Erebus: Offshore Ornithology 11.4 Technical Appendix - Displacement Analysis

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Contents

Tables

1 Introduction

1 Displacement is considered by Furness *et al.* (2013) and Bradbury *et al.* (2014) to be 'a reduced number of birds occurring within or immediately adjacent to an offshore wind farm'. This happens when birds avoid the area of operational turbines and different species are more or less likely to display this behaviour.

2 Furness *et al.* (2013) and Bradbury *et al.* (2014) give a displacement ranking for a range of species based on susceptibility to disturbance and habitat specialisation. This gives an indication of species more likely to be displaced and the potential consequences of that displacement.

3 Table 1 displays the ranking for those species recorded at Erebus (hereafter 'the Project') scoped in for displacement analysis (Volume 1, Chapter 11: Offshore Ornithology). European storm-petrel are not included as they were not recorded during the two years of digital aerial survey work of the Project array area (Volume 3, Technical Appendix 11.6: Two Year Bird Survey Report). HiDef records this species regularly during its surveys in suitable offshore habitats during the summer and post-breeding season but they were not recorded in the array area or buffer.

4 Disturbance susceptibility is considered further in sections 2.1.4 – 2.1.5 of this appendix as it influences the rates of displacement assigned to each species; a higher ranking equates to a higher level of potential displacement. Habitat specialisation is considered in section 2.1.6 as it may influence the potential mortality arising from displacement. Species which are more specialised and have a higher ranking, such as the auks, may be more severely affected by displacement impacts.

Table 1. Displacement ranking

Species	Scientific name	Disturbance susceptibility	Habitat specialisation
Guillemot	*Uria aalge*	3	3
Razorbill	*Alca torda*	3	3
Puffin	*Fratecula arctica*	2	3
Kittiwake	*Rissa tridactyla*	2	2
Gannet	*Morus bassanas*	2	1
Manx shearwater	*Puffinus puffinus*	1	1

2 Methods

2.1 Assessment method

5 Following a workshop held 6-7 May 2015, the statutory nature conservation bodies (SNCBs) issued interim advice on undertaking assessment of displacement impacts from offshore wind farms. This offers a consistent method for undertaking such assessment and promotes the use of 'displacement matrices' to give a range of displacement rates which are then considered in terms of adult mortality (SNCB, 2017).

6 The displacement matrices are informed by the following factors.

2.1.1 Spatial scales

7 For displacement assessment, the defined impact zone is the footprint of the offshore array plus a 2 km buffer. Assessment is based on this as a 'worst case'. For certain species, such as divers and seaducks, a 4 km buffer is currently recommended. However, these species were not recorded at the Project (see Volume 3, Technical Appendix 11.6: Two Year Bird Survey Report).

2.1.2 Defined seasons

8 As set out in the SNCB guidance (SNCB, 2017), displacement matrices are required for each species for the breeding and non-breeding seasons. As noted in Volume 1, Chapter 11: Offshore Ornithology, these seasons are based on the Furness (2015) report on biologically defined minimum population scales (BDMPS) and are presented in Table 2. These were sent to Natural Resources Wales (NRW) and the Joint Nature Conservation Committee (JNCC) during pre-application consultation and no objection was raised on their use (Chapter 11: Offshore Ornithology, Table 11.4).

Table 2. Defined seasons for use in assessment

Species	Migration-free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
Guillemot	Mar - Jun	n/a	Aug - Feb	n/a
Razorbill	Apr - Jun	Aug - Oct	Nov - Dec	Jan - Mar
Puffin	May - Jun	n/a	Aug - Mar	n/a
Kittiwake	May - Jul	Aug - Dec	n/a	Jan - Apr
Gannet	Apr - Aug	Sep - Nov	n/a	Dec - Mar
Manx shearwater	Jun - Jul	Aug - Oct	n/a	Mar - May

2.1.3 Mean seasonal peak population estimates

9 The SNCB guidance (SNCB 2017) defines displacement as affecting both birds on the water and in flight, therefore the mean seasonal peaks were calculated from monthly population estimates for all birds present within the impact zone which comprises the footprint of the offshore array plus a 2 km buffer. For the three auk species (guillemot, razorbill and puffin),

the estimates were adjusted for availability bias to account for birds likely to be diving at the time of survey (Volume 3, Technical Appendix 11.6: Two Year Bird Survey Report).

10 The mean seasonal peak population estimates are based on the two years of digital aerial survey data for each of the defined seasons in Table 2. Volume 3, Technical Appendix 11.1: Baseline Data sets out the monthly population estimates for each species in the Project array area plus 2 km buffer from which can be derived the peak estimates for each season in each year. The mean across the two peak estimates has been used in each of the displacement matrices in Appendix 11.4A of this report.

2.1.4 Displacement rates – SNCB guidance

11 The 'disturbance susceptibility' scores, outlined in SNCB guidance (SNCB 2017) and based on Furness *et al.* (2013) and Bradbury *et al.* (2014), can be used as a proxy for displacement rates where specific empirical evidence is lacking. For example, the SNCBs advise that species with a 'disturbance susceptibility' score of 1 (one) are unlikely to be displaced (or at least be displaced at very low levels) and so this score would translate to a displacement level of 10% or less. Species with a 'disturbance susceptibility' score of 3, where species have a moderate to high sensitivity to disturbance, would translate to a likely displacement level of between 30-70%. The SNCB guidance is used to inform the displacement rates for each species suggested in Table 3 and are presented as 'worst case' to inform assessment.

2.1.5 Displacement rates – post-construction monitoring

12 Post-construction monitoring can provide insight on how birds react to operational wind farms and this can be used to corroborate the SNCB guidance or, in the case of gannet, suggest variation.

13 **Guillemots** displayed significant avoidance of the Princess Amalia Wind Farm (PAWP) and Egmond aan Zee (OWEZ) offshore wind farms, offshore of the Netherlands, as reported by Leopold *et al.* (2013). The same was reported at Alpha Ventus in German waters (Mendel *et al.*, 2014), with a significant reduction in birds up to 10km away. Vanerman *et al.* (2014) recorded a 71% decrease in guillemot abundance after the installation of an offshore wind farm at the Belgian Bligh Bank in a region extending 0.5km away from the wind farm compared to a control area, with further reported displacement effects up to 3km away (Leopold *et al.*, 2011; Krijgsveld *et al.*, 2011). Krijgsveld *et al.* (2011) reported a 68% macro-avoidance rate by flying auks at OWEZ. Therefore a suggested rate of 70% displacement is used in assessment for guillemot.

14 Vanerman *et al.* (2014) reported a 64% decrease in **razorbill** abundance after the installation of an offshore wind farm at the Belgian Bligh Bank in a region extending 0.5km away from the wind farm compared to a control area, although did not appear to show signs of displacement beyond this. Krijgsveld *et al.* (2011) reported a 68% macro-avoidance rate by flying auks at OWEZ. Therefore a suggested rate of 70% displacement is used in assessment for razorbill. A suggested rate of 70% displacement is also used for **puffin** based on Krijgsveld *et al.* (2011).

15 Findings on **kittiwake** avoidance/attraction to wind farms post-construction is somewhat mixed. Kittiwake did not show significant avoidance in the Vanerman *et al.* (2014) study and were found to frequent the wind farm boundary, with increased foraging rates in the turbine area compared to the control area. However, Mendel *et al.* (2014) did report a

significant drop in kittiwake abundance after the construction of Alpha Ventus. Krijgsveld *et al*. (2011) reported only an 18% macro-avoidance rate (avoidance of the wind farm as a whole) by flying 'gulls' at OWEZ, although did not present rates for kittiwakes individually.

16 Despite **gannet** having a 'disturbance susceptibility' score of 2 (Table 1), and being ranked relatively low by Furness *et al*. (2013) and Bradbury *et al*. (2014), emerging studies suggest that the species is sensitive to displacement and barrier effects. Vanerman *et al*. (2014) recorded an 85% decrease in gannets in their study, with further reported displacement effects up to 3km away. Significant avoidance of both the PAWP and OWEZ wind farms was also displayed by gannets (Leopold *et al*., 2013), and a drop in abundance was reported after construction of Alpha Ventus (Mendel *et al*., 2014). Krijgsveld *et al*. (2011) reported that flying gannets displayed a 64% macro-avoidance rate at OWEZ. The species has since been ranked higher in the revised publication by Wade *et al*. (2016), reflecting increased vulnerability to disturbance and displacement by offshore windfarms.

2.1.6 Mortality rates

17 The fitness consequences of displacement on seabirds are two-fold; birds may require higher energetic expenditure deviating from their usual flight or foraging areas, whilst a loss of perceived and physical habitat may reduce available food resources, in turn risking some degree of potential mortality (Fox and Peterson, 2019; Fox *et al*., 2006; Masden *et al*., 2009). This degree of mortality will differ depending on a number of factors, including the size of the wind farm, the amount of habitat lost, the distance deviated by birds in flight, the availability of suitable replacement habitat and the level of increased competition. Mortality impacts are also likely to differ between season and species, based on their morphology, foraging range, foraging rates and seasonal energetic needs such as when provisioning for chicks (Masden *et al*., 2010).

18 Bird species showing limited flexibility in habitat use will be expected to experience greater fitness consequences from displacement compared to those species that are more generalised (at least in non-marine habitats e.g. Colles *et al*., 2009; Duraes *et al*., 2013). Therefore, the scores of species-specific 'habitat specialisation' (Table 1) can be used to provide an indication of the relative scale of mortality arising from displacement for each species. Species considered less flexible in their habitat use, are likely to be more vulnerable to displacement from favoured habitats. A high score for specialisation would therefore be expected to indicate a higher level of potential mortality.

19 It should be noted that auks have a relatively high cost of flight due to their large body mass and small wing area, and thus faster flapping. Auks undertake few short provisioning trips in the breeding season and so would experience the greatest additional costs if having to travel large distances to avoid wind farms (Masden *et al*., 2010).

20 Despite their shorter more frequent provisioning trips, the energy efficient wing loading in kittiwakes mean their energetic costs would be comparatively lower than auks for additional distances flown. When accounting for average species-specific foraging ecology, Masden *et al*. (2010) found terns to have the greatest additional energy costs, followed by kittiwake, puffin, guillemot, and gannet. Whilst razorbill was not assessed it is likely to have a similar energetic demand as guillemot.

21 In contrast, gannets undertake few, but long, foraging trips using efficient gliding flight and so their energy expenditure for additional distance would be comparatively lower.

Gannets are also likely to be less vulnerable to mortality by displacement due to their large foraging ranges (Woodward *et al*., 2019). However, this risk of mortality may increase in the breeding season, as birds are more constrained to their nest sites. Gannets at Bass Rock were recorded making consistently shorter foraging trips during the chick rearing period (Lane *et al*., 2020). However, this was somewhat negated by increased rates of birds, in particular females, entering nearby wind farms to forage during this time.

22 Manx shearwater are considered to be at a very low risk of displacement although this also has a high associated level of uncertainty (Wade *et al.* 2016). Their wide-ranging pelagic nature and high flexibility of habitat use means they are therefore unlikely to be susceptible to high levels of mortality from displacement impacts.

23 The 'worst case' of suggested mortality is informed by the rates used for Hornsea Project Three offshore wind farm, for Moray West offshore wind farm in Scotland and from the modelling work undertaken by the Centre for Hydrology and Ecology (CEH) for the Forth and Tay offshore wind farms in Scotland. The suggested 'worst case' is taken forward for assessment, however, the displacement matrices in Appendix 11.4A present the full range of possible mortalities from 0 – 100%.

Table 3. Suggested rates of displacement and resulting mortality

Species	Percentage of birds displaced	Breeding season mortality	Non-breeding season mortality
Guillemot	70%	5%	1%
Razorbill	70%	5%	1%
Puffin	70%	5%	1%
Kittiwake	30%	2%	1%
Gannet	70%	2%	1%
Manx shearwater	10%	1%	1%

3 Results

24 The 'worst case' displacement mortality estimates are presented for each species by season as discussed in section 2.1.2, and include no measure of uncertainty. Full displacement matrices for each species and each season are presented in Appendix 11.4A.

3.1 Guillemot

Table 4. Guillemot seasonal displacement mortalities (numbers of birds)

Guillemot displacement mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	Mar-Jun	n/a	Aug-Feb	n/a
Seasonal mortality	125	n/a	108	n/a

3.2 Razorbill

Table 5. Razorbill seasonal displacement mortalities (numbers of birds)

Razorbill displacement mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	Apr - Jun	Aug - Oct	Nov - Dec	Jan - Mar
Seasonal mortality	4	9	4	4

3.3 Puffin

Table 6. Puffin seasonal displacement mortalities (numbers of birds)

Puffin displacement mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	May - Jun	n/a	Aug - Mar	n/a
Seasonal mortality	16	n/a	1	n/a

3.4 Kittiwake

Table 7. Kittiwake seasonal displacement mortalities (numbers of birds)

Kittiwake displacement mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	May - Jul	Aug - Dec	n/a	Jan - Apr
Seasonal mortality	1	7	n/a	2

3.5 Gannet

Table 8. Gannet seasonal displacement mortalities (numbers of birds)

Gannet displacement mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	Apr - Aug	Sep - Nov	n/a	Dec - Mar
Seasonal mortality	4	3	n/a	1

3.6 Manx shearwater

Table 9. Manx shearwater seasonal displacement mortalities (numbers of birds)

Manx shearwater displacement mortalities	Migration free breeding season	BDMPS		
		autumn migration	non-breeding	spring migration
	Jun - Jul	Aug-Oct	n/a	Dec-Mar
Seasonal mortality	2	1	n/a	1

4 Discussion and Conclusions

25 Full displacement matrices for each species and season are presented in Appendix 11.4A.

26 Assessment is based on 'worst case' displacement rates and 'worst case' mortality, as presented in Table 3.

27 Once displacement mortality estimates have been divided by season, they can be considered in impact assessment; environmental impact assessment (EIA) as reported in Chapter 11: Offshore Ornithology, and Habitats Regulations Appraisal (HRA) as addressed in Volume 3, Technical Appendix 8.3: Report to Inform Appropriate Assessment.

28 For EIA, impacts during the breeding season are considered against the defined regional populations given in Pritchard *et al.* (2021). Impacts during the non-breeding season are considered against each relevant BDMPS, as defined by Furness (2015). For HRA, all impacts are apportioned to the relevant Special Protection Areas (SPAs) using the method set out in Volume 3, Technical Appendix 11.2: Apportioning for breeding season impacts and the approach articulated in Appendix 11.4B of this document for the non-breeding season.

4.1 Guillemot

29 The breeding season impacts can be apportioned between colonies using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For guillemot, 75.4% of birds are apportioned to Skomer, Skokholm and Seas off Pembrokeshire SPA and 17.5% to the Castlemartin Range Site of Special Scientific Interest (SSSI). This gives breeding season mortalities of 94 and 22 birds respectively.

30 In the non-breeding season, data in Furness (2015) can be used to calculate the percentage of guillemot in the BDMPS that are from Skomer, Skokholm and Seas off Pembrokeshire SPA and thus derive a weighting that can be used to apportion non-breeding season displacement impacts back to the breeding population. The method is described and the calculations presented in Appendix 11.4B of this document.

31 During the non-breeding season, the proportion of the BDMPS population that is from Skokholm and Seas off Pembrokeshire SPA is 4.3% which gives an estimate of five mortalities to assign against the SPA.

32 Combining seasonal estimates, the annual total of estimated guillemot displacement mortalities at Skomer, Skokholm and Seas off Pembrokeshire SPA is 99 birds. This is considered further through use of a population viability analysis (Volume 3, Technical Appendix 11.5: Population Viability Analysis) and assessed in Volume 3, Technical Appendix 8.3: Report to Inform Appropriate Assessment.

4.2 Razorbill

33 The breeding season impacts can be apportioned between colonies using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For razorbill, 89.2% of birds are apportioned to Skomer, Skokholm and Seas off Pembrokeshire SPA which gives a breeding season mortality of four birds.

34 In the non-breeding season, data in Furness (2015) can be used to calculate the percentage of razorbill in the BDMPS that are from Skomer, Skokholm and Seas off Pembrokeshire

SPA and thus derive a weighting that can be used to apportion non-breeding season displacement impacts back to the breeding population. The method is described and the calculations presented in Appendix 11.4B of this document.

35 During the non-breeding season razorbill have two BDMPS populations – migration and wintering. For migration the percentage of the total population that is from Skokholm and Seas off Pembrokeshire SPA is 3.3% which gives an estimate of zero mortalities in spring and zero mortalities in autumn to assign against the SPA. For the wintering BDMPS, the percentage of the total population of razorbill that is from Skokholm and Seas off Pembrokeshire SPA is 1.3% which gives an estimate of zero mortalities to assign against the SPA.

36 Combining seasonal estimates, the annual total of estimated razorbill displacement mortalities at Skomer, Skokholm and Seas off Pembrokeshire SPA is four birds, and this is not considered significant. Chapter 11: Offshore Ornithology considers estimated displacement mortalities against regional populations of razorbill.

4.3 Puffin

37 The breeding season impacts can be apportioned between colonies using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For puffin, 99.7% of birds are apportioned to Skomer, Skokholm and Seas off Pembrokeshire SPA giving a breeding season mortality of 16 birds.

38 In the non-breeding season, data in Furness (2015) can be used to calculate the percentage of puffin in the BDMPS that are from Skomer, Skokholm and Seas off Pembrokeshire SPA and thus derive a weighting that can be used to apportion non-breeding season displacement impacts back to the breeding population. The method is described and the calculations presented in Appendix 11.4B of this document.

39 During the non-breeding season the proportion of the BDMPS population that is from Skokholm and Seas off Pembrokeshire SPA is 3.2% which gives an estimate of zero mortalities to assign against the SPA.

40 Combining seasonal estimates, the annual total of estimated puffin displacement mortalities at Skomer, Skokholm and Seas off Pembrokeshire SPA is 16 birds, and this is not considered significant. Chapter 11: Offshore Ornithology considers estimated displacement mortalities against regional populations of puffin.

4.4 Kittiwake

41 The breeding season impacts can be apportioned between SPAs using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For kittiwake, 81.7% of birds are apportioned to Skomer, Skokholm and Seas off Pembrokeshire SPA, giving a breeding season displacement mortality estimate of one bird.

42 In the non-breeding season, data in Furness (2015) can be used to calculate the percentage of birds in the BDMPS that are from Skokholm and Seas off Pembrokeshire SPA and thus derive a weighting that can be used to apportion non-breeding season collision risk modelling (CRM) impacts back to the breeding population. The method is described and the calculations presented in Appendix 11.4B of this document.

43 During autumn migration the proportion of the BDMPS population that is from Skokholm and Seas off Pembrokeshire SPA is 0.2% which gives an estimate of effectively zero mortalities to assign against the SPA. During spring migration the proportion of the BDMPS population that is from Skokholm and Seas off Pembrokeshire SPA is 0.3% which gives an estimate of effectively zero mortalities to assign against the SPA.

44 Therefore, the annual total of estimated kittiwake displacement mortalities at Skokholm and Seas off Pembrokeshire SPA is one bird. As a 'worst case' this impact has been considered in combination with the estimated collision risk impacts (Volume 3, Technical Appendix 11.3: Collision Risk Modelling) against the SPA population. Chapter 11: Offshore Ornithology considers estimated displacement mortalities against regional populations of kittiwake.

4.5 Gannet

45 The breeding season impacts can be apportioned between SPAs using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For gannet, 99.5% of birds are apportioned to Grassholm SPA, giving a breeding season displacement mortality estimate of four birds.

46 In the non-breeding season, data in Furness (2015) can be used to calculate the percentage of birds in the BDMPS that are from Grassholm SPA and thus derive a weighting that can be used to apportion non-breeding season impacts back to the breeding population. The method is described and the calculations presented in Appendix 11.4B of this document.

47 During autumn migration the proportion of the BDMPS population that is from Grassholm is 23.7% which gives an estimate of one mortality to assign against the SPA. During spring migration, the proportion of the BDMPS population that is from Grassholm is 19.6% which gives an estimate of effectively zero mortalities to assign against the SPA.

48 Therefore, the annual total of estimated gannet displacement mortalities at Grassholm SPA is five birds. As a 'worst case' this impact has been considered in combination with the estimated collision risk impacts (Volume 3, Technical Appendix 11.3: Collision Risk Modelling) and the implications of total mortality considered further through use of a population viability analysis (Volume 3, Technical Appendix 11.5: Population Viability Analysis). The regional breeding population reported in Pritchard *et al.* (2021) is the same as the SPA population – therefore the one population viability analysis serves both purposes.

4.6 Manx shearwater

49 The breeding season impacts can be apportioned between SPAs using the weightings given in Volume 3, Technical Appendix 11.2: Apportioning. For Manx shearwater, 99.5% of birds are apportioned to Skomer, Skokholm and Seas off Pembrokeshire SPA, giving a breeding season displacement mortality estimate of two birds.

50 In the non-breeding season, data in Furness (2015) can be used to calculate the percentage of birds in the BDMPS that are from Skokholm and Seas off Pembrokeshire SPA and thus derive a weighting that can be used to apportion non-breeding season displacement impacts back to the breeding population. The method is described and the calculations presented in Appendix 11.4B of this document.

51 Manx shearwater has one migration BDMPS population and the proportion of this that is from Skokholm and Seas off Pembrokeshire SPA is 70.3%. This gives an estimate of two birds to assign against the SPA, one from each of the autumn and spring migration periods.

52 Combining seasonal estimates the annual total of estimated Manx shearwater displacement mortalities at Skomer, Skokholm and Seas off Pembrokeshire SPA is four birds and this is not considered significant. Chapter 11: Offshore Ornithology considers estimated displacement mortalities against regional populations of Manx shearwater.

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6 Appendix 11.4A – Displacement matrices

Shaded cells indicate the 'worst case' taken forward for the seasonal assessments, as presented in Section 3 – Results.

6.1 Guillemot

Table 10. Guillemot displacement and reasonable worst-case scenario (highlighted): breeding season

Guillemot Mar-Jun		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	4	8	11	15	18	36	54	72	107	178	285	356
	20%	0	8	15	22	29	36	72	107	143	214	356	570	712
	30%	0	11	22	33	43	54	107	161	214	321	534	854	1068
	40%	0	15	29	43	57	72	143	214	285	427	712	1139	1424
	50%	0	18	36	54	72	89	178	267	356	534	890	1424	1779
	60%	0	22	43	65	86	107	214	321	427	641	1068	1708	2135
	70%	0	25	50	75	100	125	250	374	499	748	1246	1993	2491
	80%	0	29	57	86	114	143	285	427	570	854	1424	2278	2847
	90%	0	33	65	97	129	161	321	481	641	961	1602	2562	3203
	100%	0	36	72	107	143	178	356	534	712	1068	1779	2847	3558

Table 11. Guillemot displacement and reasonable worst-case scenario (highlighted): non-breeding season

Guillemot Aug-Feb		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	16	31	46	62	77	154	230	307	460	767	1226	1533
	20%	0	31	62	92	123	154	307	460	613	920	1533	2452	3065
	30%	0	46	92	138	184	230	460	690	920	1380	2299	3678	4598
	40%	0	62	123	184	246	307	613	920	1226	1839	3065	4904	6130
	50%	0	77	154	230	307	384	767	1150	1533	2299	3831	6130	7662
	60%	0	92	184	276	368	460	920	1380	1839	2759	4598	7356	9195
	70%	0	108	215	322	430	537	1073	1610	2146	3219	5364	8582	10727
	80%	0	123	246	368	491	613	1226	1839	2452	3678	6130	9808	12260
	90%	0	138	276	414	552	690	1380	2069	2759	4138	6896	11034	13792
	100%	0	154	307	460	613	767	1533	2299	3065	4598	7662	12260	15324

6.2 Razorbill

Table 12. Razorbill displacement and reasonable worst-case scenario (highlighted): breeding season

Razorbill Apr-Jun		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	1	1	1	2	2	3	4	6	9	11
	20%	0	1	1	1	1	2	3	4	5	7	11	17	21
	30%	0	1	1	1	2	2	4	5	7	10	16	25	31
	40%	0	1	1	2	2	3	5	7	9	13	21	33	42
	50%	0	1	2	2	3	3	6	8	11	16	26	42	52
	60%	0	1	2	2	3	4	7	10	13	19	31	50	62
	70%	0	1	2	3	3	4	8	11	15	22	37	58	73
	80%	0	1	2	3	4	5	9	13	17	25	42	66	83
	90%	0	1	2	3	4	5	10	14	19	28	47	75	93
	100%	0	2	3	4	5	6	11	16	21	31	52	83	103

Table 13. Razorbill displacement and reasonable worst-case scenario (highlighted): autumn migration

Razorbill Aug-Oct		Mortality Level (% of displaced birds that die)												
		0%	**1%**	**2%**	**3%**	**4%**	**5%**	**10%**	**15%**	**20%**	**30%**	**50%**	**80%**	**100%**
Displacement Level (% of all birds on-site)	**0%**	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	2	3	4	5	7	13	19	25	37	62	99	123
	20%	0	3	5	8	10	13	25	37	50	74	123	197	246
	30%	0	4	8	12	15	19	37	56	74	111	185	295	369
	40%	0	5	10	15	20	25	50	74	99	148	246	393	492
	50%	0	7	13	19	25	31	62	93	123	185	307	492	614
	60%	0	8	15	23	30	37	74	111	148	222	369	590	737
	70%	0	9	18	26	35	43	86	129	172	258	430	688	860
	80%	0	10	20	30	40	50	99	148	197	295	492	786	983
	90%	0	12	23	34	45	56	111	166	222	332	553	885	1106
	100%	0	13	25	37	50	62	123	185	246	369	614	983	1228

Table 14. Razorbill displacement and reasonable worst-case scenario (highlighted): wintering

Razorbill Nov-Dec		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	2	2	3	3	6	9	12	17	29	46	57
	20%	0	2	3	4	5	6	12	17	23	34	57	91	114
	30%	0	2	4	6	7	9	17	26	34	51	85	136	170
	40%	0	3	5	7	10	12	23	34	46	68	114	182	227
	50%	0	3	6	9	12	15	29	43	57	85	142	227	283
	60%	0	4	7	11	14	17	34	51	68	102	170	272	340
	70%	0	4	8	12	16	20	40	60	80	119	199	317	397
	80%	0	5	10	14	19	23	46	68	91	136	227	363	453
	90%	0	6	11	16	21	26	51	77	102	153	255	408	510
	100%	0	6	12	17	23	29	57	85	114	170	283	453	566

Table 15. Razorbill displacement and reasonable worst-case scenario (highlighted): spring migration

Razorbill Jan-Mar		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	2	2	3	5	7	10	14	23	37	46
	20%	0	1	2	3	4	5	10	14	19	28	46	74	92
	30%	0	2	3	5	6	7	14	21	28	42	70	111	139
	40%	0	2	4	6	8	10	19	28	37	56	92	148	184
	50%	0	3	5	7	10	12	23	35	46	69	115	184	230
	60%	0	3	6	9	12	14	28	42	56	83	139	221	277
	70%	0	4	7	10	13	17	33	49	65	97	162	258	323
	80%	0	4	8	12	15	19	37	56	74	111	184	295	368
	90%	0	5	9	13	17	21	42	63	83	125	207	332	414
	100%	0	5	10	14	19	23	46	69	92	138	230	368	460

6.3 Puffin

Table 16. Puffin displacement and reasonable worst-case scenario (highlighted): breeding season

Puffin May-Jun		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	2	2	3	5	7	9	14	23	36	45
	20%	0	1	2	3	4	5	9	14	18	27	45	72	90
	30%	0	2	3	5	6	7	14	21	27	41	68	108	135
	40%	0	2	4	6	8	9	18	27	36	54	90	144	180
	50%	0	3	5	7	9	12	23	34	45	68	113	180	225
	60%	0	3	6	9	11	14	27	41	54	81	135	216	270
	70%	0	4	7	10	13	16	32	48	63	95	158	252	315
	80%	0	4	8	11	15	18	36	54	72	108	180	288	360
	90%	0	5	9	13	17	21	41	61	81	122	203	324	405
	100%	0	5	9	14	18	23	45	68	90	135	225	360	449

Table 17. Puffin displacement and reasonable worst-case scenario (highlighted): non-breeding season

Puffin Aug-Mar		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	1	1	1	1	1	1	1	2	3	4
	20%	0	1	1	1	1	1	1	1	2	2	4	6	7
	30%	0	1	1	1	1	1	1	2	2	3	5	8	10
	40%	0	1	1	1	1	1	2	2	3	4	7	11	13
	50%	0	1	1	1	1	1	2	3	4	5	8	13	16
	60%	0	1	1	1	1	1	2	3	4	6	10	16	20
	70%	0	1	1	1	1	2	3	4	5	7	12	18	23
	80%	0	1	1	1	2	2	3	4	6	8	13	21	26
	90%	0	1	1	1	2	2	3	5	6	9	15	24	29
	100%	0	1	1	1	2	2	4	5	7	10	16	26	32

6.4 Kittiwake

Table 18. Kittiwake displacement and reasonable worst-case scenario (highlighted): breeding season

Kittiwake May-Jul		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	1	1	1	1	1	1	1	1	1	1
	20%	0	1	1	1	1	1	1	1	1	1	1	1	1
	30%	0	1	1	1	1	1	1	1	1	1	1	1	1
	40%	0	1	1	1	1	1	1	1	1	1	1	1	1
	50%	0	1	1	1	1	1	1	1	1	1	1	1	1
	60%	0	1	1	1	1	1	1	1	1	1	1	1	2
	70%	0	1	1	1	1	1	1	1	1	1	1	2	2
	80%	0	1	1	1	1	1	1	1	1	1	1	2	2
	90%	0	1	1	1	1	1	1	1	1	1	1	2	2
	100%	0	1	1	1	1	1	1	1	1	1	1	2	2

Table 19. Kittiwake displacement and reasonable worst-case scenario (highlighted): autumn migration

Kittiwake Aug-Dec		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	3	5	7	9	11	21	31	41	61	102	162	203
	20%	0	5	9	13	17	21	41	61	81	122	203	324	405
	30%	0	7	13	19	25	31	61	91	122	182	304	486	607
	40%	0	9	17	25	33	41	81	122	162	243	405	648	809
	50%	0	11	21	31	41	51	102	152	203	304	506	809	1011
	60%	0	13	25	37	49	61	122	182	243	364	607	971	1214
	70%	0	15	29	43	57	71	142	213	284	425	708	1133	1416
	80%	0	17	33	49	65	81	162	243	324	486	809	1295	1618
	90%	0	19	37	55	73	91	182	273	364	546	910	1456	1820
	100%	0	21	41	61	81	102	203	304	405	607	1011	1618	2022

Table 20. Kittiwake displacement and reasonable worst-case scenario (highlighted): spring migration

Kittiwake Jan-Apr		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	2	2	3	3	6	8	11	16	26	41	51
	20%	0	2	3	4	5	6	11	16	21	31	51	82	102
	30%	0	2	4	5	7	8	16	23	31	46	77	122	153
	40%	0	3	5	7	9	11	21	31	41	61	102	163	204
	50%	0	3	6	8	11	13	26	39	51	77	127	204	254
	60%	0	4	7	10	13	16	31	46	61	92	153	244	305
	70%	0	4	8	11	15	18	36	54	72	107	178	285	356
	80%	0	5	9	13	17	21	41	61	82	122	204	326	407
	90%	0	5	10	14	19	23	46	69	92	138	229	366	458
	100%	0	6	11	16	21	26	51	77	102	153	254	407	508

6.5 Gannet

Table 21. Gannet displacement and reasonable worst-case scenario (highlighted): breeding season

Gannet Apr-Aug		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	1	1	2	3	4	5	7	12	18	23
	20%	0	1	1	2	2	3	5	7	9	14	23	36	45
	30%	0	1	2	3	3	4	7	11	14	21	34	54	68
	40%	0	1	2	3	4	5	9	14	18	27	45	72	90
	50%	0	2	3	4	5	6	12	17	23	34	56	90	112
	60%	0	2	3	5	6	7	14	21	27	41	68	108	135
	70%	0	2	4	5	7	8	16	24	32	48	79	126	157
	80%	0	2	4	6	8	9	18	27	36	54	90	144	180
	90%	0	3	5	7	9	11	21	31	41	61	101	162	202
	100%	0	3	5	7	9	12	23	34	45	68	112	180	224

Table 22. Gannet displacement and reasonable worst-case scenario (highlighted): autumn migration

Gannet Sep-Nov		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	2	2	2	4	6	7	11	17	27	34
	20%	0	1	2	3	3	4	7	11	14	21	34	54	67
	30%	0	2	3	4	5	6	11	16	21	31	51	81	101
	40%	0	2	3	5	6	7	14	21	27	41	67	107	134
	50%	0	2	4	6	7	9	17	26	34	51	84	134	167
	60%	0	3	5	7	9	11	21	31	41	61	101	161	201
	70%	0	3	5	8	10	12	24	36	47	71	117	188	234
	80%	0	3	6	9	11	14	27	41	54	81	134	214	268
	90%	0	4	7	10	13	16	31	46	61	91	151	241	301
	100%	0	4	7	11	14	17	34	51	67	101	167	268	334

Table 23. Gannet displacement and reasonable worst-case scenario (highlighted): spring migration

Gannet Dec-Mar		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	1	1	1	1	2	2	3	5	8	10
	20%	0	1	1	1	1	1	2	3	4	6	10	16	20
	30%	0	1	1	1	2	2	4	5	7	10	16	25	31
	40%	0	1	1	2	2	2	4	6	8	12	20	32	40
	50%	0	1	1	2	2	3	5	8	10	15	25	40	50
	60%	0	1	2	2	3	4	7	10	13	19	31	49	61
	70%	0	1	2	3	3	4	8	11	15	22	35	57	70
	80%	0	1	2	3	4	4	8	12	16	24	40	64	80
	90%	0	1	2	3	4	5	9	14	18	27	45	72	90
	100%	0	1	2	3	4	5	10	15	20	30	50	80	100

6.6 Manx shearwater

Table 24. Manx shearwater displacement and reasonable worst-case scenario (highlighted): breeding season

Manx shearwater Jun-Jul		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	2	4	5	7	8	16	24	31	47	77	124	154
	20%	0	4	7	10	13	16	31	47	62	93	154	247	308
	30%	0	5	10	14	19	24	47	70	93	139	232	370	463
	40%	0	7	13	19	25	31	62	93	124	185	308	493	616
	50%	0	8	16	24	31	39	77	116	154	231	385	616	770
	60%	0	10	19	28	37	47	93	139	185	278	463	740	925
	70%	0	11	22	33	44	54	108	162	216	324	539	863	1078
	80%	0	13	25	37	50	62	124	185	247	370	616	986	1232
	90%	0	14	28	42	56	70	139	208	278	416	693	1109	1386
	100%	0	16	31	47	62	77	154	231	308	462	770	1232	1540

Table 25. Manx shearwater displacement and reasonable worst-case scenario (highlighted): autumn migration

Manx shearwater Aug-Oct		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	2	2	3	3	6	9	12	17	28	45	56
	20%	0	2	3	4	5	6	12	17	23	34	56	90	112
	30%	0	2	4	6	7	9	17	26	34	51	84	134	168
	40%	0	3	5	7	9	12	23	34	45	67	112	179	223
	50%	0	3	6	9	12	14	28	42	56	84	140	223	279
	60%	0	4	7	11	14	17	34	51	67	101	168	268	335
	70%	0	4	8	12	16	20	39	59	78	117	195	312	390
	80%	0	5	9	14	18	23	45	67	90	134	223	357	446
	90%	0	6	11	16	21	26	51	76	101	151	251	402	502
	100%	0	6	12	17	23	28	56	84	112	168	279	446	557

Table 26. Manx shearwater displacement and reasonable worst-case scenario (highlighted): spring migration

Manx shearwater Mar-May		Mortality Level (% of displaced birds that die)												
		0%	1%	2%	3%	4%	5%	10%	15%	20%	30%	50%	80%	100%
Displacement Level (% of all birds on-site)	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	10%	0	1	1	1	1	1	1	1	1	1	1	2	2
	20%	0	1	1	1	1	1	1	1	1	2	2	3	4
	30%	0	1	1	1	1	1	1	1	2	2	3	5	6
	40%	0	1	1	1	1	1	1	2	2	3	4	6	8
	50%	0	1	1	1	1	1	1	2	2	3	5	8	9
	60%	0	1	1	1	1	1	2	2	3	4	6	9	11
	70%	0	1	1	1	1	1	2	2	3	4	7	11	13
	80%	0	1	1	1	1	1	2	3	3	5	8	12	15
	90%	0	1	1	1	1	1	2	3	4	5	9	13	17
	100%	0	1	1	1	1	1	2	3	4	6	9	15	18

7 Appendix 11.4B – Apportioning for displacement in the non-breeding season

53 This apportioning method for displacement in the non-breeding season was submitted to NRW and JNCC for comment during pre-application consultation (Chapter 11: Offshore Ornithology, Table 11.4). It uses data from Furness (2015) on biologically defined minimum population scales (BDMPS) to calculate the number of birds from each SPA as a proportion of the total BDMPS population; the tables for each species are presented in Appendix A of the report.

54 Where appropriate, this allows non-breeding season impacts to be apportioned back to breeding SPA populations and allows both breeding and non-breeding season impacts to be considered together against the reference population of concern.

55 The non-breeding apportioning calculations are provided for: guillemot, razorbill, puffin, kittiwake, gannet and Manx shearwater.

7.1 Guillemot

Guillemot have one non-breeding BDMPS from August to February.

7.1.1 Non-breeding BDMPS

Contribution from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures: 48,639 birds.
Total birds for 'UK western waters and Channel': 1,139,220 birds.
Skomer, Skokholm and Pembrokeshire coast SPA birds as proportion of total birds: 0.043

Refer to Furness (2015), Appendix A, Table 63, page 377.

7.2 Razorbill

Razorbill have two non-breeding BDMPS.

7.2.1 Migration BDMPS

Contribution from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of adults and immatures – 19,863 birds.
Total birds for 'UK western waters and Channel' – 606,914 birds.
SPA birds as proportion of total birds – 0.033

Refer to Furness (2015), Appendix A, Table 65, page 380.

7.2.2 Winter BDMPS

Contribution from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of adults and immatures: 4,501 birds.
Total birds for 'UK western waters and Channel': 341,422 birds.
SPA birds as proportion of total birds – 0.013

Refer to Furness (2015), Appendix A, Table 67, page 384.

7.3 Puffin

Puffin have one non-breeding BDMPS.

7.3.1 Non-breeding BDMPS

Contribution from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures: 9,684 birds.
Total birds for 'UK western waters and Channel': 304,557 birds.
Skomer, Skokholm and Pembrokeshire coast SPA birds as proportion of total birds: 0.032

Refer to Furness (2015), Appendix A, Table 69, page 388.

7.4 Kittiwake

Kittiwake have two migration BDMPS one during autumn and one during spring.

7.4.1 Autumn BDMPS

Contribution of kittiwake from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures: 1,990 birds.
Total birds for 'UK western waters and Channel': 911,586 birds.
Skomer, Skokholm and Pembrokeshire coast SPA birds as proportion of total birds: 0.002

Refer to Furness (2015), Appendix A, Table 48, page 350.

7.4.2 Spring BDMPS

Contribution of kittiwake from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures: 2,408 birds.
Total birds for 'UK western waters and Channel': 691,526 birds.
Skomer, Skokholm and Pembrokeshire coast SPA birds as proportion of total birds: 0.003

Refer to Furness (2015), Appendix A, Table 50, page 354.

7.5 Gannet

Gannet have two migration BDMPS one during autumn and one during spring.

7.5.1 Autumn BDMPS

Contribution of gannet from Grassholm SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures: 129,506 birds.
Total birds for 'UK western waters and Channel': 545,954 birds.
Grassholm SPA birds as proportion of total birds: 0.237

Refer to Furness (2015), Appendix A, Table 15, page 315.

7.5.2 Spring BDMPS

Contribution of gannet from Grassholm SPA to the 'UK western waters and Channel'.
Total number of SPA adults and immatures: 129,506 birds.
Total birds for 'UK western waters and Channel': 661,888 birds.
Grassholm SPA birds as proportion of total birds: 0.196

Refer to Furness (2015), Appendix A, Table 17, page 317.

7.6 Manx shearwater

Manx shearwater have one migration BDMPS covering both autumn and spring.

7.6.1 Migration BDMPS

Contribution from Skomer, Skokholm and Pembrokeshire coast SPA to the 'UK western waters and Channel'.
Total number of adults and immatures: 1,111,600 birds.
Total birds for 'UK western waters and Channel': 1,580,800 birds.
SPA birds as proportion of total birds: 0.703

Refer to Furness (2015), Appendix A, Table 13, page 313.