Dublin Array
Generation for generations

# EIAR Volume 4: Offshore Infrastructure Technical Appendices
# Appendix 4.3.6-6 Displacement Matrices

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# Dublin Array Offshore Wind Farm

## Environmental Impact Assessment Report

### Volume 4, Appendix 3.6-6 – Displacement Matrices

# Contents



# Tables

# Acronyms

| Term | Definition |
|---|---|
| BDMPS | Biologically Defined Minimum Population Scales |
| Km | Kilometre |
| NPWS | National Parks and Wildlife Service |
| OWEZ | Windpark Egmond aan Zee |
| OWF | Offshore Wind Farm |
| SNCBs | Statutory Nature Conservation Bodies |
| UK | United Kingdom |

# 1 Introduction

1.1.1 The methodology for assessing displacement and barrier effects in this assessment was based on the guidance document prepared by the UK Statutory Nature Conservation Bodies (SNCBs) (SNCBs, 2022a&b). This guidance document outlines how to present assessment information on the extent and potential consequences of seabird displacement from Offshore Wind Farm (OWF) developments, and was originally produced in January 2017, with an updated version published in January 2022. This approach has been applied to assess displacement and barrier effects on seabirds for several recent offshore wind farm projects.

1.1.2 Displacement has been defined as 'a reduced number of birds occurring within or immediately adjacent to an offshore wind farm' (Furness *et al*., 2013). As defined in the guidance, both flying birds and birds on the water are considered in this displacement assessment. In addition, displacement and barrier effects have been considered together in this assessment, as recommended by the guidance (SNCBs, 2022a&b).

1.1.3 Displacement effects for breeding seabirds are more likely to be observed as changes in productivity as opposed to survival rates (Humphreys *et al.,* 2015). Seabirds experiencing challenging conditions are more likely to abandon the current breeding attempt before compromising their own survival (Furness *et al.*, 2013), although it is likely that stressed birds could go into the wintering period in poor body condition and hence may be susceptible to higher mortality effects as a result.

1.1.4 There is also the potential for displacement effects to have direct consequences for wintering birds if they are displaced from high quality habitat by the presence of an offshore wind farm. In this scenario, birds may have to redistribute to poorer quality habitat which may result in poorer body condition leading to lower over-winter survival rates or potentially reduced breeding success in the subsequent year. However, it is considered that this scenario is unlikely to occur as outside the breeding season seabirds do not have to regularly return to a colony and so are able to move to greater distances to suitable foraging areas, thus avoiding displacement effects.

1.1.5 Depending on the season and species involved, different methods have been applied during the assessment; these are outlined further below.

1.1.6 The SNCB guidance recommends assessing the impacts of displacement based on the overall mean seasonal peak numbers of birds (averaged over the years of survey) in the development footprint and an appropriate buffer (SNCBs, 2022a&b). For this assessment, where possible, numbers of birds in the array area and the Buffer Area were estimated for each month, and then divided by the number of surveys undertaken for that month over the two survey periods (2016-2017 and 2019-2021) to give the mean estimated number per month (See Section 2.5). The mean peak number per season was then used for the displacement assessment.

1.1.7 Sensitivity to displacement differs considerably between seabird species. The SNCB guidance contains a table of species ranked from 1 to 5 according to their sensitivity to disturbance and also the degree of habitat specialization (with 5 being the most sensitive), based on previous reviews e.g. Furness *et al*., (2013) and Bradbury *et al*., (2014). This table has been reproduced here for the species that were regularly recorded on baseline surveys in the Study area (Table 1). The guidance recommends that as a general guide, any species scoring three or more under either category in Table 1, and which is present in the offshore wind farm site or buffer should be progressed to the matrix stage unless there is strong empirical evidence to the contrary. Although scores for gannet are less than three for both categories, SNCB guidance states that gannet should be included in the displacement assessment, as there are empirical studies demonstrating they are sensitive to displacement and barrier effects (e.g. Krijgsveld *et al*., 2011, Vanermen *et al*., 2013).

Table 1 'Disturbance Sensitivity' and 'Habitat Specialization' scores from Bradbury *et al.* (2014) for species that were recorded regularly on baseline surveys in the Dublin Array Study Area

| Species | Disturbance Susceptibility | Habitat Specialisation |
|---|---|---|
| Common Scoter | 5 | 4 |
| Red-throated Diver | 5 | 4 |
| Great Northern Diver | 5 | 3 |
| Cormorant | 4 | 3 |
| Black Guillemot | 3 | 4 |
| Shag | 3 | 3 |
| Guillemot | 3 | 3 |
| Razorbill | 3 | 3 |
| Little Tern | 2 | 4 |
| Sandwich Tern | 2 | 3 |
| Roseate Tern | 2 | 3 |
| Common Tern* | 2 | 3 |
| Arctic Tern | 2 | 3 |
| Puffin | 2 | 3 |
| Mediterranean Gull | 2 | 2 |
| Common Gull | 2 | 2 |
| Great Black-backed Gull | 2 | 2 |
| Kittiwake | 2 | 2 |
| Gannet | 2 | 1 |
| Lesser Black-backed gull | 2 | 1 |
| Herring Gull | 2 | 1 |

| Species | Disturbance Susceptibility | Habitat Specialisation |
|---|---|---|
| Black-headed Gull | 1 | 3 |
| Arctic Skua | 1 | 2 |
| Great Skua | 1 | 2 |
| Fulmar | 1 | 1 |
| Manx shearwater | 1 | 1 |

** Common tern is not listed in the SNCB Guidance species sensitivity table but has been included here with the same scores as other tern species*

1.1.8 Using this approach, it was determined that 15 species should be considered for the displacement assessment: common scoter, red-throated diver, great northern diver, cormorant, shag, black guillemot, guillemot, razorbill, puffin, black-headed gull, little tern, Sandwich tern, roseate tern, common tern and Arctic tern.

1.1.9 In addition, based on the NPWS response (ABPmer, 2023) to the Phase 1 East Coast Developers Methodology document submitted in December 2022 (GoBe, 2022), it was decided to include kittiwake and Manx shearwater in the displacement assessment. Although neither species have high rankings for disturbance susceptibility or habitat specialisation as defined in the SNCB guidance (SNCBs, 2022a&b), both species were assessed for potential displacement effects following the precautionary principle, as recommended in the NPWS response.

1.1.10 Sufficient numbers to conduct a Distance analysis were only recorded on Dublin Array baseline surveys for six species; Manx shearwater, gannet, shag, kittiwake, guillemot and razorbill. This means that it was only possible to assess displacement impacts using the SNCB approach on these six species, as the remaining species were not recorded in high enough numbers to estimate monthly numbers in the Study area.

1.1.11 For the remaining species, displacement impacts are assessed in the EIAR chapter using a qualitative approach, based on the numbers and distribution recorded on baseline surveys, other published survey data and available published evidence from other offshore wind farm projects. As such, they are not considered further within this report.

1.1.12 Seabird species that are susceptible to displacement from offshore wind farms may not only be displaced from the development footprint itself but also from the surrounding area (or buffer zone). SNCB guidance recommends that the additional area beyond the development footprint must also be considered in the displacement assessment. For the majority of species, a standard displacement buffer of two km is recommended, with a four km buffer applied for divers and sea ducks.

1.1.13 The SNCB guidance then recommends that the full range of potential displacement (from 0% to 100% of the mean seasonal peak bird numbers observed pre-construction) is presented within a 'Matrix Approach', using 10% intervals. These tables should be presented as array area only and array area plus an appropriate buffer. For the species within this appendix, the appropriate buffer is 2km.

1.1.14 Mortality of displaced adult birds is also required to be presented in the matrix approach, with the presentation of 0-100% mortality of displaced birds, again presented in 10% increments. It is also considered appropriate to have a finer gradation of percentage mortality impacts at the lower range of this scale e.g. 1% intervals between 0% and 10%. Potential reduction in productivity of breeding birds was not considered in this assessment, as recommended in the SNCB guidance, due to the lack of empirical evidence on the consequences of displacement on breeding seabirds.

1.1.15 The SNCB guidance also recommends that mean seasonal peak abundance is used to produce, as a minimum, two seasonal matrices covering the breeding and non-breeding seasons. For some species e.g. guillemot and razorbill, it may also be appropriate to present seasonal matrices for the post-breeding season. The definition of the breeding and non-breeding seasons was based on definitions published by Furness (2015). Where appropriate, the non-breeding season was further broken down into autumn and spring migration periods as defined in Furness (2015). Where months were listed in both breeding and non-breeding seasons, it was decided that the breeding season would take precedence, as birds are generally more sensitive to displacement effects in the breeding season, when they are typically central place foragers, tied to the breeding colony or nest.

1.1.16 Displacement impacts were assessed based on the peak monthly total per season in the array area and in the array area and 2 km buffer. For each species, a range of potential displacement rates is presented as matrix tables from 0% to 100% in 10% intervals), based on the mean seasonal peak estimated numbers from baseline surveys. Similarly, a range of mortality values are also presented, from 0% to 10% and then in 10% intervals to 100%.

1.1.17 Values are presented for the array area and the array area plus a 2 km buffer, as recommended in the SNCB guidance (2022a&b).

# 2 Displacement Matrices for Dublin Array

## 2.1 Manx Shearwater

2.1.1 There were sufficient sightings of Manx shearwaters on the water to run a Distance analysis on both the 2016-2017 and 2019-2021 datasets, therefore the Manx shearwater displacement assessment is based on the Distance analysis of the 2016-2017 and 2019-2021 data for birds on the water and flying birds. A more detailed breakdown of monthly numbers of birds on the water and in flight is presented in the Offshore and Intertidal Ornithology Technical Baseline. The breeding season for Manx shearwater has been defined as April to August (Furness, 2015). Furness (2015) considered that in addition to the breeding season there were two biologically defined minimum population scales (BDMPS) periods for Manx shearwater; autumn migration (August to early October) and spring migration (late March to May).

2.1.2 Monthly peak estimated numbers of Manx shearwaters in the array area and the array area plus 2 km buffer between January and December are presented in Table 2. In the breeding season (April to August), the peak mean estimated number of Manx shearwaters in the array area was 794 birds in April, while the peak mean estimated number of Manx shearwaters in the array area plus the 2 km buffer was 2,198 birds in April.

Table 2 Estimated monthly numbers of Manx shearwaters in the array area only, and in the array area plus 2 km buffer area, based on data from 2016-2017 and 2019-2021 surveys

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Array area only | | | | | | | | | | | | |
| Lower | 0 | 0 | 0 | 317 | 42 | 109 | 107 | 6 | 52 | 0 | 0 | 0 |
| Mean | 0 | 0 | 2 | 794 | 114 | 241 | 270 | 37 | 96 | 0 | 0 | 0 |
| Upper | 0 | 0 | 6 | 1,966 | 295 | 526 | 679 | 198 | 159 | 0 | 0 | 0 |
| Array area & 2 km Buffer | | | | | | | | | | | | |
| Lower | 0 | 0 | 1 | 881 | 99 | 320 | 292 | 51 | 86 | 0 | 0 | 0 |
| Mean | 0 | 0 | 4 | 2,198 | 293 | 682 | 733 | 148 | 176 | 2 | 0 | 0 |
| Upper | 0 | 0 | 16 | 5,403 | 785 | 1,464 | 1,834 | 587 | 312 | 5 | 0 | 0 |

2.1.3 In the autumn migration period of the non-breeding season (September to early October), mean estimated numbers were lower, with a peak mean estimated number of 96 birds in the array area in September. In the array area and 2 km buffer, the peak mean estimated number of Manx shearwaters was 176 birds in September (Table 2).

2.1.4 In the spring migration period of the non-breeding season (late March), mean estimated numbers were much lower, with a peak mean estimated number of two birds in the array area in March. In the array area and 2 km buffer, the peak mean estimated number of Manx shearwaters was four birds in March (Table 2).

2.1.5 These peak estimated means were taken as the maximum number of Manx shearwaters in the array area and the array area and 2 km buffer for the breeding and non-breeding seasons. These figures were then used in the Displacement matrices produced for this assessment (Table 3 to Table 8).

2.1.6 Post-construction studies in Europe indicate that Manx shearwaters may be likely to exhibit weak avoidance of offshore wind farms. Dierschke *et al*. (2016) concluded that although Manx shearwaters have been observed inside operating wind farms in the Celtic Sea, there is limited data on this species. Bradbury *et al.,* (2014) ranked Manx shearwater as having “very low” population vulnerability to displacement.

2.1.7 The lack of available evidence of displacement effects was also highlighted in a recent review of the risk of collision and displacement in petrels and shearwaters from offshore wind developments in Scotland (Deakin, *et al.,* 2022). This review concluded that while Manx shearwaters are generally thought to have a low vulnerability to displacement and barrier effects, there is the potential for displacement effects to occur.

2.1.8 Based on the limited available evidence from existing offshore wind farm studies, and published reviews indicating a weak avoidance of offshore wind farms, it has been assumed for this assessment that 30% of Manx shearwaters will be displaced from the array area. Although displacement is considered likely to be less than 30% for Manx shearwaters in the surrounding 2 km buffer area, it has also been assumed that 30% of Manx shearwaters will be displaced from the 2 km buffer area. The 30% displacement row has been highlighted in Table 3 to Table 8.

2.1.9 Based on the species very large foraging range and the likely weak avoidance of offshore wind farms, it is considered unlikely that there will be any mortality resulting from displacement from the array area and the 2 km buffer, as displaced birds would be able to forage elsewhere in the Irish Sea. However, for the purposes of this assessment, it has been assumed that 1% of all displaced birds from the array area and a 2 km buffer will suffer mortality as a consequence of being displaced.

2.1.10 Mortality rates of 1% to 100% are presented in Table 3 to Table 8, with the assessment mortality rate of 1% highlighted.

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Table 3 Estimated number of Manx shearwaters predicted to be at risk of mortality following displacement from the array area in the breeding season (April to August)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 71 | 79 |
| 20 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 | 16 | 32 | 48 | 64 | 79 | 95 | 111 | 127 | 143 | 159 |
| 30 | **2** | 5 | 7 | 10 | 12 | 14 | 17 | 19 | 21 | 24 | 48 | 71 | 95 | 119 | 143 | 167 | 191 | 214 | 238 |
| 40 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 25 | 29 | 32 | 64 | 95 | 127 | 159 | 191 | 222 | 254 | 286 | 318 |
| 50 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 79 | 119 | 159 | 199 | 238 | 278 | 318 | 357 | 397 |
| 60 | 5 | 10 | 14 | 19 | 24 | 29 | 33 | 38 | 43 | 48 | 95 | 143 | 191 | 238 | 286 | 333 | 381 | 429 | 476 |
| 70 | 6 | 11 | 17 | 22 | 28 | 33 | 39 | 44 | 50 | 56 | 111 | 167 | 222 | 278 | 333 | 389 | 445 | 500 | 556 |
| 80 | 6 | 13 | 19 | 25 | 32 | 38 | 44 | 51 | 57 | 64 | 127 | 191 | 254 | 318 | 381 | 445 | 508 | 572 | 635 |
| 90 | 7 | 14 | 21 | 29 | 36 | 43 | 50 | 57 | 64 | 71 | 143 | 214 | 286 | 357 | 429 | 500 | 572 | 643 | 715 |
| 100 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 71 | 79 | 159 | 238 | 318 | 397 | 476 | 556 | 635 | 715 | 794 |

Table 4 Estimated number of Manx shearwaters predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the breeding season (April to August)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 2 | 4 | 7 | 9 | 11 | 13 | 15 | 18 | 20 | 22 | 44 | 66 | 88 | 110 | 132 | 154 | 176 | 198 | 220 |
| 20 | 4 | 9 | 13 | 18 | 22 | 26 | 31 | 35 | 40 | 44 | 88 | 132 | 176 | 220 | 264 | 308 | 352 | 396 | 440 |
| 30 | **7** | 13 | 20 | 26 | 33 | 40 | 46 | 53 | 59 | 66 | 132 | 198 | 264 | 330 | 396 | 462 | 528 | 593 | 659 |
| 40 | 9 | 18 | 26 | 35 | 44 | 53 | 62 | 70 | 79 | 88 | 176 | 264 | 352 | 440 | 528 | 615 | 703 | 791 | 879 |
| 50 | 11 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 220 | 330 | 440 | 550 | 659 | 769 | 879 | 989 | 1,099 |
| 60 | 13 | 26 | 40 | 53 | 66 | 79 | 92 | 106 | 119 | 132 | 264 | 396 | 528 | 659 | 791 | 923 | 1,055 | 1,187 | 1,319 |
| 70 | 15 | 31 | 46 | 62 | 77 | 92 | 108 | 123 | 138 | 154 | 308 | 462 | 615 | 769 | 923 | 1,077 | 1,231 | 1,385 | 1,539 |
| 80 | 18 | 35 | 53 | 70 | 88 | 106 | 123 | 141 | 158 | 176 | 352 | 528 | 703 | 879 | 1,055 | 1,231 | 1,407 | 1,583 | 1,758 |
| 90 | 20 | 40 | 59 | 79 | 99 | 119 | 138 | 158 | 178 | 198 | 396 | 593 | 791 | 989 | 1,187 | 1,385 | 1,583 | 1,780 | 1,978 |
| 100 | 22 | 44 | 66 | 88 | 110 | 132 | 154 | 176 | 198 | 220 | 440 | 659 | 879 | 1,099 | 1,319 | 1,539 | 1,758 | 1,978 | 2,198 |

Table 5 Estimated number of Manx shearwaters predicted to be at risk of mortality following displacement from the array area in the autumn migration period of the non-breeding season (September to early October)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 20 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 6 | 8 | 10 | 12 | 13 | 15 | 17 | 19 |
| 30 | **0** | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 6 | 9 | 12 | 14 | 17 | 20 | 23 | 26 | 29 |
| 40 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 8 | 12 | 15 | 19 | 23 | 27 | 31 | 35 | 38 |
| 50 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 10 | 14 | 19 | 24 | 29 | 34 | 38 | 43 | 48 |
| 60 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 12 | 17 | 23 | 29 | 35 | 40 | 46 | 52 | 58 |
| 70 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 7 | 13 | 20 | 27 | 34 | 40 | 47 | 54 | 60 | 67 |
| 80 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 | 15 | 23 | 31 | 38 | 46 | 54 | 61 | 69 | 77 |
| 90 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 17 | 26 | 35 | 43 | 52 | 60 | 69 | 78 | 86 |
| 100 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 19 | 29 | 38 | 48 | 58 | 67 | 77 | 86 | 96 |

Table 6 Estimated number of Manx shearwaters predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the autumn migration period of the non-breeding season (September to early October)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 5 | 7 | 9 | 11 | 12 | 14 | 16 | 18 |
| 20 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 7 | 11 | 14 | 18 | 21 | 25 | 28 | 32 | 35 |
| 30 | **1** | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 11 | 16 | 21 | 26 | 32 | 37 | 42 | 48 | 53 |
| 40 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 |
| 50 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 18 | 26 | 35 | 44 | 53 | 62 | 70 | 79 | 88 |
| 60 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 21 | 32 | 42 | 53 | 63 | 74 | 84 | 95 | 106 |
| 70 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 12 | 25 | 37 | 49 | 62 | 74 | 86 | 99 | 111 | 123 |
| 80 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 | 14 | 28 | 42 | 56 | 70 | 84 | 99 | 113 | 127 | 141 |
| 90 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 | 16 | 32 | 48 | 63 | 79 | 95 | 111 | 127 | 143 | 158 |
| 100 | 2 | 4 | 5 | 7 | 9 | 11 | 12 | 14 | 16 | 18 | 35 | 53 | 70 | 88 | 106 | 123 | 141 | 158 | 176 |

Table 7 Estimated number of Manx shearwaters predicted to be at risk of mortality following displacement from the array area in the spring migration period of the non-breeding season (late March)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 30 | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |

Table 8 Estimated number of Manx shearwaters predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the spring migration period of the non-breeding season (late March)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| | 30 | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 |
| | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
| | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 |

## 2.2 Gannet

2.2.1 There were insufficient sightings of gannets on the water in the 2016-2017 dataset to run a Distance analysis, therefore the gannet displacement assessment is based only on the Distance analysis of the 2019-2021 data for birds on the water, and 2016-2017 and 2019-2021 datasets for flying birds. A more detailed breakdown of monthly numbers of birds on the water and in flight is presented in the Offshore and Intertidal Ornithology Technical Baseline. The breeding season for gannet has been defined as March to September, (Furness, 2015).

2.2.2 Monthly peak estimated numbers of gannets in the array area and array area plus two km buffer between January and December are presented in Table 9. In the breeding season (March to September), the peak mean estimated number of gannets in the array area was 245 birds in May, while the peak mean estimated number of gannets in the array area plus the 2 km buffer was 700 birds in May.

Table 9 Estimated monthly numbers of gannets in the array area only, and in the array area plus 2 km buffer area, based on data from 2016-2017 and 2019-2021 surveys

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Array area only | | | | | | | | | | | | |
| Lower | 0 | 0 | 4 | 32 | 113 | 31 | 41 | 17 | 11 | 3 | 1 | 5 |
| Mean | 8 | 7 | 17 | 88 | 245 | 74 | 94 | 38 | 37 | 10 | 4 | 15 |
| Upper | 22 | 16 | 54 | 221 | 572 | 157 | 208 | 74 | 115 | 22 | 14 | 37 |
| Array area & 2 km Buffer | | | | | | | | | | | | |
| Lower | 0 | 0 | 15 | 107 | 315 | 80 | 113 | 40 | 29 | 6 | 3 | 8 |
| Mean | 9 | 15 | 49 | 269 | 700 | 180 | 259 | 92 | 99 | 21 | 10 | 27 |
| Upper | 25 | 36 | 147 | 637 | 1,627 | 379 | 567 | 185 | 306 | 49 | 37 | 77 |

2.2.3 In the autumn migration period of the non-breeding season (October to November), mean estimated numbers were much lower, with a peak mean estimated number of 10 birds in the array area in October. In the array area and 2 km buffer, the peak mean estimated number of gannets was 21 birds in October (Table 9).

2.2.4 In the spring migration period of the non-breeding season (December to February), mean estimated numbers were also much lower, with a peak mean estimated number of 15 birds in the array area in December. In the array area and 2 km buffer, the peak mean estimated number of gannets was 27 birds in December (Table 9).

2.2.5 These peak estimated means were taken as the maximum number of gannets in the array area and the array area and 2 km buffer for the breeding and non-breeding seasons. These figures were then used in the Displacement matrices produced for this assessment (Table 10 to Table 15).

2.2.6 Post-construction studies in Europe indicate that gannets are likely to exhibit a high degree of avoidance of offshore wind farms. A detailed study using radar and visual observations to monitor the post-construction effects of the Windpark Egmond aan Zee (OWEZ) offshore wind farm in the Netherlands established that 64% of gannets avoided entering the wind farm (Krijgsveld *et al*., 2011). A similar result (80% macro avoidance) was observed during a study at the Thanet wind farm in the UK (Skov *et al*., 2018). Leopold *et al.* (2013) reported that most gannets avoided Dutch offshore wind farms and did not forage within the turbine areas. Dierschke *et al*. (2016) concluded that gannets show high avoidance of offshore wind farms despite showing little avoidance of ships.

2.2.7 Results from the first year of post-construction studies at the Beatrice OWF site in the Moray Firth agreed with previous studies, with gannets demonstrating a high degree of wind turbine avoidance. Statistical analysis showed that while there was no evidence for an overall change in abundance in the study area, there was a very strong and significant spatial effect, with a decline centred on the wind farm. This spatial modelling backed up the more simplistic observations of gannets avoiding the wind farm derived from post-construction digital aerial survey data (MacArthur Green, 2023).

2.2.8 Recent guidance for OWF projects in Scottish waters recommended that a displacement rate of 70% should be used for gannet (Nature Scot, 2023). Based on this, and on available evidence from existing offshore wind farm studies, it has been assumed for this assessment that 70% of gannets will be displaced from the array area. Although displacement is considered likely to be less than 70% for gannets in the surrounding 2 km buffer area, it has also been assumed that 70% of gannets will be displaced from the 2 km buffer area. The 60%-80% displacement rows have been highlighted in Table 10 to Table 15, in line with the agreed east coast method statement (GoBe, 2022), with a displacement rate of 70% displacement being taken through the assessment.

2.2.9 Recent Scoping guidance for OWF projects in Scottish waters recommended that mortality rates of 1% and 3% throughout the year should be used for gannet in displacement assessments (NatureScot, 2023).

2.2.10 However, studies on foraging gannets have shown that they are capable of extending their foraging distances in response to prey distribution, indicating that birds would easily absorb the minor increases in flight distances that a barrier such as an offshore wind farm could cause (Hamer *et al.,* 2007; Hamer *et al*., 2011). In addition, this species was rated as having a low sensitivity to barrier effects by Maclean *et al.* (2009) and Langston (2010). A review by Furness and Wade (2012) concluded that gannets use a wide range of habitats over a large area, usually with a relatively wide range of prey species, and therefore have a high flexibility of habitat use.

2.2.11 In addition, a recent review of gannet displacement and mortality based on evidence from 25 OWFs recommended that a maximum rate of 1% mortality should be used for assessing potential impacts associated with displacement for gannets from OWFs (APEM, 2022).

2.2.12 Based on the above, it is considered unlikely that there will be any mortality resulting from displacement from the array area and the 2 km buffer, as displaced birds would be able to forage elsewhere in the Irish Sea. However, for the purposes of this assessment, it has been assumed that 1% of all displaced birds from the array area and a 2 km buffer will suffer mortality as a consequence of being displaced.

2.2.13 Mortality rates of 1% to 100% are presented in Table 10 to Table 15, with the assessment mortality rate of 1% highlighted.

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Table 10 Estimated number of gannets predicted to be at risk of mortality following displacement from the array area in the breeding season (March to September)

| | | Mortality (%) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 25 |
| | 20 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 10 | 15 | 20 | 25 | 29 | 34 | 39 | 44 | 49 |
| | 30 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 7 | 15 | 22 | 29 | 37 | 44 | 51 | 59 | 66 | 74 |
| | 40 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 29 | 39 | 49 | 59 | 69 | 78 | 88 | 98 |
| | 50 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 12 | 25 | 37 | 49 | 61 | 74 | 86 | 98 | 110 | 123 |
| | 60 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 | 15 | 29 | 44 | 59 | 74 | 88 | 103 | 118 | 132 | 147 |
| | 70 | **2** | 3 | 5 | 7 | 9 | 10 | 12 | 14 | 15 | 17 | 34 | 51 | 69 | 86 | 103 | 120 | 137 | 154 | 172 |
| | 80 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 39 | 59 | 78 | 98 | 118 | 137 | 157 | 176 | 196 |
| | 90 | 2 | 4 | 7 | 9 | 11 | 13 | 15 | 18 | 20 | 22 | 44 | 66 | 88 | 110 | 132 | 154 | 176 | 198 | 221 |
| | 100 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 25 | 49 | 74 | 98 | 123 | 147 | 172 | 196 | 221 | 245 |

Table 11 Estimated number of gannets predicted to be at risk of mortality following displacement from the array area plus 2 buffer in the breeding season (March to September)

| | | Mortality (%) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 |
| | 20 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 | 14 | 28 | 42 | 56 | 70 | 84 | 98 | 112 | 126 | 140 |
| | 30 | 2 | 4 | 6 | 8 | 11 | 13 | 15 | 17 | 19 | 21 | 42 | 63 | 84 | 105 | 126 | 147 | 168 | 189 | 210 |
| | 40 | 3 | 6 | 8 | 11 | 14 | 17 | 20 | 22 | 25 | 28 | 56 | 84 | 112 | 140 | 168 | 196 | 224 | 252 | 280 |
| | 50 | 4 | 7 | 11 | 14 | 18 | 21 | 25 | 28 | 32 | 35 | 70 | 105 | 140 | 175 | 210 | 245 | 280 | 315 | 350 |
| | 60 | 4 | 8 | 13 | 17 | 21 | 25 | 29 | 34 | 38 | 42 | 84 | 126 | 168 | 210 | 252 | 294 | 336 | 378 | 420 |
| | 70 | **5** | 10 | 15 | 20 | 25 | 29 | 34 | 39 | 44 | 49 | 98 | 147 | 196 | 245 | 294 | 343 | 392 | 441 | 490 |
| | 80 | 6 | 11 | 17 | 22 | 28 | 34 | 39 | 45 | 50 | 56 | 112 | 168 | 224 | 280 | 336 | 392 | 448 | 504 | 560 |
| | 90 | 6 | 13 | 19 | 25 | 32 | 38 | 44 | 50 | 57 | 63 | 126 | 189 | 252 | 315 | 378 | 441 | 504 | 567 | 630 |
| | 100 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 140 | 210 | 280 | 350 | 420 | 490 | 560 | 630 | 700 |

Table 12 Estimated number of gannets predicted to be at risk of mortality following displacement from the array area in the autumn migration period of the non-breeding season (October to November)

| | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Displacement (%)** | | | | | | | | | | | | | | | | | | | |
| **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 |
| 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |
| 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 | 6 |
| 70 | **0** | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 |
| 80 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 90 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 | 9 |
| 100 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

Table 13 Estimated number of gannets predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the autumn migration period of the non-breeding season (October to November)

| | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Displacement (%)** | | | | | | | | | | | | | | | | | | | |
| **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 | 4 |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 6 |
| 40 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 8 |
| 50 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 11 |
| 60 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 | 13 |
| 70 | **0** | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 | 15 |
| 80 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 5 | 7 | 8 | 10 | 12 | 13 | 15 | 17 |
| 90 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 6 | 8 | 9 | 11 | 13 | 15 | 17 | 19 |
| 100 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 6 | 8 | 11 | 13 | 15 | 17 | 19 | 21 |

Table 14 Estimated number of gannets predicted to be at risk of mortality following displacement from the array area in the spring migration period of the non-breeding season (December to February)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Displacement (%) | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 |
| | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 | 6 |
| | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| | 60 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 | 9 |
| | 70 | **0** | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 11 |
| | 80 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 |
| | 90 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 11 | 12 | 14 |
| | 100 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 15 |

Table 15 Estimated number of gannets predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the spring migration period of the non-breeding season (December to February)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Displacement (%) | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 |
| | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |
| | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| | 40 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| | 50 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 11 | 12 | 14 |
| | 60 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 15 | 16 |
| | 70 | **0** | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 6 | 8 | 9 | 11 | 13 | 15 | 17 | 19 |
| | 80 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 4 | 6 | 9 | 11 | 13 | 15 | 17 | 19 | 22 |
| | 90 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 19 | 22 | 24 |
| | 100 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 5 | 8 | 11 | 14 | 16 | 19 | 22 | 24 | 27 |

## 2.3 Shag

2.3.1 There were sufficient sightings of shags on the water to run a Distance analysis on both the 2016-2017 and 2019-2021 datasets, therefore the shag displacement assessment is based on the Distance analysis of the 2016-2017 and 2019-2021 data for birds on the water and flying birds. A more detailed breakdown of monthly numbers of birds on the water and in flight is presented in the Offshore and Intertidal Ornithology Technical Baseline. The breeding season for shag has been defined as February to August (Furness, 2015), and this period has been used, on the basis that there is a large variation in the breeding season for this species.

2.3.2 Monthly peak estimated numbers of shags in the array area and array area plus 2 km buffer between January and December are presented in Table 16. In the breeding season (February to August), the peak mean estimated number of shags in the array area was 156 birds in August, while the peak mean estimated number of shags in the array area plus the 2 km buffer was 295 birds in July.

Table 16 Estimated monthly numbers of shags in the array area only, and in the array area plus 2 km buffer area, based on data from 2016-2017 and 2019-2021 surveys

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Array area only | | | | | | | | | | | | |
| Lower | 18 | 22 | 44 | 32 | 23 | 48 | 57 | 74 | 84 | 73 | 91 | 62 |
| Mean | 48 | 55 | 93 | 59 | 57 | 98 | 152 | 156 | 204 | 163 | 231 | 141 |
| Upper | 113 | 133 | 204 | 106 | 131 | 216 | 393 | 332 | 500 | 344 | 576 | 343 |
| Array area & 2 km Buffer | | | | | | | | | | | | |
| Lower | 26 | 38 | 74 | 49 | 35 | 86 | 116 | 130 | 127 | 113 | 148 | 106 |
| Mean | 72 | 93 | 158 | 85 | 85 | 175 | 295 | 275 | 321 | 248 | 373 | 247 |
| Upper | 182 | 224 | 346 | 153 | 202 | 377 | 723 | 582 | 808 | 535 | 942 | 597 |

2.3.3 In the non-breeding season (September to January), mean estimated numbers were higher, with a peak mean estimated number of 231 birds in the array area in November. In the array area and 2 km buffer, the peak mean estimated number of shags was 373 birds in November (Table 16).

2.3.4 These peak estimated means were taken as the maximum number of shags in the array area and the array area and 2 km buffer for the breeding and non-breeding seasons. These figures were then used in the Displacement matrices produced for this assessment (Table 17 to Table 20).

2.3.5 The SNCBs guidance (2022a&b) states that 'Disturbance Susceptibility' scores can be used to determine the appropriate displacement levels on a species-by-species basis. For example, for guillemots and razorbills, the SNCBs would typically advise a displacement level of 30-70% (both species have a 'Disturbance Susceptibility' score of 3, based on Bradbury *et al.*, 2014).

2.3.6 However, recent guidance for OWF projects in Scottish waters recommended a displacement level of 60% for guillemot and razorbill (NatureScot, 2023). This upper limit of 60% displacement could therefore be applied to shags, as all three species have a 'Disturbance Susceptibility' score of 3, based on Bradbury *et al*., (2014). Similarly, JNCC have recommended a displacement level of 40-60% for shags (Busch *et al.,*2015).

2.3.7 Based on these approaches, a range of 40-60% displacement effects has been applied for shags in Table 17 to Table 20. This is considered to be precautionary, given the existing but limited evidence of potential attraction to offshore wind farms for this species.

2.3.8 Although, displacement effects are likely to be lower for birds in the 2 km buffer area around the array area, for this assessment it has also been assumed that 40-60% of shags will be displaced from the 2 km buffer area.

2.3.9 The SNCB guidance does not recommend a specific mortality level to apply for shags in their displacement assessment guidance. The guidance does however suggest that the 'Habitat Specialisation' score from Bradbury *et al.,* (2014) can be useful, when combined with expert opinion, as to the likely range of possible mortality impacts resulting from particular levels of displacement. The habitat specialisation score for shag was three per Bradbury *et al.,* (2014), on a scale of one to five, where five was considered strong anticipated negative impact. Guillemot and razorbill were also given a habitat specialisation score of three by Bradbury *et al.,* (2014). As these three species have the same habitat specialisation score, the same mortality rate of 1% recommended by APEM (2022) for guillemot and razorbill has been applied for shag in this assessment.

2.3.10 Therefore, for the purposes of this assessment, a displacement rate range of 40 to 60% and a mortality rate of 1% are highlighted in each matrix, with the 60% / 1% combination representing a precautionary worst-case scenario. The same scenarios have also been applied for the Array Area plus 2 km buffer.

2.3.11 Mortality rates of 1% to 100% are presented in Table 17 to Table 20, with the assessment mortality rate of 1% highlighted.

.

Table 17 Estimated number of shags predicted to be at risk of mortality following displacement from the array area in the breeding season (February to August)

| | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Displacement (%)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| 10 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 16 |
| 20 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 6 | 9 | 12 | 16 | 19 | 22 | 25 | 28 | 31 |
| 30 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 9 | 14 | 19 | 23 | 28 | 33 | 37 | 42 | 47 |
| 40 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 12 | 19 | 25 | 31 | 37 | 44 | 50 | 56 | 62 |
| 50 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 | 16 | 23 | 31 | 39 | 47 | 55 | 62 | 70 | 78 |
| 60 | **1** | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 9 | 19 | 28 | 37 | 47 | 56 | 66 | 75 | 84 | 94 |
| 70 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 11 | 22 | 33 | 44 | 55 | 66 | 76 | 87 | 98 | 109 |
| 80 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 12 | 25 | 37 | 50 | 62 | 75 | 87 | 100 | 112 | 125 |
| 90 | 1 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 | 14 | 28 | 42 | 56 | 70 | 84 | 98 | 112 | 126 | 140 |
| 100 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 16 | 31 | 47 | 62 | 78 | 94 | 109 | 125 | 140 | 156 |

Table 18 Estimated number of shags predicted to be at risk of mortality following displacement from the array area plus 2 buffer in the breeding season (February to August)

| | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Displacement (%)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| 10 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 |
| 20 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 | 6 | 12 | 18 | 24 | 30 | 35 | 41 | 47 | 53 | 59 |
| 30 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 18 | 27 | 35 | 44 | 53 | 62 | 71 | 80 | 89 |
| 40 | 1 | 2 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 12 | 24 | 35 | 47 | 59 | 71 | 83 | 94 | 106 | 118 |
| 50 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 | 15 | 30 | 44 | 59 | 74 | 89 | 103 | 118 | 133 | 148 |
| 60 | **2** | 4 | 5 | 7 | 9 | 11 | 12 | 14 | 16 | 18 | 35 | 53 | 71 | 89 | 106 | 124 | 142 | 159 | 177 |
| 70 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 17 | 19 | 21 | 41 | 62 | 83 | 103 | 124 | 145 | 165 | 186 | 207 |
| 80 | 2 | 5 | 7 | 9 | 12 | 14 | 17 | 19 | 21 | 24 | 47 | 71 | 94 | 118 | 142 | 165 | 189 | 212 | 236 |
| 90 | 3 | 5 | 8 | 11 | 13 | 16 | 19 | 21 | 24 | 27 | 53 | 80 | 106 | 133 | 159 | 186 | 212 | 239 | 266 |
| 100 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 59 | 89 | 118 | 148 | 177 | 207 | 236 | 266 | 295 |

Table 19 Estimated number of shags predicted to be at risk of mortality following displacement from the array area in the non-breeding season (September to January)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 5 | 7 | 9 | 12 | 14 | 16 | 18 | 21 | 23 |
| | 20 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 9 | 14 | 18 | 23 | 28 | 32 | 37 | 42 | 46 |
| | 30 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 6 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 55 | 62 | 69 |
| | 40 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 18 | 28 | 37 | 46 | 55 | 65 | 74 | 83 | 92 |
| | 50 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 23 | 35 | 46 | 58 | 69 | 81 | 92 | 104 | 116 |
| | 60 | **1** | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 12 | 14 | 28 | 42 | 55 | 69 | 83 | 97 | 111 | 125 | 139 |
| | 70 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 15 | 16 | 32 | 49 | 65 | 81 | 97 | 113 | 129 | 146 | 162 |
| | 80 | 2 | 4 | 6 | 7 | 9 | 11 | 13 | 15 | 17 | 18 | 37 | 55 | 74 | 92 | 111 | 129 | 148 | 166 | 185 |
| | 90 | 2 | 4 | 6 | 8 | 10 | 12 | 15 | 17 | 19 | 21 | 42 | 62 | 83 | 104 | 125 | 146 | 166 | 187 | 208 |
| | 100 | 2 | 5 | 7 | 9 | 12 | 14 | 16 | 18 | 21 | 23 | 46 | 69 | 92 | 116 | 139 | 162 | 185 | 208 | 231 |

Table 20 Estimated number of shags predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the non-breeding season (September to January)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 | 7 | 11 | 15 | 19 | 22 | 26 | 30 | 34 | 37 |
| | 20 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 7 | 15 | 22 | 30 | 37 | 45 | 52 | 60 | 67 | 75 |
| | 30 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 22 | 34 | 45 | 56 | 67 | 78 | 90 | 101 | 112 |
| | 40 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 | 15 | 30 | 45 | 60 | 75 | 90 | 104 | 119 | 134 | 149 |
| | 50 | 2 | 4 | 6 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 37 | 56 | 75 | 93 | 112 | 131 | 149 | 168 | 187 |
| | 60 | **2** | 4 | 7 | 9 | 11 | 13 | 16 | 18 | 20 | 22 | 45 | 67 | 90 | 112 | 134 | 157 | 179 | 201 | 224 |
| | 70 | 3 | 5 | 8 | 10 | 13 | 16 | 18 | 21 | 23 | 26 | 52 | 78 | 104 | 131 | 157 | 183 | 209 | 235 | 261 |
| | 80 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 60 | 90 | 119 | 149 | 179 | 209 | 239 | 269 | 298 |
| | 90 | 3 | 7 | 10 | 13 | 17 | 20 | 23 | 27 | 30 | 34 | 67 | 101 | 134 | 168 | 201 | 235 | 269 | 302 | 336 |
| | 100 | 4 | 7 | 11 | 15 | 19 | 22 | 26 | 30 | 34 | 37 | 75 | 112 | 149 | 187 | 224 | 261 | 298 | 336 | 373 |

## 2.4 Kittiwake

2.4.1 There were sufficient sightings of kittiwakes on the water to run a Distance analysis on both the 2016-2017 and 2019-2021 datasets, therefore the kittiwake displacement assessment is based on the Distance analysis of the 2016-2017 and 2019-2021 data for birds on the water and flying birds. A more detailed breakdown of monthly numbers of birds on the water and in flight is presented in the Offshore and Intertidal Ornithology Technical Baseline. The breeding season for kittiwake has been defined as March to August, although May to July is considered the "migration free" breeding season (Furness, 2015), and that has been applied for the displacement assessment. Furness (2015) considered that for kittiwake outside the breeding season there were two BDMPS periods; autumn migration (August to December) and spring migration (January to April).

2.4.2 Monthly peak estimated numbers of kittiwakes in the array area and the array area plus 2 km buffer between January and December are presented in Table 21.

Table 21 Estimated monthly numbers of kittiwakes in the array area only, and in the array area plus 2 km buffer area, based on data from 2016-2017 and 2019-2021 surveys

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Array area only | | | | | | | | | | | | |
| Lower | 32 | 23 | 112 | 151 | 72 | 76 | 36 | 86 | 100 | 26 | 81 | 104 |
| Mean | 70 | 72 | 247 | 314 | 153 | 191 | 78 | 204 | 227 | 95 | 246 | 268 |
| Upper | 157 | 181 | 528 | 651 | 322 | 470 | 153 | 473 | 551 | 333 | 735 | 701 |
| Array area and 2 km Buffer | | | | | | | | | | | | |
| Lower | 50 | 42 | 324 | 411 | 202 | 284 | 136 | 202 | 212 | 111 | 221 | 274 |
| Mean | 130 | 137 | 709 | 850 | 485 | 622 | 247 | 470 | 538 | 387 | 666 | 749 |
| Upper | 328 | 386 | 1,506 | 1,756 | 1,053 | 1,405 | 437 | 1,108 | 1,394 | 1,116 | 1,979 | 1,965 |

2.4.3 In the migration-free breeding season (May to July), the peak mean estimated number of kittiwakes in the array area was 191 birds in May, while the peak mean estimated number of kittiwakes in the array area plus 2 km buffer was 622 birds in May (Table 21).

2.4.4 In the autumn migration period of the non-breeding season (August to December), mean estimated numbers of kittiwakes were slightly higher, with a peak mean estimated number of 268 birds in the array area in December. In the array area and 2 km buffer, the peak mean estimated number of kittiwakes in the autumn migration period was 749 birds in December (Table 21).

2.4.5 In the spring migration period of the non-breeding season (January to April), mean estimated numbers of kittiwakes reached a peak mean estimated number of 314 birds in the array area in April. In the array area and 2 km buffer, the peak mean estimated number of kittiwakes in the spring migration period was 850 birds in April (Table 21).

2.4.6 These revised peak estimated means were taken as the maximum number of kittiwakes in the array area and in the array area and 2 km buffer for the breeding and non-breeding seasons and were used in the displacement matrices produced for this assessment (Table 22 to Table 27).

2.4.7 There is evidence from other operating OWF projects that displacement of kittiwakes is not likely to occur to any significant level. A review of post-construction studies of seabirds at OWFs in European waters concluded that kittiwake was one of the species which were hardly affected by OWFs or with attraction and avoidance approximately equal over all studies (Dierschke *et al.,* 2016).

2.4.8 More recently, post-construction monitoring studies at Beatrice OWF concluded that there was no overall significant change in kittiwake abundance between pre-construction and post-construction surveys. Within the wind farm, kittiwakes were more abundant on post-construction surveys than on pre-construction surveys. Results from spatial modelling of the pre and post-construction survey data indicated that there was a significant redistribution effect for kittiwakes, but no overall change in abundance (MacArthur Green, 2021).

2.4.9 Analysis was also conducted of the distribution of kittiwakes within Beatrice OWF, comparing the observed bird densities around turbines with randomised alternative turbine locations, to determine if the observed bird locations are related to turbine locations. This analysis was conducted independently on the data from both post-construction years (2019 and 2021) and also took rotor speed into account. The results of the analysis showed that kittiwakes did not avoid turbines at Beatrice OWF, irrespective of the turbine operational status (MacArthur Green, 2023).

2.4.10 Recent guidance from NatureScot for OWF projects in Scottish waters recommended that a displacement rate of 30% should be used for kittiwake (NatureScot, 2023). Although there is evidence from operating OWF projects that kittiwake displacement is not likely to occur to any significant level, a displacement rate of 30% has therefore been used in this assessment.

2.4.11 However, it should be noted that based on available evidence from operating OWF projects, this level of displacement is considered very precautionary. A recent post-construction study at Beatrice Offshore Wind Farm in the Moray Firth concluded that there was no displacement effect for kittiwake, with no significant differences observed between mean density of birds and expected density (Trinder *et al*., 2024).

2.4.12 Recent NatureScot guidance for OWF projects in Scottish waters recommended that mortality rates of 1% and 3% should be used for kittiwake in the breeding and non-breeding seasons (NatureScot, 2023). However, there is no current evidence that kittiwake have suffered mortality from displacement from windfarms. SNCB guidance suggests that the 'Habitat Specialisation' score from Bradbury *et al*. (2014) can be useful, when combined with expert opinion, as to the likely range of possible mortality impacts resulting from particular levels of displacement. The habitat specialisation score for kittiwake was 2 per Bradbury *et al*. (2014), lower than both guillemot and razorbill. As this species has a lower habitat specialisation score, the same mortality rate of 1% recommended by APEM (2022) for guillemot and razorbill has been applied for kittiwake in this assessment, noting this is likely precautionary based on the habitat specialisation score. Moreover, a recent study at Beatrice OWF shows there is also a lack of evidence of displacement (MacArthur Green, 2023, Trinder *et al*., 2024). Therefore, a mortality rate of 1% has been applied for kittiwake in this assessment similarly to the rates suggested for auks in Section 2.5.

2.4.13 Mortality rates of 1% to 100% are presented in Table 22 to Table 27, with the assessment mortality rate of 1% highlighted.

Table 22 Estimated number of kittiwakes predicted to be at risk of mortality following displacement from the array area in the migration-free breeding season (May to July)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Displacement (%) | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | 10 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 6 | 8 | 10 | 11 | 13 | 15 | 17 | 19 |
| | 20 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 8 | 11 | 15 | 19 | 23 | 27 | 31 | 34 | 38 |
| | 30 | **1** | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 11 | 17 | 23 | 29 | 34 | 40 | 46 | 52 | 57 |
| | 40 | 1 | 2 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 | 15 | 23 | 31 | 38 | 46 | 53 | 61 | 69 | 76 |
| | 50 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 19 | 29 | 38 | 48 | 57 | 67 | 76 | 86 | 96 |
| | 60 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 23 | 34 | 46 | 57 | 69 | 80 | 92 | 103 | 115 |
| | 70 | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 11 | 12 | 13 | 27 | 40 | 53 | 67 | 80 | 94 | 107 | 120 | 134 |
| | 80 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 15 | 31 | 46 | 61 | 76 | 92 | 107 | 122 | 138 | 153 |
| | 90 | 2 | 3 | 5 | 7 | 9 | 10 | 12 | 14 | 15 | 17 | 34 | 52 | 69 | 86 | 103 | 120 | 138 | 155 | 172 |
| | 100 | 2 | 4 | 6 | 8 | 10 | 11 | 13 | 15 | 17 | 19 | 38 | 57 | 76 | 96 | 115 | 134 | 153 | 172 | 191 |

Table 23 Estimated number of kittiwakes predicted to be at risk of mortality following displacement from the array area plus 2 buffer in the migration-free breeding season (May to July)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Displacement (%) | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | 10 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 12 | 19 | 25 | 31 | 37 | 44 | 50 | 56 | 62 |
| | 20 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 12 | 25 | 37 | 50 | 62 | 75 | 87 | 100 | 112 | 124 |
| | 30 | **2** | 4 | 6 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 37 | 56 | 75 | 93 | 112 | 131 | 149 | 168 | 187 |
| | 40 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 25 | 50 | 75 | 100 | 124 | 149 | 174 | 199 | 224 | 249 |
| | 50 | 3 | 6 | 9 | 12 | 16 | 19 | 22 | 25 | 28 | 31 | 62 | 93 | 124 | 156 | 187 | 218 | 249 | 280 | 311 |
| | 60 | 4 | 7 | 11 | 15 | 19 | 22 | 26 | 30 | 34 | 37 | 75 | 112 | 149 | 187 | 224 | 261 | 299 | 336 | 373 |
| | 70 | 4 | 9 | 13 | 17 | 22 | 26 | 30 | 35 | 39 | 44 | 87 | 131 | 174 | 218 | 261 | 305 | 348 | 392 | 435 |
| | 80 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 100 | 149 | 199 | 249 | 299 | 348 | 398 | 448 | 498 |
| | 90 | 6 | 11 | 17 | 22 | 28 | 34 | 39 | 45 | 50 | 56 | 112 | 168 | 224 | 280 | 336 | 392 | 448 | 504 | 560 |
| | 100 | 6 | 12 | 19 | 25 | 31 | 37 | 44 | 50 | 56 | 62 | 124 | 187 | 249 | 311 | 373 | 435 | 498 | 560 | 622 |

Table 24 Estimated number of kittiwakes predicted to be at risk of mortality following displacement from the array area in the autumn migration period of the non-breeding season (August to December)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Displacement (%) | 10 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 5 | 8 | 11 | 13 | 16 | 19 | 21 | 24 | 27 |
| | 20 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 11 | 16 | 21 | 27 | 32 | 38 | 43 | 48 | 54 |
| | 30 | **1** | 2 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 |
| | 40 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 | 21 | 32 | 43 | 54 | 64 | 75 | 86 | 96 | 107 |
| | 50 | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 11 | 12 | 13 | 27 | 40 | 54 | 67 | 80 | 94 | 107 | 121 | 134 |
| | 60 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 14 | 16 | 32 | 48 | 64 | 80 | 96 | 113 | 129 | 145 | 161 |
| | 70 | 2 | 4 | 6 | 8 | 9 | 11 | 13 | 15 | 17 | 19 | 38 | 56 | 75 | 94 | 113 | 131 | 150 | 169 | 188 |
| | 80 | 2 | 4 | 6 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 43 | 64 | 86 | 107 | 129 | 150 | 172 | 193 | 214 |
| | 90 | 2 | 5 | 7 | 10 | 12 | 14 | 17 | 19 | 22 | 24 | 48 | 72 | 96 | 121 | 145 | 169 | 193 | 217 | 241 |
| | 100 | 3 | 5 | 8 | 11 | 13 | 16 | 19 | 21 | 24 | 27 | 54 | 80 | 107 | 134 | 161 | 188 | 214 | 241 | 268 |

Table 25 Estimated number of kittiwakes predicted to be at risk of mortality following displacement from the array area plus 2 buffer in the autumn migration period of the non-breeding season (August to December)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Displacement (%) | 10 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 | 7 | 15 | 22 | 30 | 37 | 45 | 52 | 60 | 67 | 75 |
| | 20 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 | 15 | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 |
| | 30 | **2** | 4 | 7 | 9 | 11 | 13 | 16 | 18 | 20 | 22 | 45 | 67 | 90 | 112 | 135 | 157 | 180 | 202 | 225 |
| | 40 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 |
| | 50 | 4 | 7 | 11 | 15 | 19 | 22 | 26 | 30 | 34 | 37 | 75 | 112 | 150 | 187 | 225 | 262 | 300 | 337 | 375 |
| | 60 | 4 | 9 | 13 | 18 | 22 | 27 | 31 | 36 | 40 | 45 | 90 | 135 | 180 | 225 | 270 | 315 | 360 | 404 | 449 |
| | 70 | 5 | 10 | 16 | 21 | 26 | 31 | 37 | 42 | 47 | 52 | 105 | 157 | 210 | 262 | 315 | 367 | 419 | 472 | 524 |
| | 80 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 120 | 180 | 240 | 300 | 360 | 419 | 479 | 539 | 599 |
| | 90 | 7 | 13 | 20 | 27 | 34 | 40 | 47 | 54 | 61 | 67 | 135 | 202 | 270 | 337 | 404 | 472 | 539 | 607 | 674 |
| | 100 | 7 | 15 | 22 | 30 | 37 | 45 | 52 | 60 | 67 | 75 | 150 | 225 | 300 | 375 | 449 | 524 | 599 | 674 | 749 |

Table 26 Estimated number of kittiwakes predicted to be at risk of mortality following displacement from the array area in the spring migration period of the non-breeding season (January to April)

| | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Displacement (%) | 10 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 6 | 9 | 13 | 16 | 19 | 22 | 25 | 28 | 31 |
| | 20 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 6 | 13 | 19 | 25 | 31 | 38 | 44 | 50 | 57 | 63 |
| | 30 | **1** | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 9 | 19 | 28 | 38 | 47 | 57 | 66 | 75 | 85 | 94 |
| | 40 | 1 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 | 13 | 25 | 38 | 50 | 63 | 75 | 88 | 100 | 113 | 126 |
| | 50 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 13 | 14 | 16 | 31 | 47 | 63 | 79 | 94 | 110 | 126 | 141 | 157 |
| | 60 | 2 | 4 | 6 | 8 | 9 | 11 | 13 | 15 | 17 | 19 | 38 | 57 | 75 | 94 | 113 | 132 | 151 | 170 | 188 |
| | 70 | 2 | 4 | 7 | 9 | 11 | 13 | 15 | 18 | 20 | 22 | 44 | 66 | 88 | 110 | 132 | 154 | 176 | 198 | 220 |
| | 80 | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 | 50 | 75 | 100 | 126 | 151 | 176 | 201 | 226 | 251 |
| | 90 | 3 | 6 | 8 | 11 | 14 | 17 | 20 | 23 | 25 | 28 | 57 | 85 | 113 | 141 | 170 | 198 | 226 | 254 | 283 |
| | 100 | 3 | 6 | 9 | 13 | 16 | 19 | 22 | 25 | 28 | 31 | 63 | 94 | 126 | 157 | 188 | 220 | 251 | 283 | 314 |

Table 27 Estimated number of kittiwakes predicted to be at risk of mortality following displacement from the array area plus 2 buffer in the spring migration period of the non-breeding season (January to April)

| | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Displacement (%) | 10 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 17 | 26 | 34 | 43 | 51 | 60 | 68 | 77 | 85 |
| | 20 | 2 | 3 | 5 | 7 | 9 | 10 | 12 | 14 | 15 | 17 | 34 | 51 | 68 | 85 | 102 | 119 | 136 | 153 | 170 |
| | 30 | **3** | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 26 | 51 | 77 | 102 | 128 | 153 | 179 | 204 | 230 | 255 |
| | 40 | 3 | 7 | 10 | 14 | 17 | 20 | 24 | 27 | 31 | 34 | 68 | 102 | 136 | 170 | 204 | 238 | 272 | 306 | 340 |
| | 50 | 4 | 9 | 13 | 17 | 21 | 26 | 30 | 34 | 38 | 43 | 85 | 128 | 170 | 213 | 255 | 298 | 340 | 383 | 425 |
| | 60 | 5 | 10 | 15 | 20 | 26 | 31 | 36 | 41 | 46 | 51 | 102 | 153 | 204 | 255 | 306 | 357 | 408 | 459 | 510 |
| | 70 | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 119 | 179 | 238 | 298 | 357 | 417 | 476 | 536 | 595 |
| | 80 | 7 | 14 | 20 | 27 | 34 | 41 | 48 | 54 | 61 | 68 | 136 | 204 | 272 | 340 | 408 | 476 | 544 | 612 | 680 |
| | 90 | 8 | 15 | 23 | 31 | 38 | 46 | 54 | 61 | 69 | 77 | 153 | 230 | 306 | 383 | 459 | 536 | 612 | 689 | 765 |
| | 100 | 9 | 17 | 26 | 34 | 43 | 51 | 60 | 68 | 77 | 85 | 170 | 255 | 340 | 425 | 510 | 595 | 680 | 765 | 850 |

## 2.5 Guillemot

2.5.1 There were sufficient sightings of guillemots on the water to run a Distance analysis on both the 2016-2017 and 2019-2021 datasets, therefore the guillemot displacement assessment is based on the Distance analysis of the 2016-2017 and 2019-2021 data for birds on the water and flying birds. A more detailed breakdown of monthly numbers of birds on the water and in flight is presented in the Offshore and Intertidal Ornithology Technical Baseline. The breeding season for guillemot has been defined as March to July (Furness, 2015). Furness (2015) considered that outside the breeding season there was one BDMPS period for guillemot; the non-breeding season (August to February).

2.5.2 Monthly peak estimated numbers of guillemots in the array area and the array area plus 2 km buffer between January and December are presented in Table 28.

Table 28 Estimated monthly numbers of guillemots in the array area only, and in the array area plus 2 km buffer area, based on data from 2016-2017 and 2019-2021 surveys

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Array area only | | | | | | | | | | | | |
| Lower | 319 | 142 | 758 | 5,556 | 1,768 | 986 | 972 | 614 | 591 | 243 | 342 | 378 |
| Mean | 504 | 207 | 1,384 | 9,208 | 3,002 | 1,453 | 1,603 | 1,004 | 943 | 421 | 654 | 654 |
| Upper | 797 | 303 | 2,578 | 15,340 | 5,246 | 2,173 | 2,755 | 1,684 | 1,520 | 740 | 1,253 | 1,136 |
| Array area and 2 km Buffer | | | | | | | | | | | | |
| Lower | 556 | 243 | 1,272 | 9,655 | 2,994 | 1,655 | 1,632 | 1,033 | 984 | 409 | 574 | 617 |
| Mean | 946 | 361 | 2,358 | 16,055 | 5,081 | 2,444 | 2,675 | 1,690 | 1,566 | 702 | 1,095 | 1,070 |
| Upper | 1,549 | 531 | 4,423 | 26,692 | 8,857 | 3,662 | 4,596 | 2,832 | 2,525 | 1,231 | 2,097 | 1,866 |

2.5.3 In addition, there were sightings of guillemots/razorbills on baseline surveys that could not be determined to species. Estimated numbers of unidentified guillemots/razorbills were derived from baseline survey data by applying Distance sampling techniques to the 2019-2021 dataset only for birds on the water, as there were insufficient sightings on the water in the 2016-2017 dataset to run a Distance analysis. Both datasets were used for birds in flight. Furthers details are presented in the Offshore and Intertidal Ornithology Technical Baseline.

2.5.4 For the displacement assessment, the ratios of identified guillemots and razorbills were calculated for each month, based on the mean estimate of each species for each month (Table 29).

2.5.5 These ratios were applied to the monthly estimated totals of unidentified guillemots/razorbills (see Offshore and Intertidal Ornithology Technical Baseline), to provide an additional estimate of guillemots from these unidentified birds in the array area. These additional guillemots were then added to the mean monthly estimates of guillemots (Table 30).

Table 29 Ratio of the total number of identified guillemots and razorbills by month in the array area and 4 km buffer from the 2016-2017 and 2019-2021 surveys

| Month | Guillemot | Razorbill | Total | Ratio GU/RA |
|---|---|---|---|---|
| Jan | 2,405 | 230 | 2,635 | 0.91/0.09 |
| Feb | 989 | 126 | 1,115 | 0.89/0.11 |
| Mar | 6,602 | 1,289 | 7,891 | 0.84/0.16 |
| Apr | 43,913 | 583 | 44,496 | 0.99/0.01 |
| May | 14,318 | 936 | 15,254 | 0.94/0.06 |
| Jun | 6,931 | 587 | 7,518 | 0.92/0.08 |
| Jul | 7,643 | 2,346 | 9,989 | 0.77/0.23 |
| Aug | 4790 | 1,972 | 6,762 | 0.71/0.29 |
| Sep | 4,496 | 5,784 | 10,280 | 0.44/0.56 |
| Oct | 2,009 | 275 | 2,284 | 0.88/0.12 |
| Nov | 3,117 | 781 | 3,898 | 0.80/0.20 |
| Dec | 3,119 | 620 | 3,739 | 0.83/0.17 |

Table 30 Estimated numbers of additional guillemots by month in the array area based on 2016-2017 and 2019-2021 surveys

| Month | Unidentified GU/RA | Ratio GU/RA | Additional guillemots | Mean estimated guillemots | Revised monthly mean |
|---|---|---|---|---|---|
| Jan | 3 | 0.91/0.09 | 3 | 504 | 507 |
| Feb | 0 | 0.89/0.11 | 0 | 207 | 207 |
| Mar | 30 | 0.84/0.16 | 25 | 1,384 | 1,409 |
| Apr | 961 | 0.99/0.01 | 951 | 9,208 | 10,159 |
| May | 427 | 0.94/0.06 | 401 | 3,002 | 3,403 |
| Jun | 19 | 0.92/0.08 | 17 | 1,453 | 1,470 |
| Jul | 388 | 0.77/0.23 | 299 | 1,603 | 1,902 |
| Aug | 196 | 0.71/0.29 | 139 | 1,004 | 1,143 |
| Sep | 19 | 0.44/0.56 | 8 | 943 | 951 |
| Oct | 1 | 0.88/0.12 | 1 | 421 | 422 |
| Nov | 1 | 0.80/0.20 | 1 | 654 | 655 |
| Dec | 10 | 0.83/0.17 | 8 | 654 | 662 |

2.5.6 This process was repeated for additional guillemots in the array area and 2km buffer (Table 31).

Table 31 Estimated numbers of additional guillemots by month in the array area and 2 km buffer based on 2016-2017 and 2019-2021 surveys

| Month | Unidentified GU/RA | Ratio GU/RA | Additional guillemots | Mean estimated guillemots | Revised monthly mean |
|---|---|---|---|---|---|
| Jan | 43 | 0.91/0.09 | 39 | 946 | 985 |
| Feb | 0 | 0.89/0.11 | 0 | 361 | 361 |
| Mar | 80 | 0.84/0.16 | 67 | 2,358 | 2,425 |
| Apr | 2,659 | 0.99/0.01 | 2,632 | 16,055 | 18,687 |
| May | 1,146 | 0.94/0.06 | 1,077 | 5,081 | 6,158 |
| Jun | 36 | 0.92/0.08 | 33 | 2,444 | 2,477 |
| Jul | 1,041 | 0.77/0.23 | 802 | 2,675 | 3,477 |
| Aug | 526 | 0.71/0.29 | 373 | 1,690 | 2,063 |
| Sep | 51 | 0.44/0.56 | 22 | 1,566 | 1,588 |
| Oct | 2 | 0.88/0.12 | 2 | 702 | 704 |
| Nov | 2 | 0.80/0.20 | 2 | 1,095 | 1,097 |
| Dec | 39 | 0.83/0.17 | 32 | 1,070 | 1,102 |

2.5.7 In the breeding season (March to July), the peak mean estimated number of guillemots in the array area was 10,159 birds in April (Table 30), while the peak mean estimated number of guillemots in the array area plus 2 km buffer was 18,687 birds in April (Table 31).

2.5.8 In the non-breeding season (August to February), mean estimated numbers of guillemots were lower, with a peak mean estimated number of 1,143 birds in the array area in August (Table 30). In the array area and 2 km buffer, the peak mean estimated number of guillemots in the non-breeding season was 2,063 birds in August (Table 31).

2.5.9 These revised peak estimated means were taken as the maximum number of guillemots in the array area and in the array area and 2 km buffer for the breeding and non-breeding seasons and were used in the displacement matrices produced for this assessment (Table 32 to Table 35).

2.5.10 A review of studies on auk displacement in response to the presence of wind turbines by Dierschke *et al*., (2016) examined results from 13 OWF sites in Europe that compared changes in seabird abundance between baseline and post-construction scenarios. The review concluded that the mean outcome across all 13 OWFs for auks was ‘weak displacement’ but this was highly variable.

2.5.11 The strongest displacement effects were reported for Thorntonbank and Bligh Bank OWFs in Belgian waters, with reductions in density of 68% and 75% for guillemot respectively at these two OWFs. Reported razorbill displacement at these two OWFs was slightly lower, with reductions in density of 55% and 67% respectively (Dierschke *et al*., 2016).

2.5.12 A more recent review considered that the displacement effects reported by Dierschke *et al*., (2016) may be over-estimates. The review considered all OWF post-construction monitoring studies undertaken to date within the North Sea and UK Western Waters and found that results of the post-construction studies varied considerably across the different sites, with one OWF showing positive displacement effects (attraction), eight OWFs with no significant effects or weak displacement effects, three with inferred displacement effects (but not statistically tested) and eight with negative displacement effects (APEM, 2022).

2.5.13 After examining the analysis methods used in these different studies, the APEM (2022) review suggested that not all estimated displacement effects were equally robust, as there were many sites where high displacement rates were predicted that had low or very low auk abundance. The review suggested that for sites with high numbers of zero counts, prediction of likely displacement rates is highly problematic, given the natural spatial and temporal variation in auk abundance and distribution. The review concluded that at such sites, the reported displacement effects are most likely unreliable. One example of this is from the Prinses Amalia and Egmond aan Zee OWFs off the coast of the Netherlands, where significant displacement effects were previously reported. Independent re-analysis of the post-construction data using the statistical package R-INLA did not detect a statistically significant effect (Zuur, 2018). The same study also concluded that previously reported displacement effects at Alpha Ventus, Blighbank, Thorntonbank and Horns Rev OWFs, may also be misleading since there were high numbers of zero observations of guillemots in their datasets which is a major challenge for statistical analysis, requiring advanced statistical methods (Zuur, 2018). These studies make up the majority of reported auk displacement rates of up to 75%. The APEM (2022) review recommended that results from these studies should be regarded with caution and not presented as strong evidence in support of high displacement effects, following the work undertaken by Zuur (2018).

2.5.14 The APEM (2022) review concluded that OWF sites with moderate to high auk abundances (e.g. densities of ≥5/km$^2$), tend to have reported displacement effects that are non-significant or weak. This is based on analysis of post-construction data from UK OWF projects such as Beatrice, Robin Rigg, Westermost Rough, North Hoyle, Lincs and Thanet.

2.5.15 The Year 1 post-construction study report for Beatrice OWF reported that both guillemots and razorbills were more abundant within the wind farm on post-construction surveys than on pre-construction surveys. Results showed that there was a significant increase in the overall guillemot and razorbill abundance post-construction but found that the spatial component of this relationship was not significant. No parts of the study area were found to have significant reductions, but the southern half of the study area had significant increases. Overall, the report concluded that for both guillemot and razorbill, the displacement rates of 30-70% currently used in wind farm assessments are considerably over-estimated, at least in the breeding season for similar wind farms (BOWL, 2021). Results from Year 2 post-construction analyses corroborate the findings of Year 1 (MacArthur Green, 2023). A further analysis of post-construction data at Beatrice Offshore Wind Farm in the Moray Firth concluded that there were no displacement effects for guillemot or razorbill, with no significant differences observed between mean density and expected density of birds (Trinder *et al*., 2024).

2.5.16 The APEM (2022) review concluded that a precautionary approach would be to use a displacement rate of up to 50% for guillemots and razorbills.

2.5.17 Studies investigating potential guillemot and razorbill mortality as a result of displacement from offshore wind turbines are extremely limited. Empirical evidence is anecdotal with implied low additional mortality rates for guillemots breeding on Helgoland in the German North Sea, close to where OWFs have been operating since 2014 (Peschko *et al*., 2020). Displacement rates for guillemots were predicted to be 44% in the breeding season and 63% in the non-breeding season (Peschko *et al*., 2020). Colony counts since 2014 provide supporting evidence that rates of mortality higher than 1% are not apparent, as the number of breeding guillemots remained largely stable between 2000–2018 (Dierschke *et al*., 2011; Dierschke *et al*., 2018).

2.5.18 A review undertaken by Norfolk Vanguard (MacArthur Green 2019) included an investigation on the likely consequences of displacement at the population level. This review concluded that displacement of guillemots and razorbills by OWFs is likely to be incomplete, may reduce with habituation, and that in the long term there may be increased food availability to guillemots and razorbills through providing enhanced habitat for fish populations around OWFs. These factors, together with the very low level of natural mortality of adult guillemots and razorbills (approximately 6% and 10% per annum respectively; Horswill and Robinson, 2015), suggest that impacts of displacement from OWFs are unlikely to represent levels of mortality anywhere close to the 6% or 10% total annual mortality that occurs due to the combination of many natural factors plus existing human activities (MacArthur Green 2019).

2.5.19 Based on the above, it is considered that a displacement rate of 50% and a mortality rate of 1% for the breeding and non-breeding seasons is suitably precautionary for an assessment of displacement effects from Dublin Array on guillemots and razorbills. However, based on guidance from NatureScot (2023), the assessment also includes a displacement rate of 60% and mortality rates of 3% and 5% for the breeding season, and 1% and 3% for the non-breeding season. These rates are also in line with those values discussed and agreed between the east coast Phase 1 developers, and circulated to NPWS in December 2022 (GoBe, 2022)

2.5.20 For the purposes of this assessment, a displacement rate range of 50-60%% is highlighted in each matrix. The same scenarios have also been applied for the array area plus 2 km buffer. Mortality rates of 1% to 100% are presented in Table 32 to Table 35, with the assessment mortality rate of 1%, 3% and 5% highlighted, depending on season.

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Table 32 Estimated number of guillemots predicted to be at risk of mortality following displacement from the array area in the breeding season (March to July)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 10 | 20 | 30 | 41 | 51 | 61 | 71 | 81 | 91 | 102 | 203 | 305 | 406 | 508 | 610 | 711 | 813 | 914 | 1,016 |
| 20 | 20 | 41 | 61 | 81 | 102 | 122 | 142 | 163 | 183 | 203 | 406 | 610 | 813 | 1,016 | 1,219 | 1,422 | 1,625 | 1,829 | 2,032 |
| 30 | 30 | 61 | 91 | 122 | 152 | 183 | 213 | 244 | 274 | 305 | 610 | 914 | 1,219 | 1,524 | 1,829 | 2,133 | 2,438 | 2,743 | 3,048 |
| 40 | 41 | 81 | 122 | 163 | 203 | 244 | 284 | 325 | 366 | 406 | 813 | 1,219 | 1,625 | 2,032 | 2,438 | 2,845 | 3,251 | 3,657 | 4,064 |
| 50 | **51** | 102 | 152 | 203 | 254 | 305 | 356 | 406 | 457 | 508 | 1,016 | 1,524 | 2,032 | 2,540 | 3,048 | 3,556 | 4,064 | 4,572 | 5,080 |
| 60 | 61 | 122 | **183** | 244 | **305** | 366 | 427 | 488 | 549 | 610 | 1,219 | 1,829 | 2,438 | 3,048 | 3,657 | 4,267 | 4,876 | 5,486 | 6,095 |
| 70 | 71 | 142 | 213 | 284 | 356 | 427 | 498 | 569 | 640 | 711 | 1,422 | 2,133 | 2,845 | 3,556 | 4,267 | 4,978 | 5,689 | 6,400 | 7,111 |
| 80 | 81 | 163 | 244 | 325 | 406 | 488 | 569 | 650 | 731 | 813 | 1,625 | 2,438 | 3,251 | 4,064 | 4,876 | 5,689 | 6,502 | 7,314 | 8,127 |
| 90 | 91 | 183 | 274 | 366 | 457 | 549 | 640 | 731 | 823 | 914 | 1,829 | 2,743 | 3,657 | 4,572 | 5,486 | 6,400 | 7,314 | 8,229 | 9,143 |
| 100 | 102 | 203 | 305 | 406 | 508 | 610 | 711 | 813 | 914 | 1,016 | 2,032 | 3,048 | 4,064 | 5,080 | 6,095 | 7,111 | 8,127 | 9,143 | 10,159 |

Table 33 Estimated number of guillemots predicted to be at risk of mortality following displacement from the array area plus 2 buffer in the breeding season (March to July)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 19 | 37 | 56 | 75 | 93 | 112 | 131 | 149 | 168 | 187 | 374 | 561 | 747 | 934 | 1,121 | 1,308 | 1,495 | 1,682 | 1,869 |
| 20 | 37 | 75 | 112 | 149 | 187 | 224 | 262 | 299 | 336 | 374 | 747 | 1,121 | 1,495 | 1,869 | 2,242 | 2,616 | 2,990 | 3,364 | 3,737 |
| 30 | 56 | 112 | 168 | 224 | 280 | 336 | 392 | 448 | 505 | 561 | 1,121 | 1,682 | 2,242 | 2,803 | 3,364 | 3,924 | 4,485 | 5,045 | 5,606 |
| 40 | 75 | 149 | 224 | 299 | 374 | 448 | 523 | 598 | 673 | 747 | 1,495 | 2,242 | 2,990 | 3,737 | 4,485 | 5,232 | 5,980 | 6,727 | 7,475 |
| 50 | **93** | 187 | 280 | 374 | 467 | 561 | 654 | 747 | 841 | 934 | 1,869 | 2,803 | 3,737 | 4,672 | 5,606 | 6,540 | 7,475 | 8,409 | 9,344 |
| 60 | 112 | 224 | **336** | 448 | **561** | 673 | 785 | 897 | 1,009 | 1,121 | 2,242 | 3,364 | 4,485 | 5,606 | 6,727 | 7,849 | 8,970 | 10,091 | 11,212 |
| 70 | 131 | 262 | 392 | 523 | 654 | 785 | 916 | 1,046 | 1,177 | 1,308 | 2,616 | 3,924 | 5,232 | 6,540 | 7,849 | 9,157 | 10,465 | 11,773 | 13,081 |
| 80 | 149 | 299 | 448 | 598 | 747 | 897 | 1,046 | 1,196 | 1,345 | 1,495 | 2,990 | 4,485 | 5,980 | 7,475 | 8,970 | 10,465 | 11,960 | 13,455 | 14,950 |
| 90 | 168 | 336 | 505 | 673 | 841 | 1,009 | 1,177 | 1,345 | 1,514 | 1,682 | 3,364 | 5,045 | 6,727 | 8,409 | 10,091 | 11,773 | 13,455 | 15,136 | 16,818 |
| 100 | 187 | 374 | 561 | 747 | 934 | 1,121 | 1,308 | 1,495 | 1,682 | 1,869 | 3,737 | 5,606 | 7,475 | 9,344 | 11,212 | 13,081 | 14,950 | 16,818 | 18,687 |

Table 34 Estimated number of guillemots predicted to be at risk of mortality following displacement from the array area in the non-breeding season (August to February)

| | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Displacement (%) | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| | **10** | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 23 | 34 | 46 | 57 | 69 | 80 | 91 | 103 | 114 |
| | 20 | 2 | 5 | 7 | 9 | 11 | 14 | 16 | 18 | 21 | 23 | 46 | 69 | 91 | 114 | 137 | 160 | 183 | 206 | 229 |
| | 30 | 3 | 7 | 10 | 14 | 17 | 21 | 24 | 27 | 31 | 34 | 69 | 103 | 137 | 171 | 206 | 240 | 274 | 309 | 343 |
| | 40 | 5 | 9 | 14 | 18 | 23 | 27 | 32 | 37 | 41 | 46 | 91 | 137 | 183 | 229 | 274 | 320 | 366 | 411 | 457 |
| | 50 | **6** | 11 | 17 | 23 | 29 | 34 | 40 | 46 | 51 | 57 | 114 | 171 | 229 | 286 | 343 | 400 | 457 | 514 | 572 |
| | 60 | **7** | 14 | **21** | 27 | 34 | 41 | 48 | 55 | 62 | 69 | 137 | 206 | 274 | 343 | 411 | 480 | 549 | 617 | 686 |
| | 70 | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 160 | 240 | 320 | 400 | 480 | 560 | 640 | 720 | 800 |
| | 80 | 9 | 18 | 27 | 37 | 46 | 55 | 64 | 73 | 82 | 91 | 183 | 274 | 366 | 457 | 549 | 640 | 732 | 823 | 914 |
| | 90 | 10 | 21 | 31 | 41 | 51 | 62 | 72 | 82 | 93 | 103 | 206 | 309 | 411 | 514 | 617 | 720 | 823 | 926 | 1,029 |
| | 100 | 11 | 23 | 34 | 46 | 57 | 69 | 80 | 91 | 103 | 114 | 229 | 343 | 457 | 572 | 686 | 800 | 914 | 1,029 | 1,143 |

Table 35 Estimated number of guillemots predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the non-breeding season (August to February)

| | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Displacement (%) | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| | 10 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 17 | 19 | 21 | 41 | 62 | 83 | 103 | 124 | 144 | 165 | 186 | 206 |
| | 20 | 4 | 8 | 12 | 17 | 21 | 25 | 29 | 33 | 37 | 41 | 83 | 124 | 165 | 206 | 248 | 289 | 330 | 371 | 413 |
| | 30 | 6 | 12 | 19 | 25 | 31 | 37 | 43 | 50 | 56 | 62 | 124 | 186 | 248 | 309 | 371 | 433 | 495 | 557 | 619 |
| | 40 | 8 | 17 | 25 | 33 | 41 | 50 | 58 | 66 | 74 | 83 | 165 | 248 | 330 | 413 | 495 | 578 | 660 | 743 | 825 |
| | 50 | **10** | 21 | 31 | 41 | 52 | 62 | 72 | 83 | 93 | 103 | 206 | 309 | 413 | 516 | 619 | 722 | 825 | 928 | 1,032 |
| | 60 | **12** | 25 | **37** | 50 | 62 | 74 | 87 | 99 | 111 | 124 | 248 | 371 | 495 | 619 | 743 | 866 | 990 | 1,114 | 1,238 |
| | 70 | 14 | 29 | 43 | 58 | 72 | 87 | 101 | 116 | 130 | 144 | 289 | 433 | 578 | 722 | 866 | 1,011 | 1,155 | 1,300 | 1,444 |
| | 80 | 17 | 33 | 50 | 66 | 83 | 99 | 116 | 132 | 149 | 165 | 330 | 495 | 660 | 825 | 990 | 1,155 | 1,320 | 1,485 | 1,650 |
| | 90 | 19 | 37 | 56 | 74 | 93 | 111 | 130 | 149 | 167 | 186 | 371 | 557 | 743 | 928 | 1,114 | 1,300 | 1,485 | 1,671 | 1,857 |
| | 100 | 21 | 41 | 62 | 83 | 103 | 124 | 144 | 165 | 186 | 206 | 413 | 619 | 825 | 1,032 | 1,238 | 1,444 | 1,650 | 1,857 | 2,063 |

## 2.6 Razorbill

2.6.1 There were sufficient sightings of razorbills on the water to run a Distance analysis on both the 2016-2017 and 2019-2021 datasets, therefore the razorbill displacement assessment is based on the Distance analysis of the 2016-2017 and 2019-2021 data for birds on the water and flying birds. A more detailed breakdown of monthly numbers of birds on the water and in flight is presented in the Offshore and Intertidal Ornithology Technical Baseline. The breeding season for razorbill has been defined as April to July (Furness, 2015). Furness (2015) considered that outside the breeding season there were three BDMPS periods for razorbill; autumn migration (August to October), winter (November to December) and spring migration (January to March).

2.6.2 Monthly peak estimated numbers of razorbills in the array area and the array area plus 2 km buffer between January and December are presented in Table 36.

Table 36 Estimated monthly numbers of razorbills in the array area only, and in the array area plus 2 km buffer area, based on data from 2016-2017 and 2019-2021 surveys

| | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Array area only | | | | | | | | | | | | |
| Lower | 20 | 5 | 128 | 67 | 104 | 70 | 222 | 245 | 808 | 25 | 90 | 63 |
| Mean | 48 | 26 | 270 | 122 | 196 | 123 | 492 | 413 | 1,213 | 58 | 164 | 130 |
| Upper | 107 | 123 | 573 | 222 | 371 | 211 | 1,075 | 702 | 1,864 | 125 | 304 | 266 |
| Array area and 2 km Buffer | | | | | | | | | | | | |
| Lower | 34 | 8 | 216 | 122 | 175 | 117 | 377 | 410 | 1,360 | 53 | 149 | 97 |
| Mean | 81 | 44 | 465 | 238 | 335 | 205 | 829 | 690 | 2,041 | 120 | 281 | 204 |
| Upper | 173 | 206 | 996 | 433 | 637 | 350 | 1,809 | 1,173 | 3,134 | 244 | 532 | 426 |

2.6.3 In addition, there were sightings of guillemots/razorbills on baseline surveys that could not be determined to species. Estimated numbers of unidentified guillemots/razorbills were derived from baseline survey data by applying Distance sampling techniques to the 2019-2021 dataset only for birds on the water, as there were insufficient sightings on the water in the 2016-2017 dataset to run a Distance analysis. Both datasets were used for birds in flight. Furthers details are presented in the Offshore and Intertidal Ornithology Technical Baseline.

2.6.4 For the displacement assessment, the ratios of identified guillemots and razorbills were calculated for each month, based on the mean estimate of each species for each month (Table 29).

2.6.5 These ratios were applied to the monthly estimated totals of unidentified guillemots/razorbills (see Offshore and Intertidal Ornithology Technical Baseline), to provide an additional estimate of razorbills from these unidentified birds in the array area (Table 37). These additional razorbills were then added to the mean monthly estimates of razorbills (from Table 36).

Table 37 Estimated numbers of additional razorbills by month in the array area based on 2016-2017 and 2019-2021 surveys

| Month | Unidentified GU/RA | Ratio GU/RA | Additional razorbills | Mean estimated razorbills | Revised monthly mean |
|---|---|---|---|---|---|
| Jan | 3 | 0.91/0.09 | 0 | 48 | 48 |
| Feb | 0 | 0.89/0.11 | 0 | 26 | 26 |
| Mar | 30 | 0.84/0.16 | 5 | 270 | 275 |
| Apr | 961 | 0.99/0.01 | 10 | 122 | 132 |
| May | 427 | 0.94/0.06 | 26 | 196 | 222 |
| Jun | 19 | 0.92/0.08 | 2 | 123 | 125 |
| Jul | 388 | 0.77/0.23 | 89 | 492 | 581 |
| Aug | 196 | 0.71/0.29 | 57 | 413 | 470 |
| Sep | 19 | 0.44/0.56 | 11 | 1,213 | 1,224 |
| Oct | 1 | 0.88/0.12 | 0 | 58 | 58 |
| Nov | 1 | 0.80/0.20 | 0 | 164 | 164 |
| Dec | 10 | 0.83/0.17 | 2 | 130 | 132 |

2.6.6 This process was repeated for additional razorbills in the array area and 2km buffer (Table 38).

Table 38 Estimated numbers of additional razorbills by month in the array area and 2 km buffer based on 2016-2017 and 2019-2021 surveys

| Month | Unidentified GU/RA | Ratio GU/RA | Additional razorbills | Mean estimated razorbills | Revised monthly mean |
|---|---|---|---|---|---|
| Jan | 43 | 0.91/0.09 | 4 | 81 | 85 |
| Feb | 0 | 0.89/0.11 | 0 | 44 | 44 |
| Mar | 80 | 0.84/0.16 | 13 | 465 | 478 |
| Apr | 2,659 | 0.99/0.01 | 27 | 238 | 265 |
| May | 1,146 | 0.94/0.06 | 69 | 335 | 404 |
| Jun | 36 | 0.92/0.08 | 3 | 205 | 208 |
| Jul | 1,041 | 0.77/0.23 | 239 | 829 | 1,068 |
| Aug | 526 | 0.71/0.29 | 153 | 690 | 843 |
| Sep | 51 | 0.44/0.56 | 29 | 2,041 | 2,070 |
| Oct | 2 | 0.88/0.12 | 0 | 120 | 120 |
| Nov | 2 | 0.80/0.20 | 0 | 281 | 281 |
| Dec | 39 | 0.83/0.17 | 7 | 204 | 211 |

2.6.7 In the breeding season (April to July), the peak mean estimated number of razorbills in the array area was 581 birds in July (Table 37), while the peak mean estimated number of razorbills in the array area plus 2 km buffer was 1,068 birds in July (Table 38).

2.6.8 In the autumn migration period of the non-breeding season (August to October), mean estimated numbers of razorbills were higher, with a peak mean estimated number of 1,224 birds in the array area in September (Table 37). In the array area and 2 km buffer, the peak mean estimated number of razorbills in the autumn migration period was 2,070 birds in September (Table 38).

2.6.9 In the winter period of the non-breeding season (November to December), mean estimated numbers of razorbills were lowest, with a peak mean estimated number of 164 birds in the array area in November (Table 37). In the array area and 2 km buffer, the peak mean estimated number of razorbills in the winter period was 281 birds in November (Table 38).

2.6.10 In the spring migration period of the non-breeding season (January to March), mean estimated numbers of razorbills were slightly higher, with a peak mean estimated number of 275 birds in the array area in March (Table 37). In the array area and 2 km buffer, the peak mean estimated number of razorbills in the spring migration period was 478 birds in March (Table 38).

2.6.11 These peak estimated means were taken as the maximum number of razorbills in the array area and in the array area and 2 km buffer for the breeding season, the autumn migration period, the winter period and the spring migration period of the non-breeding seasons, and were used in the Displacement matrices produced for this assessment (Table 39 to Table 46).

2.6.12 For the purposes of this assessment, displacement rates of 50% and 60% are highlighted in each matrix. The same scenarios have also been applied for the array area plus 2 km buffer. Mortality rates of 1% to 100% are presented in Table 39 to Table 46, with mortality rates of 1%, 3% and 5% highlighted. An explanation of why these rates have been applied is presented above in the guillemot text.

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Table 39 Estimated number of razorbills predicted to be at risk of mortality following displacement from the array area in the breeding season (April to July)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 12 | 17 | 23 | 29 | 35 | 41 | 46 | 52 | 58 |
| | 20 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 23 | 35 | 46 | 58 | 70 | 81 | 93 | 105 | 116 |
| | 30 | 2 | 3 | 5 | 7 | 9 | 10 | 12 | 14 | 16 | 17 | 35 | 52 | 70 | 87 | 105 | 122 | 139 | 157 | 174 |
| | 40 | 2 | 5 | 7 | 9 | 12 | 14 | 16 | 19 | 21 | 23 | 46 | 70 | 93 | 116 | 139 | 163 | 186 | 209 | 232 |
| | 50 | **3** | 6 | 9 | 12 | 15 | 17 | 20 | 23 | 26 | 29 | 58 | 87 | 116 | 145 | 174 | 203 | 232 | 261 | 291 |
| | 60 | 3 | 7 | **10** | 14 | **17** | 21 | 24 | 28 | 31 | 35 | 70 | 105 | 139 | 174 | 209 | 244 | 279 | 314 | 349 |
| | 70 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 33 | 37 | 41 | 81 | 122 | 163 | 203 | 244 | 285 | 325 | 366 | 407 |
| | 80 | 5 | 9 | 14 | 19 | 23 | 28 | 33 | 37 | 42 | 46 | 93 | 139 | 186 | 232 | 279 | 325 | 372 | 418 | 465 |
| | 90 | 5 | 10 | 16 | 21 | 26 | 31 | 37 | 42 | 47 | 52 | 105 | 157 | 209 | 261 | 314 | 366 | 418 | 471 | 523 |
| | 100 | 6 | 12 | 17 | 23 | 29 | 35 | 41 | 46 | 52 | 58 | 116 | 174 | 232 | 291 | 349 | 407 | 465 | 523 | 581 |

Table 40 Estimated number of razorbills predicted to be at risk of mortality following displacement from the array area plus 2 buffer in the breeding season (April to July)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 21 | 32 | 43 | 53 | 64 | 75 | 85 | 96 | 107 |
| | 20 | 2 | 4 | 6 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 43 | 64 | 85 | 107 | 128 | 150 | 171 | 192 | 214 |
| | 30 | 3 | 6 | 10 | 13 | 16 | 19 | 22 | 26 | 29 | 32 | 64 | 96 | 128 | 160 | 192 | 224 | 256 | 288 | 320 |
| | 40 | 4 | 9 | 13 | 17 | 21 | 26 | 30 | 34 | 38 | 43 | 85 | 128 | 171 | 214 | 256 | 299 | 342 | 384 | 427 |
| | 50 | **5** | 11 | 16 | 21 | 27 | 32 | 37 | 43 | 48 | 53 | 107 | 160 | 214 | 267 | 320 | 374 | 427 | 481 | 534 |
| | 60 | 6 | 13 | **19** | 26 | **32** | 38 | 45 | 51 | 58 | 64 | 128 | 192 | 256 | 320 | 384 | 449 | 513 | 577 | 641 |
| | 70 | 7 | 15 | 22 | 30 | 37 | 45 | 52 | 60 | 67 | 75 | 150 | 224 | 299 | 374 | 449 | 523 | 598 | 673 | 748 |
| | 80 | 9 | 17 | 26 | 34 | 43 | 51 | 60 | 68 | 77 | 85 | 171 | 256 | 342 | 427 | 513 | 598 | 684 | 769 | 854 |
| | 90 | 10 | 19 | 29 | 38 | 48 | 58 | 67 | 77 | 87 | 96 | 192 | 288 | 384 | 481 | 577 | 673 | 769 | 865 | 961 |
| | 100 | 11 | 21 | 32 | 43 | 53 | 64 | 75 | 85 | 96 | 107 | 214 | 320 | 427 | 534 | 641 | 748 | 854 | 961 | 1,068 |

Table 41 Estimated number of razorbills predicted to be at risk of mortality following displacement from the array area in the autumn migration period of the non-breeding season (August to October)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Displacement (%) | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | 10 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 12 | 24 | 37 | 49 | 61 | 73 | 86 | 98 | 110 | 122 |
| | 20 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 24 | 49 | 73 | 98 | 122 | 147 | 171 | 196 | 220 | 245 |
| | 30 | 4 | 7 | 11 | 15 | 18 | 22 | 26 | 29 | 33 | 37 | 73 | 110 | 147 | 184 | 220 | 257 | 294 | 330 | 367 |
| | 40 | 5 | 10 | 15 | 20 | 24 | 29 | 34 | 39 | 44 | 49 | 98 | 147 | 196 | 245 | 294 | 343 | 392 | 441 | 490 |
| | 50 | **6** | 12 | 18 | 24 | 31 | 37 | 43 | 49 | 55 | 61 | 122 | 184 | 245 | 306 | 367 | 428 | 490 | 551 | 612 |
| | 60 | **7** | 15 | **22** | 29 | 37 | 44 | 51 | 59 | 66 | 73 | 147 | 220 | 294 | 367 | 441 | 514 | 588 | 661 | 734 |
| | 70 | 9 | 17 | 26 | 34 | 43 | 51 | 60 | 69 | 77 | 86 | 171 | 257 | 343 | 428 | 514 | 600 | 685 | 771 | 857 |
| | 80 | 10 | 20 | 29 | 39 | 49 | 59 | 69 | 78 | 88 | 98 | 196 | 294 | 392 | 490 | 588 | 685 | 783 | 881 | 979 |
| | 90 | 11 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 220 | 330 | 441 | 551 | 661 | 771 | 881 | 991 | 1,102 |
| | 100 | 12 | 24 | 37 | 49 | 61 | 73 | 86 | 98 | 110 | 122 | 245 | 367 | 490 | 612 | 734 | 857 | 979 | 1,102 | 1,224 |

Table 42 Estimated number of razorbills predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the autumn migration period of the non-breeding season (August to October)

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Displacement (%) | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | 10 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 17 | 19 | 21 | 41 | 62 | 83 | 104 | 124 | 145 | 166 | 186 | 207 |
| | 20 | 4 | 8 | 12 | 17 | 21 | 25 | 29 | 33 | 37 | 41 | 83 | 124 | 166 | 207 | 248 | 290 | 331 | 373 | 414 |
| | 30 | 6 | 12 | 19 | 25 | 31 | 37 | 43 | 50 | 56 | 62 | 124 | 186 | 248 | 311 | 373 | 435 | 497 | 559 | 621 |
| | 40 | 8 | 17 | 25 | 33 | 41 | 50 | 58 | 66 | 75 | 83 | 166 | 248 | 331 | 414 | 497 | 580 | 662 | 745 | 828 |
| | 50 | **10** | 21 | 31 | 41 | 52 | 62 | 72 | 83 | 93 | 104 | 207 | 311 | 414 | 518 | 621 | 725 | 828 | 932 | 1,035 |
| | 60 | **12** | 25 | **37** | 50 | 62 | 75 | 87 | 99 | 112 | 124 | 248 | 373 | 497 | 621 | 745 | 869 | 994 | 1,118 | 1,242 |
| | 70 | 14 | 29 | 43 | 58 | 72 | 87 | 101 | 116 | 130 | 145 | 290 | 435 | 580 | 725 | 869 | 1,014 | 1,159 | 1,304 | 1,449 |
| | 80 | 17 | 33 | 50 | 66 | 83 | 99 | 116 | 132 | 149 | 166 | 331 | 497 | 662 | 828 | 994 | 1,159 | 1,325 | 1,490 | 1,656 |
| | 90 | 19 | 37 | 56 | 75 | 93 | 112 | 130 | 149 | 168 | 186 | 373 | 559 | 745 | 932 | 1,118 | 1,304 | 1,490 | 1,677 | 1,863 |
| | 100 | 21 | 41 | 62 | 83 | 104 | 124 | 145 | 166 | 186 | 207 | 414 | 621 | 828 | 1,035 | 1,242 | 1,449 | 1,656 | 1,863 | 2,070 |

Table 43 Estimated number of razorbills predicted to be at risk of mortality following displacement from the array area in the winter period of the non-breeding season (November to December)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| **10** | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 8 | 10 | 11 | 13 | 15 | 16 |
| **20** | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 7 | 10 | 13 | 16 | 20 | 23 | 26 | 30 | 33 |
| **30** | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 10 | 15 | 20 | 25 | 30 | 34 | 39 | 44 | 49 |
| **40** | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 7 | 13 | 20 | 26 | 33 | 39 | 46 | 52 | 59 | 66 |
| **50** | **1** | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 16 | 25 | 33 | 41 | 49 | 57 | 66 | 74 | 82 |
| **60** | **1** | 2 | **3** | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 39 | 49 | 59 | 69 | 79 | 89 | 98 |
| **70** | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 23 | 34 | 46 | 57 | 69 | 80 | 92 | 103 | 115 |
| **80** | 1 | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 12 | 13 | 26 | 39 | 52 | 66 | 79 | 92 | 105 | 118 | 131 |
| **90** | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 13 | 15 | 30 | 44 | 59 | 74 | 89 | 103 | 118 | 133 | 148 |
| **100** | 2 | 3 | 5 | 7 | 8 | 10 | 11 | 13 | 15 | 16 | 33 | 49 | 66 | 82 | 98 | 115 | 131 | 148 | 164 |

Table 44 Estimated number of razorbills predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the winter period of the non-breeding season (November to December)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| 10 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 6 | 8 | 11 | 14 | 17 | 20 | 22 | 25 | 28 |
| 20 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 11 | 17 | 22 | 28 | 34 | 39 | 45 | 51 | 56 |
| 30 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 17 | 25 | 34 | 42 | 51 | 59 | 67 | 76 | 84 |
| 40 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 22 | 34 | 45 | 56 | 67 | 79 | 90 | 101 | 112 |
| 50 | **1** | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 | 14 | 28 | 42 | 56 | 70 | 84 | 98 | 112 | 126 | 141 |
| 60 | **2** | 3 | **5** | 7 | 8 | 10 | 12 | 13 | 15 | 17 | 34 | 51 | 67 | 84 | 101 | 118 | 135 | 152 | 169 |
| 70 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 39 | 59 | 79 | 98 | 118 | 138 | 157 | 177 | 197 |
| 80 | 2 | 4 | 7 | 9 | 11 | 13 | 16 | 18 | 20 | 22 | 45 | 67 | 90 | 112 | 135 | 157 | 180 | 202 | 225 |
| 90 | 3 | 5 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 | 51 | 76 | 101 | 126 | 152 | 177 | 202 | 228 | 253 |
| 100 | 3 | 6 | 8 | 11 | 14 | 17 | 20 | 22 | 25 | 28 | 56 | 84 | 112 | 141 | 169 | 197 | 225 | 253 | 281 |

Table 45 Estimated number of razorbills predicted to be at risk of mortality following displacement from the array area in the spring migration period of the non-breeding season (January to March)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 6 | 8 | 11 | 14 | 17 | 19 | 22 | 25 | 28 |
| 20 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 11 | 17 | 22 | 28 | 33 | 39 | 44 | 50 | 55 |
| 30 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 17 | 25 | 33 | 41 | 50 | 58 | 66 | 74 | 83 |
| 40 | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 |
| 50 | **1** | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 12 | 14 | 28 | 41 | 55 | 69 | 83 | 96 | 110 | 124 | 138 |
| 60 | **2** | 3 | **5** | 7 | 8 | 10 | 12 | 13 | 15 | 17 | 33 | 50 | 66 | 83 | 99 | 116 | 132 | 149 | 165 |
| 70 | 2 | 4 | 6 | 8 | 10 | 12 | 13 | 15 | 17 | 19 | 39 | 58 | 77 | 96 | 116 | 135 | 154 | 173 | 193 |
| 80 | 2 | 4 | 7 | 9 | 11 | 13 | 15 | 18 | 20 | 22 | 44 | 66 | 88 | 110 | 132 | 154 | 176 | 198 | 220 |
| 90 | 2 | 5 | 7 | 10 | 12 | 15 | 17 | 20 | 22 | 25 | 50 | 74 | 99 | 124 | 149 | 173 | 198 | 223 | 248 |
| 100 | 3 | 6 | 8 | 11 | 14 | 17 | 19 | 22 | 25 | 28 | 55 | 83 | 110 | 138 | 165 | 193 | 220 | 248 | 275 |

Table 46 Estimated number of razorbills predicted to be at risk of mortality following displacement from the array area plus 2 km buffer in the spring migration period of the non-breeding season (January to March)

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 0 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 10 | 14 | 19 | 24 | 29 | 33 | 38 | 43 | 48 |
| 20 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 19 | 29 | 38 | 48 | 57 | 67 | 76 | 86 | 96 |
| 30 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 11 | 13 | 14 | 29 | 43 | 57 | 72 | 86 | 100 | 115 | 129 | 143 |
| 40 | 2 | 4 | 6 | 8 | 10 | 11 | 13 | 15 | 17 | 19 | 38 | 57 | 76 | 96 | 115 | 134 | 153 | 172 | 191 |
| 50 | **2** | 5 | 7 | 10 | 12 | 14 | 17 | 19 | 22 | 24 | 48 | 72 | 96 | 120 | 143 | 167 | 191 | 215 | 239 |
| 60 | **3** | 6 | **9** | 11 | 14 | 17 | 20 | 23 | 26 | 29 | 57 | 86 | 115 | 143 | 172 | 201 | 229 | 258 | 287 |
| 70 | 3 | 7 | 10 | 13 | 17 | 20 | 23 | 27 | 30 | 33 | 67 | 100 | 134 | 167 | 201 | 234 | 268 | 301 | 335 |
| 80 | 4 | 8 | 11 | 15 | 19 | 23 | 27 | 31 | 34 | 38 | 76 | 115 | 153 | 191 | 229 | 268 | 306 | 344 | 382 |
| 90 | 4 | 9 | 13 | 17 | 22 | 26 | 30 | 34 | 39 | 43 | 86 | 129 | 172 | 215 | 258 | 301 | 344 | 387 | 430 |
| 100 | 5 | 10 | 14 | 19 | 24 | 29 | 33 | 38 | 43 | 48 | 96 | 143 | 191 | 239 | 287 | 335 | 382 | 430 | 478 |

# 3 Cumulative Displacement Matrices

3.1.1 The following displacement matrices have been produced based on annual cumulative estimated numbers of displaced gannets, kittiwakes, guillemots and razorbills in the breeding and non-breeding seasons (Table 47 to Table 50). Shag has not been included as no other projects have predicted impacts on this species therefore the cumulative impact would be the same as project alone.

3.1.2 The Cumulative Effects Assessment (CEA) long list of projects, plans and activities with which Dublin Array's offshore infrastructure has the potential to interact with to produce a cumulative impact is presented within the Cumulative Effect Assessment Methodology chapter (Volume 2, Chapter 4, Annex A: Offshore Long-list). For the cumulative assessment, any projects beyond the Offshore Ornithology Regional Study Area (509.4 km) were not considered to have the potential to add any direct or indirect cumulative impact to offshore ornithology receptors in the breeding season. In the non-breeding season, all consented or submitted projects within the ICES Area Celtic Seas were considered in the CEA. Further details of projects screened in / out for the cumulative assessment are presented in Volume 3, Chapter 6: Offshore and Intertidal Ornithology.

3.1.3 The numbers of potential individuals vulnerable to displacement are derived from the project specific submitted applications. The annual abundances for each project are listed presented in Volume 3, Chapter 6: Offshore and Intertidal Ornithology.

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## Gannet

Table 47 Estimated annual cumulative numbers of gannets predicted to be at risk of mortality following displacement from Tier 1, 2 and 3 projects & 2 km buffer

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 8 | 15 | 23 | 31 | 39 | 46 | 54 | 62 | 69 | 77 | 154 | 231 | 308 | 386 | 463 | 540 | 617 | 694 | 771 |
| | 20 | 15 | 31 | 46 | 62 | 77 | 93 | 108 | 123 | 139 | 154 | 308 | 463 | 617 | 771 | 925 | 1,079 | 1,234 | 1,388 | 1,542 |
| | 30 | 23 | 46 | 69 | 93 | 116 | 139 | 162 | 185 | 208 | 231 | 463 | 694 | 925 | 1,157 | 1,388 | 1,619 | 1,850 | 2,082 | 2,313 |
| | 40 | 31 | 62 | 93 | 123 | 154 | 185 | 216 | 247 | 278 | 308 | 617 | 925 | 1,234 | 1,542 | 1,850 | 2,159 | 2,467 | 2,776 | 3,084 |
| | 50 | 39 | 77 | 116 | 154 | 193 | 231 | 270 | 308 | 347 | 386 | 771 | 1,157 | 1,542 | 1,928 | 2,313 | 2,699 | 3,084 | 3,470 | 3,855 |
| | 60 | 46 | 93 | 139 | 185 | 231 | 278 | 324 | 370 | 416 | 463 | 925 | 1,388 | 1,850 | 2,313 | 2,776 | 3,238 | 3,701 | 4,163 | 4,626 |
| | 70 | **54** | 108 | 162 | 216 | 270 | 324 | 378 | 432 | 486 | 540 | 1,079 | 1,619 | 2,159 | 2,699 | 3,238 | 3,778 | 4,318 | 4,857 | 5,397 |
| | 80 | 62 | 123 | 185 | 247 | 308 | 370 | 432 | 493 | 555 | 617 | 1,234 | 1,850 | 2,467 | 3,084 | 3,701 | 4,318 | 4,934 | 5,551 | 6,168 |
| | 90 | 69 | 139 | 208 | 278 | 347 | 416 | 486 | 555 | 625 | 694 | 1,388 | 2,082 | 2,776 | 3,470 | 4,163 | 4,857 | 5,551 | 6,245 | 6,939 |
| | 100 | 77 | 154 | 231 | 308 | 386 | 463 | 540 | 617 | 694 | 771 | 1,542 | 2,313 | 3,084 | 3,855 | 4,626 | 5,397 | 6,168 | 6,939 | 7,710 |

## Kittiwake

Table 48 Estimated annual cumulative numbers of kittiwakes predicted to be at risk of mortality following displacement from Tier 1, 2 and 3 projects & 2 km buffer

| Displacement (%) | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 10 | 32 | 64 | 95 | 127 | 159 | 191 | 222 | 254 | 286 | 318 | 635 | 953 | 1,270 | 1,588 | 1,905 | 2,223 | 2,541 | 2,858 | 3,176 |
| 20 | 64 | 127 | 191 | 254 | 318 | 381 | 445 | 508 | 572 | 635 | 1,270 | 1,905 | 2,541 | 3,176 | 3,811 | 4,446 | 5,081 | 5,716 | 6,351 |
| 30 | **95** | 191 | 286 | 381 | 476 | 572 | 667 | 762 | 857 | 953 | 1,905 | 2,858 | 3,811 | 4,764 | 5,716 | 6,669 | 7,622 | 8,574 | 9,527 |
| 40 | 127 | 254 | 381 | 508 | 635 | 762 | 889 | 1,016 | 1,143 | 1,270 | 2,541 | 3,811 | 5,081 | 6,351 | 7,622 | 8,892 | 10,162 | 11,433 | 12,703 |
| 50 | 159 | 318 | 476 | 635 | 794 | 953 | 1,111 | 1,270 | 1,429 | 1,588 | 3,176 | 4,764 | 6,351 | 7,939 | 9,527 | 11,115 | 12,703 | 14,291 | 15,879 |
| 60 | 191 | 381 | 572 | 762 | 953 | 1,143 | 1,334 | 1,524 | 1,715 | 1,905 | 3,811 | 5,716 | 7,622 | 9,527 | 11,433 | 13,338 | 15,243 | 17,149 | 19,054 |
| 70 | 222 | 445 | 667 | 889 | 1,111 | 1,334 | 1,556 | 1,778 | 2,001 | 2,223 | 4,446 | 6,669 | 8,892 | 11,115 | 13,338 | 15,561 | 17,784 | 20,007 | 22,230 |
| 80 | 254 | 508 | 762 | 1,016 | 1,270 | 1,524 | 1,778 | 2,032 | 2,287 | 2,541 | 5,081 | 7,622 | 10,162 | 12,703 | 15,243 | 17,784 | 20,324 | 22,865 | 25,406 |
| 90 | 286 | 572 | 857 | 1,143 | 1,429 | 1,715 | 2,001 | 2,287 | 2,572 | 2,858 | 5,716 | 8,574 | 11,433 | 14,291 | 17,149 | 20,007 | 22,865 | 25,723 | 28,581 |
| 100 | 318 | 635 | 953 | 1,270 | 1,588 | 1,905 | 2,223 | 2,541 | 2,858 | 3,176 | 6,351 | 9,527 | 12,703 | 15,879 | 19,054 | 22,230 | 25,406 | 28,581 | 31,757 |

## Guillemot

Table 49 Estimated annual cumulative numbers of guillemots predicted to be at risk of mortality following displacement from Tier 1, 2 and 3 projects & 2 km buffer

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **%** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** |
| Displacement (%) | **10** | 176 | 353 | 529 | 705 | 882 | 1,058 | 1,234 | 1,410 | 1,587 | 1,763 | 3,526 | 5,289 | 7,052 | 8,815 | 10,578 | 12,341 | 14,104 | 15,867 | 17,631 |
| | **20** | 353 | 705 | 1,058 | 1,410 | 1,763 | 2,116 | 2,468 | 2,821 | 3,173 | 3,526 | 7,052 | 10,578 | 14,104 | 17,631 | 21,157 | 24,683 | 28,209 | 31,735 | 35,261 |
| | **30** | 529 | 1,058 | 1,587 | 2,116 | 2,645 | 3,173 | 3,702 | 4,231 | 4,760 | 5,289 | 10,578 | 15,867 | 21,157 | 26,446 | 31,735 | 37,024 | 42,313 | 47,602 | 52,892 |
| | **40** | 705 | 1,410 | 2,116 | 2,821 | 3,526 | 4,231 | 4,937 | 5,642 | 6,347 | 7,052 | 14,104 | 21,157 | 28,209 | 35,261 | 42,313 | 49,365 | 56,418 | 63,470 | 70,522 |
| | **50** | **882** | 1,763 | 2,645 | 3,526 | 4,408 | 5,289 | 6,171 | 7,052 | 7,934 | 8,815 | 17,631 | 26,446 | 35,261 | 44,076 | 52,892 | 61,707 | 70,522 | 79,337 | 88,153 |
| | **60** | **1,058** | **2,116** | **3,173** | **4,231** | **5,289** | 6,347 | 7,405 | 8,463 | 9,520 | 10,578 | 21,157 | 31,735 | 42,313 | 52,892 | 63,470 | 74,048 | 84,626 | 95,205 | 105,783 |
| | **70** | 1,234 | 2,468 | 3,702 | 4,937 | 6,171 | 7,405 | 8,639 | 9,873 | 11,107 | 12,341 | 24,683 | 37,024 | 49,365 | 61,707 | 74,048 | 86,389 | 98,731 | 111,072 | 123,414 |
| | **80** | 1,410 | 2,821 | 4,231 | 5,642 | 7,052 | 8,463 | 9,873 | 11,284 | 12,694 | 14,104 | 28,209 | 42,313 | 56,418 | 70,522 | 84,626 | 98,731 | 112,835 | 126,940 | 141,044 |
| | **90** | 1,587 | 3,173 | 4,760 | 6,347 | 7,934 | 9,520 | 11,107 | 12,694 | 14,281 | 15,867 | 31,735 | 47,602 | 63,470 | 79,337 | 95,205 | 111,072 | 126,940 | 142,807 | 158,675 |
| | **100** | 1,763 | 3,526 | 5,289 | 7,052 | 8,815 | 10,578 | 12,341 | 14,104 | 15,867 | 17,631 | 35,261 | 52,892 | 70,522 | 88,153 | 105,783 | 123,414 | 141,044 | 158,675 | 176,305 |

## Razorbill

Table 50 Estimated annual cumulative numbers of razorbills predicted to be at risk of mortality following displacement from Tier 1, 2 and 3 projects & 2 km buffer

| | | Mortality (%) | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Displacement (%) | 10 | 49 | 97 | 146 | 195 | 243 | 292 | 341 | 389 | 438 | 487 | 973 | 1,460 | 1,947 | 2,434 | 2,920 | 3,407 | 3,894 | 4,380 | 4,867 |
| | 20 | 97 | 195 | 292 | 389 | 487 | 584 | 681 | 779 | 876 | 973 | 1,947 | 2,920 | 3,894 | 4,867 | 5,840 | 6,814 | 7,787 | 8,761 | 9,734 |
| | 30 | 146 | 292 | 438 | 584 | 730 | 876 | 1,022 | 1,168 | 1,314 | 1,460 | 2,920 | 4,380 | 5,840 | 7,301 | 8,761 | 10,221 | 11,681 | 13,141 | 14,601 |
| | 40 | 195 | 389 | 584 | 779 | 973 | 1,168 | 1,363 | 1,557 | 1,752 | 1,947 | 3,894 | 5,840 | 7,787 | 9,734 | 11,681 | 13,628 | 15,574 | 17,521 | 19,468 |
| | 50 | **243** | 487 | 730 | 973 | 1,217 | 1,460 | 1,703 | 1,947 | 2,190 | 2,434 | 4,867 | 7,301 | 9,734 | 12,168 | 14,601 | 17,035 | 19,468 | 21,902 | 24,335 |
| | 60 | **292** | **584** | **876** | **1,168** | **1,460** | 1,752 | 2,044 | 2,336 | 2,628 | 2,920 | 5,840 | 8,761 | 11,681 | 14,601 | 17,521 | 20,441 | 23,362 | 26,282 | 29,202 |
| | 70 | 341 | 681 | 1,022 | 1,363 | 1,703 | 2,044 | 2,385 | 2,726 | 3,066 | 3,407 | 6,814 | 10,221 | 13,628 | 17,035 | 20,441 | 23,848 | 27,255 | 30,662 | 34,069 |
| | 80 | 389 | 779 | 1,168 | 1,557 | 1,947 | 2,336 | 2,726 | 3,115 | 3,504 | 3,894 | 7,787 | 11,681 | 15,574 | 19,468 | 23,362 | 27,255 | 31,149 | 35,042 | 38,936 |
| | 90 | 438 | 876 | 1,314 | 1,752 | 2,190 | 2,628 | 3,066 | 3,504 | 3,942 | 4,380 | 8,761 | 13,141 | 17,521 | 21,902 | 26,282 | 30,662 | 35,042 | 39,423 | 43,803 |
| | 100 | 487 | 973 | 1,460 | 1,947 | 2,434 | 2,920 | 3,407 | 3,894 | 4,380 | 4,867 | 9,734 | 14,601 | 19,468 | 24,335 | 29,202 | 34,069 | 38,936 | 43,803 | 48,670 |

# References

ABPmer, (2023), ‘Review of Method Statement, Offshore Wind Ornithology Assessment for East Coast Phase 1 Projects’, ABPmer Report No. R.4394, A report produced by ABPmer for An tSeirbhis Páirceanna Náisiúnta agus Fiadhúlra (National Parks and Wildlife Service)

APEM. (2022), ‘Review of evidence to support auk displacement and mortality rates in relation to offshore wind farms’, APEM Scientific Report P00007416, Ørsted, January 2022, Final, 49 pp, https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010098/EN010098-001044-Hornsea%20Project%20Four%20-%20G1.47%20Auk%20Displacement%20and%20Mortality%20Evidence%20Review.pdf

Busch, M., Buisson, R., Barrett, Z., Davies, S., Rehfisch, M. (2015), ‘Review of the Habitat Loss Method for Assessing Displacement Impacts from Offshore Wind Farms’, JNCC Report 551, Peterborough, https://data.jncc.gov.uk/data/f14d5e73-07ac-4705-b6da-1f3ec800e1ad/JNCC-Report-551-FINAL-WEB.pdf

Bradbury, G., Trinder, M., Furness, B., Banks, A.N., and Caldow, R.W.G. (2014), ‘Mapping Seabird Sensitivity to Offshore Wind farms’,. PLoS ONE 9(9): e106366. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0106366

Deakin, Z., Cook, A., Daunt, F., McCluskie, A., Morley, N., Witcutt, E., Wright, L. and Bolton, M. (2022), ‘A review to inform the assessment of the risk of collision and displacement in petrels and shearwaters from offshore wind developments in Scotland’, A report to Marine Scotland, https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2022/12/review-inform-assessment-risk-collision-displacement-petrels-shearwaters-offshore-wind-developments-scotland/documents/review-inform-assessment-risk-collision-displacement-petrels-shearwaters-offshore-wind-developments-scotland/review-inform-assessment-risk-collision-displacement-petrels-shearwaters-offshore-wind-developments-scotland/govscot%3Adocument/review-inform-assessment-risk-collision-displacement-petrels-shearwaters-offshore-wind-developments-scotland.pdf

Dierschke, J., Dierschke, V., Hüppop, O., Jachmann, K.F. (2011), ‘Die Vogelwelt der Insel Helgoland’, OAG Helgoland, Helgoland, https://ifv-vogelwarte.de/fileadmin/user_upload/Geschichtskapitel_.pdf

Dierschke, V., Furness, R.W., and Garthe, S. (2016), ‘Seabirds and offshore wind farms in European waters: Avoidance and attraction’, (Biological Conservation, Volume 202, pages 59-68), https://www.sciencedirect.com/science/article/abs/pii/S0006320716303196?via%3Dihub

Horswill, C. and Robinson R. A. (2015), ‘Review of seabird demographic rates and density dependence’, (JNCC Report No. 552, Joint Nature Conservation Committee, Peterborough), https://hub.jncc.gov.uk/assets/897c2037-56d0-42c8-b828-02c0c9c12d13

Furness, R.W., Wade, H.M. and Masden, E.A. (2013), ‘Assessing vulnerability of marine bird populations to offshore wind farms’, (Journal of Envvironmental Management, 119; 56-66), https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-001838-%C3%98rsted%20Hornsea%20Project%20Three%20(UK)%20Ltd%20-%20Appendix%2011%20-%20Furness%20et%20al.,%202013.pdf

Furness, R.W. (2015), ‘Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS)’,(Natural England

Commissioned Report Number 164), https://publications.naturalengland.org.uk/publication/6427568802627584
Furness, R.W., Wade, H.M. and Masden, E.A. (2013), 'Assessing vulnerability of marine bird populations to offshore wind farms', (Journal of Envvironmental Management, 119; 56-66), https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-001838-%C3%98rsted%20Hornsea%20Project%20Three%20(UK)%20Ltd%20-%20Appendix%2011%20-%20Furness%20et%20al.,%202013.pdf
GoBe. (2022), 'Method Statement - Offshore Wind Ornithology Assessment for East Coast Phase 1 Projects'
Hamer K.C., Humphreys E.M., Garthe S., Hennicke J., Peters G., Grémillet D., Phillips R.A., Harris M.P. & Wanless S. (2007) Annual variation in diets, feeding locations and foraging behaviour of Gannets in the North Sea: flexibility, consistency and constraint. (Marine Ecology Progress Series, 338, 295-305)
Hamer, K.C., Holt, N. & Wakefield, E. (2011) The distribution and behaviour of northern gannets in the Firth of Forth and Tay area. A review on behalf of the Forth and Tay Offshore Wind Developers Group. (Institute of Integrative & Comparative Biology, University of Leeds).
Humphreys, E.M., Cook, A.S.C.P and Burton, N.H.K. (2015), 'Collision, Displacement and Barrier Effect Concept Note', BTO Research Report No. 669, Thetford, Norfolk, https://www.bto.org/sites/default/files/shared_documents/publications/research-reports/2015/rr669.pdf
Krijgsveld, K.L., Fijn, R.C., Japink, M., van Horssen, P.W., Heunks, C., Collier, M.P., Poot, M.J.M., Beuker, D. and Dirksen, S. (2011), 'Effect studies Offshore Wind Farm Egmond aan Zee. Final report on fluxes, flight altitudes and behaviour of flying birds', NoordzeeWind report OWEZ_R_231_T1_20111114_flux&flight / Bureau Waardenburg report nr 10-219. Bureau Waardenburg, Culemborg, Netherlands, https://www.buwa.nl/fileadmin/buwa_upload/Bureau_Waardenburg_rapporten/06-467_effectstudies_offshore_windpark_Egmond_02.pdf
Langston, R.H.W. (2010), 'Offshore wind farms and birds: Round 3 zones, extensions to Round 1 & 2 sites & Scottish Territorial Waters', (RSPB Research Report No. 39), https://tethys.pnnl.gov/sites/default/files/publications/Langston_2010.pdf
Leopold, M.F., van Bemmelen, R.S.A., Zuur, A.F. (2013), 'Responses of local birds to the offshore wind farms PAWP and OWEZ off the Dutch mainland coast', Report C151/12. Imares, Wageningen, https://research.wur.nl/en/publications/responses-of-local-birds-to-the-offshore-wind-farms-pawp-and-owez
MacArthur Green, (2021), 'Beatrice Offshore Wind Farm. Year 1 Post-construction Ornithological Monitoring Report 2019', https://marine.gov.scot/sites/default/files/bowl_2019_post-con_monitoring_report_v2.2_30042021.pdf
MacArthur Green, (2023), 'Beatrice Offshore Wind Farm. Year 2 Post-construction Ornithological Monitoring Report 2021', https://marine.gov.scot/sites/default/files/bowl_2021_post_construction_ornithology_monitoring_report_25_07_2023.pdf
Maclean, I.M.D., Wright, L.J., Showler, D.A. and Rehfisch, M.M. (2009), 'A Review of assessment methodologies for offshore wind farms', (British Trust for Ornithology Report commissioned by COWRIE), https://tethys.pnnl.gov/sites/default/files/publications/Maclean-et-al-2009.pdf

Marine Scotland. (2022a), 'Marine Scotland - Licensing Operations Team Scoping Opinion for Berwick Bank Offshore Wind Farm', https://marine.gov.scot/sites/default/files/scoping_opinion_7.pdf
Marine Scotland. (2022b), 'Marine Scotland - Licensing Operations Team Scoping Opinion for West of Orkney Offshore Wind Farm', https://marine.gov.scot/sites/default/files/scoping_opinion_-_west_of_orkney_-_june_2022.pdf
Marine Scotland (2017a), 'Scoping Opinion for the proposed Section 36 Consent and Associated Marine Licence Application for the Revised NnG Offshore Wind Farm and Revised NnG Offshore Transmission Works', http://www.gov.scot/Topics/marine/Licensing/marine/scoping/NnGRev2017/SO-092017
Marine Scotland (2017b), 'Scoping Opinion for the proposed Section 36 Consent and Associated Marine Licence Application for the Revised Inch Cape Offshore Wind Farm and Revised Inch Cape Offshore Transmission Works',
https://marine.gov.scot/data/inch-cape-offshore-windfarm-revised-design-scoping-opinion
Peschko, V., Mendel, B., Müller, S., Markones, N., Mercker, M. and Garthe, S. (2020), 'Effects of offshore windfarms on seabird abundance: Strong effects in spring and in the breeding season', Marine Environmental Research 162: 105157, https://www.sciencedirect.com/science/article/pii/S0141113620304402
Skov, H., Heinänen, S., Norman, T., Ward, R.M., Méndez-Roldán, S. & Ellis, I. (2018), 'ORJIP Bird Collision and Avoidance Study Final report – April 2018', The Carbon Trust. 247 pp, https://tethys.pnnl.gov/sites/default/files/publications/Skov-et-al-2018.pdf
SNCBs. (2022a). Joint SNCB Interim Displacement Advice Note. JNCC, Natural Resources Wales, Department of Agriculture, Environment and Rural Affairs/Northern Ireland Environment Agency, Natural England and NatureScot. https://data.jncc.gov.uk/data/9aecb87c-80c5-4cfb-9102-39f0228dcc9a/joint-sncb-interim-displacement-advice-note-2022.pdf
SNCBs. (2022b). Joint SNCB Interim Advice on the Treatment of Displacement for Red-throated Diver. JNCC, Natural Resources Wales, Department of Agriculture, Environment and Rural Affairs/Northern Ireland Environment Agency, Natural England and NatureScot. https://data.jncc.gov.uk/data/9aecb87c-80c5-4cfb-9102-39f0228dcc9a/interim-sncb-advice-rtd-displacement-buffer.pdf
Trinder M, O'Brien SH and Deimel J (2024), 'A new method for quantifying redistribution of seabirds within operational offshore wind farms finds no evidence of within-wind farm displacement', Front. Mar. Sci. 11:1235061. https://www.frontiersin.org/articles/10.3389/fmars.2024.1235061/full
Vanermen N., E.W.M. Stienen, W. Courtens, T. Onkelinx, M. Van de walle & H. Verstraete (2013), 'Bird monitoring at offshore wind farms in the Belgian part of the North Sea - Assessing seabird displacement effects', (Rapporten van het Instituut voor Natuur- en Bosonderzoek 2013 (INBO.R.2013.755887). Instituut voor Natuur- en Bosonderzoek, Brussels, Belgium), https://tethys.pnnl.gov/sites/default/files/publications/Vanermen-et-al-2013.pdf
Zuur, A. F. (2018). Effects of wind farms on the spatial distribution of guillemots. Wageningen Marine Research T, 31(0), 317. Available at: https://www.noordzeeloket.nl/publish/pages/161187/effects_of_wind_farms_on_the_spatial_distribution_of_guillemots.pdf

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