2] Codes used in Furness *et al.* (2013) and Bradbury *et al.* (2014) are as follows: a = % time bird at blade height; b = flight manoeuvrability; c = % time flying; d = nocturnal activity; and e = conservation importance scores.

[3] Where VL = Very Low; L = Low; M = Moderate; H = High; VH = Very High.

[4] Numerical Collision Risk Score recalculated as = a x (b + c + d) x 1/3.

[5] Category score recalculated as: Very Low (VL) = ≥5; Low (L) = >5 to ≤15; Moderate (M) = >15 to ≤25; High (H) = >25 to ≤50; and Very High (VH) = > 50+.

Table B. Summary of displacement scores (numerical and categorical) as extracted from three key reviews: Langston (2010), Furness *et al.* (2013) and Bradbury *et al.* (2014). Additional information from reviews of post-consent monitoring reports is also given: Furness (2013) and Cook *et al*. (2014). The final Displacement Score is based on Bradbury *et al.* (2014). Grey cells indicate a lack of available data.

Species	**Langston (2010)**	**Furness *et al.* (2013)[1]**				**Bradbury *et al.* (2014)[1]**							**Furness. (2013) review of post consent monitoring reports[5]**	**Cook *al.* (2014) review of post consent monitoring reports**	**Final Displacement Score[6]**
		a	**b**	**c**	**Final score**	**a**	**b**	**c**	**Final score (as published)**	**Category (as published)[2]**	**Final score – no conservation score[3]**	**Category - no conservation score[4]**			
Greater scaup	**	4	4	11	18	4	4	10	16	M	**16**	H			****
Common eider	*	3	4	13	16	3	4	12	14	M	**12**	M			***
Long-tailed duck	**	3	4	8	10	3	4	7	8	L	**12**	M	SD(1)		***
Common scoter	**	5	4	12	24	5	4	12	24	H	**20**	H	NR(1)		****
Velvet scoter	**	5	3	11	17	5	3	11	16	M	**15**	M			***
Common goldeneye	*	4	4	12	19	4	4	11	18	M	**16**	H			****
Red-breasted merganser	*					3	4	8	10	M	**12**	M			***
Goosander						4	4	9	14	M	**16**	H			****
Red-throated diver	***	5	4	16	32	5	4	16	32	H	**20**	H	SD(1),WD(2)[7]		****
Black-throated diver	***	5	4	16	32	5	4	15	30	H	**20**	H			****
Great northern diver	***	5	3	18	27	5	3	15	22	H	**15**	M			***
White-billed diver						5	4	7	14	M	**20**	H			****
Northern fulmar	*	1	1	16	2	1	1	13	1	VL	**1**	VL			*
Cory's shearwater	*					1	1	12	1	VL	**1**	VL			*

Species	Langston (2010)	Furness *et al.* (2013)[1]				Bradbury *et al.* (2014)[1]							Furness. (2013) review of post consent monitoring reports [5]	Cook *al.* (2014) review of post consent monitoring reports	Final Displacement Score[6]
		a	b	c	Final score	a	b	c	Final score (as published)	Category (as published) [2]	Final score – no conservation score [3]	Category - no conservation score[4]			
Great shearwater	*					1	1	8	1	VL	**1**	VL			*
Sooty shearwater	*	1	1	12	1	1	1	13	1	VL	**1**	VL			*
Manx shearwater	*	1	1	17	2	1	1	13	1	VL	**1**	VL			*
Balearic shearwater	*					1	1	17	2	VL	**1**	VL			*
Wilson's storm-petrel						1	1	7	1	VL	**1**	VL			*
European storm-petrel	*	1	1	17	2	1	1	14	1	VL	**1**	VL			*
Leach's storm-petrel	*	1	1	16	2	1	1	14	1	VL	**1**	VL			*
Northern gannet	*	2	1	17	3	2	1	16	3	VL	**2**	VL	WD(2),NR(2)	D(2),NR (2)	*
Great cormorant	*	4	3	11	13	4	3	10	12	M	**12**	M	A(2)		***
Shag	**	3	3	15	14	3	3	13	12	M	**9**	L			**
Great crested grebe		3	4	7	8	3	4	7	8	L	**12**	M			***
Slavonian grebe	**	3	4	13	16	3	4	13	16	M	**12**	M			***
Red-necked phalarope						1	2	12	2	VL	**2**	VL			*
Grey phalarope						1	2	4	1	VL	**2**	VL			*
Pomarine skua	*					1	2	8	2	VL	**2**	VL			*
Arctic skua	*	1	2	14	3	1	2	14	3	VL	**2**	VL			*
Long-tailed skua	*					1	2	7	1	VL	**2**	VL			*
Great skua	*	1	2	16	3	1	2	16	3	VL	**2**	VL			*
Sabine's gull						2	3	6	4	VL	**6**	L			**

Species	Langston (2010)	Furness *et al.* (2013)[1]				Bradbury *et al.* (2014)[1]							Furness. (2013) review of post consent monitoring reports[5]	Cook *al.* (2014) review of post consent monitoring reports	Final Displacement Score[6]
		a	b	c	Final score	a	b	c	Final score (as published)	Category (as published)[2]	Final score – no conservation score[3]	Category - no conservation score[4]			
Black-legged kittiwake	*	2	2	14	6	2	2	12	5	VL	**4**	VL	NR(3), A(1)	NR(2), A(1)	*
Black-headed gull	*	2	2	12	5	2	2	15	6	L	**4**	VL			*
Little gull	*					1	3	13	4	VL	**3**	VL			*
Mediterranean gull	*					2	2	13	5	VL	**4**	VL			*
Common gull	*	2	2	13	5	2	2	15	6	L	**4**	VL	NR(2), A(1)		*
Lesser black-backed gull	*	2	1	16	3	2	1	16	3	VL	**2**	VL	NR(3)	D(1),A(1)	*
Herring gull	*	2	1	16	3	2	1	18	4	VL	**2**	VL	NR(5)	D(2),A(1)	*
Iceland gull	*					2	1	10	2	VL	**2**	VL			*
Glaucous gull	*					2	1	10	2	VL	**2**	VL			*
Great black-backed gull	*	2	2	15	6	2	2	14	6	L	**4**	VL	NR (2), A(1)	D(1), A(1)[8]	*
Little tern	*	2	4	13	10	2	4	16	13	M	**8**	L			**
Black tern						2	3	13	8	L	**6**	L			**
Sandwich tern	*	2	3	15	9	2	3	17	10	M	**6**	L	NR(2), A(1)[7]		**
Common tern	*	2	3	14	8	2	3	14	8	L	**6**	L			**
Roseate tern	*	2	3	15	9	2	3	16	10	M	**6**	L			**
Arctic tern	*	2	3	17	10	2	3	14	8	L	**6**	L			**
Common guillemot	**	3	3	16	14	3	3	14	13	M	**9**	L	MD(1),WD(2) , NR(1)		**
Razorbill	**	3	3	16	14	3	3	14	13	M	**9**	L	WD(1),NR(3)		**

Species	Langston (2010)	Furness *et al.* (2013)[1]				Bradbury *et al.* (2014)[1]							Furness. (2013) review of post consent monitoring reports [5]	Cook *al.* (2014) review of post consent monitoring reports	Final Displacement Score[6]
		a	b	c	Final score	a	b	c	Final score (as published)	Category (as published) [2]	Final score – no conservation score [3]	Category - no conservation score[4]			
Black guillemot	**	3	4	13	16	3	4	10	12	M	**12**	M			***
Little auk	**	2	2	9	4	2	2	9	4	VL	**4**	VL			*
Atlantic puffin	**	2	3	16	10	2	3	14	8	L	**6**	L			**

[1] Codes used in Furness *et al.* (2013) and Bradbury *et al.* (2014) are as follows: a = disturbance susceptibility; b =habitat specialisation; c = conservation importance score.

[2] Where VL = Very Low; L = Low; M = Moderate H = High. Note there was no category of Very High for displacement used by Bradbury *et al.* (2014).

[3] Numerical Collision Risk Score recalculated as = a x b.

[4] Category score recalculated as: Very Low (VL) = ≥5; Low (L) = >5 to≤ 10; Moderate (M) = >10 to≤ 15; High (H) = >15. Following Bradbury *et al.* (2014) there was no category of VL>.

[5] Additional information from Furness (2013) and Cook *et al*. (2014) is provided (SD = strong displacement, WD = weak displacement, NR = no response and A = Attraction. Number of studies is given in parentheses). Note that Furness (2013) treated all divers and all terns collectively.

[6] Divers, tern species treated collectively.

Table C. Summary of barrier effect scores as extracted from Langston (2010) – no information was available from Bradbury *et al.* (2014) or Furness (2013). Additional information from Cook *et al.* (2014) also provided. Grey cells indicate a lack of available data.

Species	Langston (2010)	Cook *et al*. (2014) review of post consent monitoring of barrier effects (macro-avoidance rates derived given in parentheses)	Final Barrier Score
Greater scaup	**		**
Common eider	**	(0.78 or 0.63-0.83)	**
Long-tailed duck	**		**
Common scoter	**	(0.71 - 0.86)	**
Velvet scoter	**		**
Common goldeneye	**		**
Red-breasted merganser	**		**
Goosander			
Red-throated diver	**	(0.68 divers)	**
Black-throated diver	**	(0.68 divers)	**
Great northern diver	**	(0.68 divers)	**
White-billed diver			
Northern fulmar	**		**
Cory's shearwater			
Great shearwater			
Sooty shearwater			
Manx shearwater	**		**
Balearic shearwater	**		**
Wilson's storm-petrel			
European storm-petrel	**		**
Leach's storm-petrel	**		**
Northern gannet	*	(0.64) [1]	*
Great cormorant	**		**
Shag	**		**

Species	**Langston (2010)**	**Cook *et al*. (2014) review of post consent monitoring of barrier effects (macro-avoidance rates derived given in parentheses)**	**Final Barrier Score**
Great crested grebe			
Slavonian grebe			
Red-necked phalarope			
Grey phalarope			
Pomarine skua	*	(0.28 skuas)	*
Arctic skua	*	(0.28 skuas)	*
Long-tailed skua	*	(0.28 skuas)	*
Great skua	*	(0.28 skuas)	*
Sabine's Gull			
Black-legged kittiwake	*	(0.18 gulls)	*
Black-headed gull	*	(0.18 gulls)	*
Little gull	*	(0.18 gulls)	*
Mediterranean gull	*	(0.18 gulls)	*
Common gull	*	(0.18 gulls)	*
Lesser black-backed gull	*	(0.18 gulls)	*
Herring gull	*	(0.18 gulls)	*
Iceland gull	*	(0.18 gulls)	*
Glaucous gull	*	(0.18 gulls)	*
Great black-backed gull	*	(0.18 gulls)	*
Little tern	*	(0.28 terns)	*
Black tern			
Sandwich tern	*	(0.28 terns)	*
Common tern	*	(0.28 terns)	*
Roseate tern	*	(0.28 terns)	*
Arctic tern	*	(0.28 terns)	*
Common guillemot	**	(0.68 alcids)	**
Razorbill	**	(0.68 alcids)	**

Species	Langston (2010)	Cook *et al*. (2014) review of post consent monitoring of barrier effects (macro-avoidance rates derived given in parentheses)	Final Barrier Score
Black guillemot	**	(0.68 alcids)	**
Little auk	**	(0.68 alcids)	**
Atlantic puffin	**	(0.68 alcids)	**

[1] The methodology used may not have distinguished barrier effects from displacement – see Cook *et al.* (2014).