Pentland floating offshore wind farm

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Marine Ornithology: Population Modelling

PENTLAND
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APPENDIX 12.5: MARINE ORNITHOLOGY –

POPULATION MODELLING

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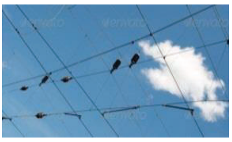

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Acronyms and abbreviations

Acronyms / abbreviation	Full name
CEH	Centre for Ecology and Hydrology
CGR	Counterfactual Growth Rate
CI	Confidence Intervals
CPS	Counterfactual Population Size
CRM	Collision Risk Modelling
EIAR	Environmental Impact Assessment Report
HRA	Habitats Regulations Appraisal
JNCC	Joint Nature Conservation Committee
MOWWL	Moray Offshore Windfarm (West) Limited
MS	Marine Scotland
MS-LOT	Marine Scotland Licensing Operations Team
MSS	Marine Scotland Science
MSP	Mean Seasonal Peak
NE	Natural England
NS	NatureScot
PFOWF	Pentland Floating Offshore Wind Farm
PVA	Population Viability Analysis
RIAA	Report to Inform the Appropriate Assessment
RSPB	Royal Society for the Protection of Birds
SNCB	Statutory Nature Conservation Bodies
SPA	Special Protection Area

1 Introduction

1 This report (Technical Appendix Marine Ornithology 12.5: Population Modelling) presents the method for, and results obtained from, modelling the population consequences of potential impacts to the protected seabird features of Special Protection Areas (SPAs) arising from the Offshore Development. This population modelling informs the assessments and conclusions presented in the Offshore Environmental Impact Assessment Report (EIAR) (Volume 2) Chapter 12: Marine Ornithology, and in the Report to Inform the Appropriate Assessment (RIAA).

2 The Pentland Floating Offshore Wind Farm (PFOWF) Array and Offshore Export Cable(s) (the Offshore Development) may give rise to a range of impacts during operation of the scheme (as discussed in Section 12.6.2 of the Offshore Environmental Impact Assessment Report (EIAR) (Volume 2) Chapter 12: Marine Ornithology). In this regard, collision risk and displacement/barrier effects are quantified for assessment resulting in estimates of mortality for each species of concern, as agreed through consultation, as set out in Technical Appendix 12.3 Marine Ornithology: Collision Risk Modelling and Technical Appendix 12.4 Marine Ornithology: Displacement Analysis.

3 As set out in Technical Appendix 12.4 Marine Ornithology: Displacement Analysis, modelling of displacement/barrier impacts has been undertaken using both SeabORD and the Statutory Nature Conservation Bodies (SNCB, 2017) advised displacement matrices. For project-alone impacts, the SeabORD outputs are used preferentially (as NatureScot (NS) advises these are 'best available evidence', email dated 18 March 2021). However, in respect of other developments for cumulative assessment (i.e., the Moray Firth offshore wind farms), the matrix outputs have been used as the only information available to refer to. Technical Appendix 12.4 Marine Ornithology: Displacement Analysis sets out the detail of each method.

4 The population-level consequences of these estimated mortalities (collision risk and displacement) need to be considered for seabirds in relation to their breeding populations, notably SPA colonies. The estimated mortalities are apportioned between relevant SPAs within foraging range using the methods and weightings set out in Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning.

5 As presented in the Scoping Opinion (MS-LOT, 2021), NS suggest using a change of 0.2% of adult survival (against the SPA populations of concern) as a means of determining whether to model the population consequences of the estimated mortalities; a so-called 'threshold of significance' (as discussed in the RIAA). Application of such a threshold indicates that estimated mortalities against the following seabird populations at North Caithness Cliffs SPA, the closest SPA to the PFOWF Array Area, need further consideration through Population Viability Analysis (PVA):

- Black-legged kittiwake (*Rissa tridactyla*), hereafter 'kittiwake';
- Common guillemot (*Uria aalge*), hereafter 'guillemot'; and
- Atlantic puffin (*Fratecula arctica*), hereafter 'puffin'.

6 PVA is the method for modelling the population-level consequences of estimated mortalities. PVA uses the estimated demographic rates for a population (typically survival and productivity) in a mathematical model to forecast future levels of a population. In this regard, Natural England (NE) commissioned the Centre for Hydrology and Ecology (CEH) to devise a standard, PVA tool for undertaking such modelling (Searle *et al*., 2019). It is this NE PVA tool that Marine Scotland Science (MSS), NS and the Royal Society for the Protection of Birds (RSPB) Scotland recommend be used in relation to the Offshore Development, as advised in the Scoping Opinion (MS-LOT, 2021).

7 The NE PVA tool was used to simulate population trends for a range of impacts scenarios arising from the Offshore Development, predicted to start in 2027 and to last for 30 years. The key outputs from the NE PVA tool are the ratios of the impacted to unimpacted (baseline) scenarios, called ‘counterfactuals’, which allow meaningful interpretation of the predicted effects against the populations in question. Counterfactuals are discussed in Section 2.1.4, with the results for each species from the PVA models undertaken presented in Section 3 (kittiwake in Table 6, guillemot in Table 7 and puffin in Table 8).

8 Note that there are multiple spreadsheets and model plots supporting the PVA discussion presented in this Technical Appendix. This can be made available upon request from Marine Scotland.

2 Methods

2.1 Assessment method

9 The NE PVA tool constructs a stochastic Leslie matrix which can be run through a web-based 'R-Shiny' package with a user-friendly interface.

2.1.1 Demographic parameters

10 In the PVA models, the productivity rates for each species were taken from Horswill & Robinson (2015), while the survival rates have been obtained from the default parameters contained in the NE PVA tool (Table 1). These default survival rates are also derived from Horswill & Robinson (2015) but have been recalculated from the underlying source data to correct issues regarding the standard errors.

11 For kittiwake and puffin, the productivity and survival rates used in the PVA are national estimates. For guillemot, the productivity rate used is regional-specific to the "North" area, while the survival rates are national estimates. The demographic data were used to parameterise a stochastic Leslie matrix (Caswell, 2000) built into the PVA tool (Searle *et al.*, 2019). Models included environmental and demographic stochasticity, but not density dependence, as has been standard practice based on scoping advice for other Scottish developments (e.g., Seagreen and Inch Cape).

Table 1 Summary of demographic rates for PVA species. Source is NE PVA tool default values which are derived from Horswill & Robinson (2015), unless otherwise specified

Demographic rates	Kittiwake		Guillemot		Puffin	
	Mean	SD	Mean	SD	Mean	SD
Adult survival	0.854	0.077	0.940	0.025	0.906	0.083
Productivity (per pair)	0.690	0.296	0.629	0.174	0.617	0.151
Age of recruitment	4	-	6	-	5	-
Brood size (per pair)[1]	2	-	1	-	1	-
Survival 0 → 1	0.790	0.092	0.560	0.058	0.709	0.108
Survival 1 → 2	0.854	0.077	0.792	0.152	0.709	0.108
Survival 2 → 3	0.854	0.077	0.917	0.098	0.709	0.108
Survival 3 → 4	0.854	0.077	0.938	0.107	0.760	0.093
Survival 4 → 5	-	-	0.940	0.025	0.805	0.083
Survival 5 → 6	-	-	0.940	0.025	-	-

1. Mean brood size (per pair) values taken from Snow & Perrins (1998).

2.1.2 PVA reference populations

12 The reference populations used for each species in the modelling are presented in Table 2. These are the most recent counts for each species at North Caithness Cliffs SPA, as confirmed by the Joint Nature Conservation Committee (JNCC) in their email dated 9 May 2022 (Annex A of Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning). The census year for these SPA population counts is taken to be 2016.

Table 2 SPA seabird populations considered under PVA

Species	SPA	SPA population size (breeding individuals)	Year of census
Kittiwake	North Caithness Cliffs	11,146	2015/16
Guillemot	North Caithness Cliffs	38,898	2015/16
Puffin	North Caithness Cliffs	3,053	2015/16

2.1.3 Age classes

13 The PVA tool allows the user to choose whether to use the same survival rate across all age groups, or to use age-dependent survival rates. In all cases in this analysis, survival rates were split into age classes as specified in Horswill & Robinson (2015).

14 The mortality estimates from collision risk and displacement which were input into the tool were split proportionally by adult and immature birds. Guillemot and puffin proportions were obtained by using the “burn in” function of the PVA tool, to obtain a stable age structure for the start of the projection period. This approach was also used for kittiwake non-breeding season proportions. For breeding season kittiwake, adult-immature proportions were based on observations from the aerial digital video surveys (Technical Appendix 12.1 Marine Ornithology: Baseline Data).

15 Note that assessment for the Offshore Development has made no allowance for sabbatical birds. There is no site-specific information on sabbatical rates for the species included in the PVA. In the case of kittiwake, the figures presented in Horswill & Robinson (2015) include all non-breeders, i.e., sub adults, rather than just sabbatical birds and therefore do not accurately reflect the annual percentage of birds on sabbatical at the breeding site. For guillemot and razorbill, estimated occurrences of sabbatical birds are low (~8% per year), although this figure may have changed since data were collected in the early 1990s. However, even if appropriate rates were to exist, the code in the NE PVA tool does not currently allow for sabbatical rates to be included. Therefore, no ‘discount’ has been applied to the collision or displacement mortality estimates in respect of sabbatical birds.

2.1.4 Model duration

16 To understand kittiwake and puffin population declines, and to place predicted mortalities from the Offshore Development into context, 50-year baseline models were run for these two species from the year of the SPA population census (i.e., 2016-2066). The baseline populations at the end of this modelled period (in year 2066), in the absence of any wind farm development, are reported in Table 6 for kittiwake and Table 8 for puffin.

17 The PVAs used to model the population consequences of predicted impacts (Table 3 to Table 5), also ran from 2016 (the year of the SPA population census, as noted in Table 2) and impacts were assumed to commence in 2027, based on the wider project programme and an assumed commissioning date, end of Q4 2026. Impacts were modelled to last for 30 years, which is the proposed lifespan of the Offshore Development. In this regard, it is recognised that for the other wind farms included for cumulative assessment (as detailed in Annex A), impacts may already be occurring. However, the PVA tool does not allow for varied levels of mortality for different years, therefore, for all cumulative scenarios, impacts were also assumed to commence in 2027 and to last for 30 years.

18 For each species, each simulation was run 1,000 times to obtain a projected population trajectory and associated uncertainty due to environmental and demographic stochasticity.

19 Density dependence was not modelled due to a lack of available data in this regard for each species. It is still possible to investigate and interpret the significance of modelled impacts using a density independent model.

2.1.5 Modelled mortality (impact scenarios)

20 For each species, each simulation was paired with an impact scenario, as set out in Table 3 for kittiwake, Table 4 for guillemot and Table 5 for puffin. The detailed derivation of each of these impact scenarios (project-alone and cumulative) is given in Annex A. The mortality estimates in each scenario have been apportioned between adult and immatures as set out in each table (with the supporting calculations presented in Annex A).

21 Following NS advice in the Scoping Opinion (MS-LOT, 2021), the kittiwake breeding season proportions are based on those observed during survey work (0.95 adults / 0.05 immatures), while non-breeding season proportions are derived from stable-age population models using the PVA tool (0.55 adults / 0.45 immatures). As it is not possible to age guillemot and puffin in the site survey data, the proportions of adults to immatures for these two species are derived from stable-age population models using the PVA tool (guillemot: 0.52 adults / 0.48 immatures, puffin: 0.53 adults / 0.47 immatures).

22 Kittiwake mortalities (Table 3) arise from potential collision risk and displacement/barrier effects summed together, while guillemot and puffin mortalities arise from potential displacement/barrier effects only (Table 4 and Table 5). For kittiwake and guillemot, it is annual mortalities that are being considered whereas for puffin the focus is more on the breeding season. All figures in these Tables are the estimated mortalities apportioned to North Caithness Cliffs SPA (Annex A).

23 For each scenario, relative rates of mortality were applied separately in the PVA for adults and juveniles. The relative rates of mortality are calculated from the adult and immature mortality estimates, as given Table 3 to Table 5, as a proportion of the respective adult and immature population at the year which impact commences (i.e., 2027).

24 Impacts are modelled for the Offshore Development in isolation, and in combination with other offshore wind farms that could potentially impact the same populations at North Caithness Cliffs SPA, notably the Moray Firth wind farms. Annex A provides the supporting information used to determine the impact scenarios modelled for each species.

Table 3 Modelled impact scenarios for kittiwake

Scenario	Impacts modelled *(annual impacts, displacement and collision risk)*	Absolute mortalities[2]			Relative mortality rates[3]	
		Total	Adults	Immatures	Adults	Immatures
1	PFOWF SeabORD and mean density CRM	7.64	7.40	0.25	0.83×10^{-3}	0.03×10^{-3}
2	PFOWF SeabORD and max density CRM	11.27	10.84	0.43	1.22×10^{-3}	0.06×10^{-3}
3	PFOWF SeabORD and mean density CRM; Moray Firth (matrix 30% / 2%)[1] and mean density CRM	17.99	16.15	1.84	1.82×10^{-3}	0.26×10^{-3}
4	North Sea wind farm mean density CRM non-breeding (excluding PFOWF and Moray Firth)	65.02	35.76	29.26	4.13×10^{-3}	4.16×10^{-3}
5	Scenarios 3 and 4 together	83.01	51.91	31.10	5.95×10^{-3}	4.41×10^{-3}

1. *% in brackets refer to the rates of displacement and mortality used in relation to displacement matrices. (See Annex A for further detail).*
2. *Absolute mortalities = estimated annual number of bird mortalities.*
3. *Relative mortality rates = absolute mortalities as a proportion of the 2027 baseline adult and immature North Caithness Cliffs SPA population estimates.*

Table 4 Modelled impact scenarios for guillemot

Scenario	Impacts modelled *(annual impacts, displacement)*	Absolute mortalities[2]			Relative mortality rates[3]	
		Total	Adults	Immatures	Adults	Immatures
1	PFOWF SeabORD	5.54	5.54	0	0.10×10^{-3}	0
2	PFOWF SeabORD and Moray Firth (matrix 60% / 1%, breeding / non-breeding)[1]	27.26	16.83	10.43	0.31×10^{-3}	0.21×10^{-3}

1. *% in brackets refer to the displacement and mortality parameters used to estimate mortality. (See Annex A for further detail).*
2. *Absolute mortalities = estimated annual number of bird mortalities.*
3. *Relative mortality rates = absolute mortalities as a proportion of the 2027 baseline adult and immature North Caithness Cliffs SPA population estimates.*

Table 5 Modelled impact scenarios for puffin

Scenario	Impacts modelled *(breeding season, displacement)*	Absolute mortalities[2]			Relative mortality rates[3]	
		Total	Adults	Immatures	Adults	Immatures
1	PFOWF SeabORD	1.80	1.80	0	0.75×10^{-3}	0
2	PFOWF Array Area alone (matrix 60% / 1%)[1]	5.07	2.69	2.38	1.12×10^{-3}	1.12×10^{-3}
3	Moray Firth (matrix 60% / 1%)[1]	19.91	10.55	9.36	4.40×10^{-3}	4.40×10^{-3}
4	Moray Firth (matrix 60% / 2%)[1]	39.83	21.11	18.72	8.81×10^{-3}	8.81×10^{-3}
5	PFOWF SeabORD and Moray Firth (matrix 60% / 1%)[1]	21.71	12.35	9.36	5.15×10^{-3}	4.40×10^{-3}

1. *% in brackets refer to the displacement and mortality parameters used to estimate mortality. (See Annex A for further detail).*
2. *Absolute mortalities = estimated annual number of bird mortalities.*
3. *Relative mortality rates = absolute mortalities as a proportion of the 2027 baseline adult and immature North Caithness Cliffs SPA population estimates.*

2.1.6 Model outputs (population metrics)

25 The key outputs from the PVA tool are the counterfactuals of population growth rate and of population size (Searle *et al.*, 2019). These are the ratios of the impacted to unimpacted (baseline) scenarios and allow meaningful interpretation of the predicted effects against the populations in question (Cook & Robinson, 2016). Developing guidance from the SNCBs including NS, and from MSS and RSPB Scotland, indicates that these are the metrics that will be used in making judgements on the viability of protected seabird populations.

26 Testing the sensitivities of these metrics has suggested that counterfactual of growth rate is useful to illustrate impacts regardless of population status or trend (Cook & Robinson, 2016). Cook & Robinson (2016) also found the counterfactual of population size can be used to assess the population level effects of impacts for stable or increasing populations and may also offer a useful context for the counterfactual of growth rate.

27 Model outputs are presented in Table 6 for kittiwake, Table 7 for guillemot and Table 8 for puffin.

3 Results

3.1 Kittiwake

28 Both baseline and impacted populations decreased between the census year (2016) and the commencement of impacts (2027), with the baseline reducing from 11,146 adult birds to 8,878. After this point, the impact scenario populations decreased at a faster rate than baseline population. Table 6 presents the differences in growth rate (decreasing population in this case) at the end of the 30 years of impact (2057) as estimated by the PVA tool, the difference in median population size ranged from 2% (Scenario 1) to 18.7% (Scenario 5).

Table 6 Metrics and counterfactuals (with 95% Confidence Intervals (CI)) for 200 simulations of the kittiwake PVA

Kittiwake scenarios	Mortality - relative rate		Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
	Adult	Immature		CGR[1] (95% CIs)	CPS[2] (95% CIs)
Baseline 50yr	-	-	2,526	-	-
Baseline 30yr	-	-	3,497	-	-
1 - PFOWF SeabORD and CRM mean densities	0.83×10^{-3}	0.03×10^{-3}	3,413	0.999 *(0.996-1.002)*	0.980 *(0.893-1.066)*
2 - PFOWF SeabORD and CRM max densities	1.22×10^{-3}	0.06×10^{-3}	3,394	0.999 *(0.996-1.001)*	0.970 *(0.892-1.054)*
3 - PFOWF SeabORD and CRM mean densities; Moray Firth (matrix 30% / 2%) and CRM mean densities	1.82×10^{-3}	0.26×10^{-3}	3,320	0.998 *(0.996-1.001)*	0.952 *(0.876-1.046)*
4 - North Sea wind farm non-breeding CRM mean densities (excluding PFOWF and Moray Firth)	4.13×10^{-3}	4.16×10^{-3}	2,957	0.995 *(0.992-0.997)*	0.854 *(0.777-0.926)*
5 - Scenarios 3 and 4 together	5.95×10^{-3}	4.41×10^{-3}	2,847	0.993 *(0.991-0.996)*	0.813 *(0.740-0.891)*

[1]*CGR = Counterfactual Growth Rate.* [2]*CPS = Counterfactual Population Size.*

3.2 Guillemot

29 Both baseline and impacted populations increased between the census year (2016) and the commencement of impacts (2027), with baseline rising from 38,898 adult birds to 53,897. After this point, the baseline population increased slightly more than all the impact scenario populations. Table 7 presents the differences in growth rate at the end of the 30 years of impact (2057) as estimated by the PVA tool, the difference in median population size was 0.4% for Scenario 1 and to 0.9% for Scenario 5.

Table 7 Metrics and counterfactuals (with 95% CI) for 1000 simulations of the guillemot PVA

Guillemot scenarios	Mortality - relative rate		Median pop. size at end of modelled period (adult individuals)	Median counterfactuals	
	Adult	Immature		CGR[1] (95% CIs)	CPS[2] (95% CIs)
Baseline 30yr	-	-	135,480	-	-
1 - PFOWF SeabORD	0.10×10^{-3}	0	135,037	1.000 *(0.999-1.000)*	0.996 *(0.981-1.012)*
2 - PFOWF SeabORD and Moray Firth (matrix 60% / 1%, breeding and non-breeding)	0.31×10^{-3}	0.21×10^{-3}	134,018	1.000 *(0.999-1.000)*	0.991 *(0.974-1.007)*

[1]CGR = Counterfactual Growth Rate. [2]CPS = Counterfactual Population Size.

3.3 Puffin

30 Both baseline and impacted populations decreased between the census year (2016) and the commencement of impacts (2027), with baseline falling from 3,053 adult birds to 2,399. After this point, the baseline population decreased at a lesser rate than all the impact scenario populations. Table 8 presents the differences in growth rate at the end of the 30 years of impact (2057) as estimated by the PVA tool, the difference in median population size ranged from 3% (Scenario 1) to 16.4% (Scenario 5).

Table 8 Metrics and counterfactuals (with 95% CI) for 1000 simulations of the puffin PVA

Puffin scenarios	Mortality - relative rate		Median pop. size at end f modelled period (adult individuals)	Median counterfactuals	
	Adult	Immature		CGR[1] (95% CIs)	CPS[2] (95% CIs)
Baseline 50yr	-	-	979	-	-
Baseline 30yr	-	-	1,150	-	-
1 - PFOWF SeabORD	0.75×10^{-3}	0	1,113	0.999 *(0.995-1.003)*	0.970 *(0.861-1.114)*
2 - PFOWF Array Area alone (matrix 60% / 1%, breeding)	1.12×10^{-3}	1.12×10^{-3}	1,110	0.999 *(0.995-1.003)*	0.957 *(0.836-1.098)*
3 - Moray Firth (matrix 60% / 1%, breeding)	4.40×10^{-3}	4.40×10^{-3}	988	0.995 *(0.990-0.999)*	0.854 *(0.733-0.977)*
4 - Moray Firth (matrix 60% / 2%, breeding)	8.81×10^{-3}	8.81×10^{-3}	834	0.990 *(0.985-0.994)*	0.724 *(0.620-0.840)*
5 - PFOWF SeabORD and Moray Firth (matrix 60% / 1%, breeding)	5.15×10^{-3}	4.40×10^{-3}	956	0.994 *(0.990-0.998)*	0.836 *(0.724-0.957)*

[1]*CGR = Counterfactual Growth Rate.* [2]*CPS = Counterfactual Population Size.*

4 Discussion and Conclusions

4.1 Kittiwake

31 The kittiwake population at North Caithness Cliffs SPA has been steadily declining over a 20-year period from site designation in 1996 to the most recent census count in 2015/16. The outputs from our analysis using the PVA tool using the default input parameters from Horswill & Robinson (2015) reflect this decline with a predicted baseline adult bird population of 8,878 in 2027 falling to 3,497 in 2057.

32 Projecting forward, the 50-year baseline modelling predicts a continuing decline in kittiwake numbers at the SPA with 2,526 individuals predicted in 2066.

33 The PVA tool indicates that median growth rates will be reduced in each of the five impact scenarios which consequently reduces the median population sizes over the 30 years modelled. Estimated collision and displacement mortalities arising from the Offshore Development in combination with the Moray Firth wind farms (impact scenario 3) results in a final median population size of 0.952 of a non-impacted baseline.

34 If all wintering kittiwake mortality estimated for other wind farms in the North Sea is apportioned against North Caithness Cliffs SPA (impact scenario 4) then the final median population size is 0.854 of a non-impacted baseline. In this regard, adding in the estimated mortality from the Offshore Development and the Moray Firth wind farms to the North Sea total would only lead to a further 0.041 (or 4.1%) decrease in the counterfactuals for final median population size (i.e., comparing impact scenario 5 with impact scenario 4).

35 Finally, all predicted population sizes for impacted populations at the end of a 30-year modelled period (year 2057) remain higher than the end population size predicted by the 50-year baseline model at year 2066 (Table 6).

4.2 Guillemot

36 Using the default input parameters from Horswill & Robinson (2015), the baseline scenario for the guillemot population at North Caithness Cliffs SPA shows a positive growth rate and a large increase in population size. While Swann (2018) indicate that the most recent guillemot count (2015/16) is 93% higher than the numbers present in 1986 it still seems that the population growth predicted by the PVA tool may be overestimated (e.g., the baseline increases from 53,897 to 135,480 adults in 30 years).

37 However, the counterfactuals (ratio) of population growth and size can still be informative in assessing the impact of each scenario against the baseline. For guillemot, median growth rates are only very slightly reduced in each of the five impacted scenarios. Even at the highest level of potential wind farm mortality (impact scenario 2) there is only a <0.1% reduction in the final median population size compared to the non-impacted baseline.

4.3 Puffin

38 Using the default input parameters from Horswill & Robinson (2015), the baseline scenario for the puffin population at North Caithness Cliffs SPA shows a declining population. This reflects the observed trend at the site, with Swann (2018) giving a 13% reduction between 1986 and 2016.

39 The counterfactuals (ratio) of population growth and size are informative in assessing the impact of each scenario against the baseline. Estimated puffin displacement mortalities arising from the Offshore Development alone (impact scenario 1) will result in a final median population size of 0.970 of a non-impacted baseline, a reduction of 3.0%.

40 Adding this project-alone estimated mortality to that for the Moray Firth wind farms at a 60% displacement rate and 1% mortality rate (comparing impact scenario 5 with impact scenario 3), leads to a further reduction of only 1.8% in the counterfactuals for final median population size (on top of the 14.6% estimated for Moray Firth at these rates).

41 If the level of puffin displacement mortality already consented for Moray Firth wind farms is modelled (impact scenario 4, displacement at a 60% displacement rate and 2% mortality rate), it can be seen that a change in counterfactuals of 0.276 has already been allowed, equating to a reduction in final median population size of 27.6% compared to baseline.

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Annex A Impact scenarios for PVA

1 This Annex presents the supporting calculations used to determine the impact scenarios (i.e., the estimates of collision risk and displacement mortality) to model against the kittiwake, guillemot and puffin populations at North Caithness Cliffs SPA.

A.1 Kittiwake

A.1.1 Offshore Development, kittiwake displacement / collision mortalities

2 The Scoping Opinion (MS-LOT, 2021) advised the following in respect of kittiwake:

> *For kittiwake, NS advise that there needs to be further discussion to reach agreement on whether the species is assessed for displacement and barrier effects in addition to collision risk. RSPB Scotland do not provide specific comment on this. As NS note it was previously unclear whether collision risk and displacement risk are mutually exclusive. A soon-to-be-published Marine Scotland commissioned study* [1] *now indicates that these are not mutually exclusive risks at the population scale, though the study also indicates complexities around how collision and displacement/barrier effect assessments should be parameterised in a common way. Once that report is published MSS advise that there should be further discussion to reach agreement on the approach to be taken for kittiwake.*

3 However, the MS study has not yet been published and no further pre-application advice has been provided on assessing potential kittiwake impacts. Therefore, as a simple 'worst-case', estimated collision and displacement mortalities have been summed for input into the PVAs.

4 SeabORD modelling was used to investigate potential kittiwake displacement/barrier effects arising from the Offshore Development in relation to North Caithness Cliffs SPA, as discussed in Technical Appendix 12.4 Marine Ornithology: Displacement Analysis. The kittiwake mortality estimates derived from SeabORD (all breeding adults) are used in the relevant PVAs and do not need to be apportioned as they directly relate to North Caithness Cliffs SPA.

5 Kittiwake collision mortalities have been calculated for the Offshore Development at both mean and maximum densities (Technical Appendix 12.3 Marine Ornithology: Collision Risk Modelling). In this regard, Section 4.1 of Technical Appendix 12.3 quantifies the collision risk mortalities to be apportioned to North Caithness Cliffs SPA, in both the breeding and non-breeding season.

6 For the latter, a method for kittiwake non-breeding season SPA apportioning is presented in Section 4.2 of Technical Appendix 12.3 Marine Ornithology: Connectivity and Apportioning. This uses information from Furness (2015) on Biologically Defined Minimum Population Scales (BDMPS) and gives non-breeding apportioning weightings for kittiwake at North Caithness Cliffs SPA of 0.023 (autumn) and 0.028 (spring) respectively.

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1 Study to examine how seabird collision risk, displacement and barrier effects could be integrated for assessment of offshore wind developments (ITQ-0246). Marine Scotland commissioned study.

7 In this regard, these non-breeding SPA apportioning weightings are generic rather than specific to a particular development (as is the case for the breeding season SPA apportioning), therefore they can be applied both to the Offshore Development as well as to the Moray Firth wind farms (Section A1.2) and other wind farm projects in the North Sea (Section A1.3).

8 As set out in Section 2.1.5, kittiwake breeding season proportions are based on those observed during survey work (0.95 adults / 0.05 immatures), while the non-breeding season proportion was derived from a stable-age population model using the PVA tool (0.55 adults / 0.45 immatures).

9 Therefore, the first two project-alone kittiwake impact scenarios for the Offshore Development (Table 3) are calculated as follows, all apportioned to North Caithness Cliffs:

Kittiwake Scenario 1.

PFOWF SeabORD and CRM mean densities
SeabORD: 2.6 breeding adult mortalities
CRM mean densities: 5.02 breeding mortalities (4.77 adults, 0.25 immatures), 0.02 non-breeding (assigned as adults).
Total mortalities: 7.40 adults / 0.25 immatures

Kittiwake Scenario 2.

PFOWF SeabORD and CRM max densities
SeabORD: 2.6 breeding adult mortalities
CRM max densities: 8.60 breeding mortalities (8.17 adults, 0.43 immatures), 0.07 non-breeding (assigned as adults).
Total mortalities: 10.84 adults / 0.43 immatures

A1.2 Offshore Development and Moray Firth wind farms kittiwake displacement/collision mortalities

10 The following information has been reviewed to determine kittiwake collision and displacement mortalities potentially arising from the Offshore Development in combination with the Moray Firth wind farms (Beatrice, Moray East and Moray West):

- Hornsea project four, Table 5.60 of ES Volume A2, Chapter 5, Offshore and Intertidal Ornithology (Orsted, 2021).
- Moray West, paragraph 10.8.4.44 (kittiwake displacement) and Table 10.8.13 (kittiwake collisions) of Chapter 10 of Offshore EIA Report (MOWWL, 2018a).
- Moray West, Table 3.23 (kittiwake displacement) and Table 3.51 (kittiwake collisions) of EIA Addendum (MOWWL, 2018b).
- Moray West, Scottish Minister's Appropriate Assessment (Scottish Ministers, 2019).

11 On displacement, SeabORD model outputs for kittiwake at North Caithness Cliffs SPA most closely align with use of a 60% displacement rate and 2% mortality rate (Table 13, Technical Appendix 12.4 Marine Ornithology: Displacement Analysis). This seems to accord with the rates used for the Moray Firth wind farms, although it has not been

possible to establish from the Moray West submission (MOWWL, 2018a; 2018b) what calculations were carried out to estimate kittiwake displacement mortalities arising from Moray East or Beatrice, as apportioned to North Caithness Cliffs SPA, (i.e., it's not been possible to verify the figures in Table 3.23 of the EIA Addendum).

12 In this regard, mean seasonal peak (MSP) estimates of kittiwake do not seem to be readily available for Moray East or for Beatrice, instead the figures noted in Table A.1.2.1 below (presented in italics because they are uncertain) are a back calculation from Table 3.23 in the Moray West EIA Addendum (MOWWL, 2018b), assuming the use of a 60% displacement rate and 2% mortality rate. For Moray West itself, the MSP has been obtained from Table 3.19 in the EIA Addendum (a figure of 6,902 kittiwake).

13 Breeding season apportioning weightings for kittiwake at North Caithness Cliffs SPA (Table A.1.2.1) were calculated separately for each wind farm; Beatrice, Moray East and Moray West, by retrospectively applying the MS apportioning tool to each. Further information on use of the MS apportioning tool is provided in Section 3.2.1 of Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning.

Table A.1.2.1 Moray Firth kittiwake displacement mortalities, breeding, from Moray West EIA Addendum (Table 3.23) (MOWWL, 2018b)

Wind Farms	Kittiwake MSPs	Kittiwake displacement mortalities at 30% / 2%	MS breeding apportioning weightings for NCC	Kittiwake displacement mortalities apportioned against NCC
Moray West	6,902	83	0.015	1.25
Moray East	4,000	24	0.023	0.55
Beatrice	2,167	13	0.026	0.34
			Total	2.13

14 While a figure of 2.1 kittiwake displacement mortalities has been determined in Table A.1.2.1, the figure that has been used in 'impact scenario 3' is that of three birds; this is the figure quoted in the MS appropriate assessment for Moray West, based on Table 3.23 of the EIA Addendum (MOWWL, 2018b). However, as noted, it is unclear how it has been calculated.

15 Note that the Moray Firth kittiwake displacement mortality estimates are so low in the non-breeding season, that effectively zero birds are apportioned against North Caithness Cliffs SPA using the 0.023 (autumn) and 0.028 (spring) weighting values. They are therefore not considered further.

16 On collision, there are differences in the kittiwake mortality estimates provided for Beatrice and for Moray East in the Moray West EIAR (MOWWL, 2018a) and Hornsea project four ES (Orsted, 2021) (although Moray West figures are the same in each). It has not been possible to establish why this is the case. So, Hornsea project four figures have been taken forward for cumulative PVA as these are the higher estimates, and most recent.

17 Table A.1.2.2 provides the apportioning for Moray Firth breeding season kittiwake mortalities to North Caithness Cliffs SPA. Table A.1.2.3 provides this for the non-breeding season mortalities.

Table A.1.2.2 Moray Firth kittiwake cumulative collision mortalities, breeding, from Hornsea project four ES (Orsted, 2021)

Wind Farms	MSS breeding apportioning weightings	Total kittiwake CRM estimates	Kittiwake CRM estimates apportioned to NCC
Moray West	0.015	79.0	1.19
Moray East	0.023	43.6	1.00
Beatrice	0.026	94.7	2.46
	Totals	217.3	4.65

Table A.1.2.3 Moray Firth kittiwake cumulative collision mortalities, non-breeding, from Hornsea project four ES (Orsted, 2021)

Wind Farms	Total kittiwake CRM estimates		Kittiwake CRM estimates apportioned to NCC	
	Autumn migration	Spring migration	Autumn migration 0.023 weighting	Spring migration 0.028 weighting
Moray West	24	7	0.55	0.20
Moray East	2	19.3	0.05	0.54
Beatrice	10.7	39.8	0.25	1.11
		Totals	0.85	1.85

18 Therefore, the calculations for kittiwake cumulative impact scenario 3 (Table 3), the Offshore Development in combination with Moray Firth wind farms, are as follows:

Kittiwake Scenario 3.

PFOWF SeabORD and CRM mean densities

Moray Firth displacement matrix (30% / 2%) and CRM mean densities

PFOWF SeabORD and CRM mean density: 7.40 breeding adults, 0.25 immatures

Moray Firth (matrix 30% / 2%): 3 breeding mortalities (2.85 adults, 0.15 immatures)

Moray Firth CRM mean density, breeding: 4.65 total (4.42 adults, 0.23 immatures)

Moray Firth CRM mean density, non-breeding: 2.70 total (1.49 adults, 1.21 immatures)

Total mortalities: 16.15 adults / 1.84 immatures

A1.3 North Sea wind farms, non-breeding kittiwake collision mortalities

19 Table 5.60 of the Hornsea project four ES (Orsted, 2021), summarises all the non-breeding kittiwake mortality arising from consented, constructed and proposed offshore wind farms in the North Sea BDMPS (Furness, 2015). This is geographic area over which MSS and NS advise consideration of non-breeding cumulative impacts to kittiwake (MS-LOT, 2021).

20 Non-breeding collision mortalities from wind farms in this area can be considered in totality against the BDMPS population (as is done for Hornsea project four, currently under consideration by the Planning Inspectorate) or could potentially be apportioned to North Caithness Cliffs SPA kittiwake population using the same non-breeding season apportioning weightings as for the Offshore Development (paragraph 6). This latter approach was undertaken for the Moray West in combination Habitats Regulations Appraisal (HRA) and is further discussed in the RIAA for this application.

21 Table A.1.3.1 summarises all the non-breeding season kittiwake collision mortalities for North Sea wind farms (excluding the Offshore Development and Moray Firth projects) as reported for kittiwake PVA impact scenarios 4 and 5 (Table 3).

Kittiwake Scenario 4.

North Sea wind farms non-breeding CRM mean densities
North Sea CRM mean densities, non-breeding: 65.02 total mortalities
Total mortalities: 35.76 adults / 29.26 immatures

Kittiwake Scenario 5.

PFOWF SeabORD and CRM mean densities
Moray Firth displacement matrix (30% / 2%) and CRM mean densities
North Sea wind farms non-breeding CRM mean densities
Adding together scenario 3 plus scenario 4
Total mortalities: 51.91 adults / 31.10 immatures

Table A.1.3.1 North Sea kittiwake collision mortalities, non-breeding (Hornsea project four figures)

Offshore wind farm project	Total kittiwake CRM estimates	
	Autumn BDMPS	Spring BDMPS
Blyth Demonstration (Phase 1)	2.3	1.4
Dogger Bank A & B	135	295.4
Dogger Bank C & Sofia	90.7	216.9
Dudgeon Offshore Wind Farm	-	-
Dudgeon Extension Project	8.6	2.2

Offshore wind farm project	Total kittiwake CRM estimates	
	Autumn BDMPS	**Spring BDMPS**
East Anglia ONE	160.4	46.8
East Anglia ONE North	8.1	3.5
East Anglia THREE	56.5	30.8
East Anglia TWO	5.4	7.4
European Offshore Wind Deployment Centre (EOWDC)	5.8	1.1
Galloper Wind Farm	27.8	31.8
Greater Gabbard	15	11.4
Gunfleet Sands Offshore Wind Farm	-	-
Hornsea Project Four	38.4	25.1
Hornsea Project One	55.9	20.9
Hornsea Project Two	9	3
Hornsea Project Three	6	3
Humber Gateway Offshore Wind Farm	3.2	1.9
Hywind Scotland	0.9	0.9
Inch Cape Offshore Wind Farm	224.8	63.5
Kentish Flats Offshore Wind Farm	0.9	0.7
Kentish Flats Extension	0	2.7
Kincardine Floating Offshore Wind Farm	9	1
Lincs, Lynn & Inner Dowsing Offshore Wind Farms	0.7	1.2
London Array	2.3	1.8
Levenmouth Demonstration Turbine	0	0
Neart na Gaoithe Offshore Wind Farm	56.1	4.4
Norfolk Boreas Offshore Wind Farm	32.2	11.9
Norfolk Vanguard	16.4	19.3
Race Bank Offshore Wind Farm	23.9	5.6
Rampion Offshore Wind Farm	0	0
Scroby Sands Offshore Wind Farm	-	-

Offshore wind farm project	Total kittiwake CRM estimates	
	Autumn BDMPS	Spring BDMPS
Seagreen (Phase 1)	313.1	247.6
Sheringham Shoal Offshore Wind Farm	-	-
Sheringham Shoal Offshore Wind Farm Extension	1.9	0
Teesside Wind Farm	24	2.5
Thanet Offshore Wind Farm	0.5	0.4
Triton Knoll Offshore Wind Farm	139	45.4
Westermost Rough Offshore Wind Farm	0.2	0.1
Total	1,474.0	1,111.6
Apportioning weighting for North Caithness Cliffs SPA	*0.023*	*0.028*
Kittiwake mortalities apportioned to North Caithness Cliffs SPA	**33.90**	**31.12**

22 Note that there may be anomalies in these mortality estimates across the different wind farms. This is because it is not certain that they have all been calculated in a standardised way or are completely comparative in respect of model choice and input parameters. However, the Hornsea project four ES (2021) is currently the most up-to-date source of published information in respect of these North Sea non-breeding kittiwake collisions.

A2 Guillemot

A2.1 Offshore Development, guillemot displacement mortalities

23 MSS and NS advised using SeabORD to investigate potential guillemot displacement/barrier effects arising from the Offshore Development in relation to North Caithness Cliffs SPA (Technical Appendix 12.4 Marine Ornithology: Displacement Analysis). The guillemot mortality estimates thus derived from SeabORD (all breeding adults) are now taken forward into the relevant PVAs and do not need to be apportioned as they directly relate to North Caithness Cliffs SPA.

Guillemot Scenario 1.

PFOWF SeabORD
SeabORD: 5.54 breeding adult mortalities

A2.2 Offshore Development and Moray Firth wind farms, guillemot displacement mortalities

24 Screening for cumulative assessment indicates that it is Beatrice, Moray East and Moray West which need to be considered together with the Offshore Development for guillemot breeding and non-breeding season impacts. The Moray West RIAA (MOWWL, 2018c) provides the most up to date, published figures for guillemot MSPs in respect of the three Moray Firth wind farms; paragraphs 6.9.5.38 – 6.9.5.45 and Tables 6.9.36 and 6.9.37.

25 Table A2.2.1 and Table A2.2.2 present the estimated guillemot displacement mortalities for Moray Firth wind farms, breeding and non-breeding respectively, taken forward into cumulative impact scenario 2 for PVA (Table 4). SeabORD model outputs for guillemot at North Caithness Cliffs SPA most closely align with use of a 60% displacement rate and a 1% mortality rate (Tables 14 and 15, Technical Appendix 12.4 Marine Ornithology: Displacement Analysis), and this accords with the rates used for Beatrice, Moray East and Moray West in the RIAA submitted for the latter.

26 The relevant breeding season apportioning weightings for guillemot at North Caithness Cliffs SPA were calculated by retrospectively applying the MS apportioning tool to each of the Moray Firth wind farms (Table A2.2.1).

Table A2.2.1 Moray Firth guillemot displacement mortalities, breeding taken from Moray West RIAA (MOWWL, 2018c)

Wind Farms	Guillemot MSPs breeding	Guillemot displacement mortalities at 60% / 1%	MS breeding apportioning weightings for NCC	Guillemot displacement mortalities apportioned against NCC
Moray West	24,426	146.56	0.029	4.25
Moray East	9,820	58.92	0.051	3.00
Beatrice	13,610	81.66	0.051	4.16
			Total	11.41

27 Although NS have advised an approach to non-breeding SPA guillemot apportioning based on definition of a regional population (Section 4.3 of Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning), it is only possible to apply this to project-alone assessment as it is based on those SPAs within specific foraging range of the Offshore Development.

28 For any cumulative assessment, different regional populations would apply, dependent on the SPAs found within the foraging ranges of each of the developments, and it would seem that different non-breeding apportioning weightings would need to be calculated. As it has not been possible to do this for the current assessment, the figures presented in Table A2.2.2 are taken from Table 6.9.35 of the Moray West RIAA (MOWWL, 2018c). In this regard, the apportioning weightings have not been explicitly stated in the Moray West RIAA (MOWWL, 2018c) nor has it been possible to ascertain why the guillemot non-breeding MSP is so much higher for Moray West compared to Moray East and Beatrice.

Table A2.2.2 Moray Firth guillemot displacement mortalities, breeding, taken from Moray West RIAA (MOWWL, 2018c)

Wind Farms	Guillemot MSPs non-breeding	Guillemot MSPs non-breeding apportioned to NCC	Guillemot displacement mortalities at 60% / 1%
Moray West	38,174	1,553	9.32
Moray East	1,245	51	0.31
Beatrice	2,755	112	0.67
		Total	10.30

29 The total estimated guillemot displacement mortalities for the Moray Firth wind farms calculated in Table A2.2.1 and Table A2.2.2 inform the impact scenario 2 for the PVA (Table 4). For guillemot the proportion of adults to immatures is derived from a stable-age population model using the PVA tool, a proportion of 0.52 adults / 0.48 immatures.

Guillemot Scenario 2.

PFOWF SeabORD

Moray Firth displacement matrix (60% / 1%)

PFOWF SeabORD: 5.54 breeding adults

Moray Firth displacement matrix (60% / 1%), breeding: 5.93 adults, 5.48 immatures

Moray Firth displacement matrix (60% / 1%), non-breeding: 5.36 adults, 4.94 immatures)

Total mortalities: 16.83 adults / 10.42 immatures

A3 Puffin

A3.1 Offshore Development, puffin displacement mortalities

30 MSS and NS advised using SeabORD to investigate potential puffin displacement/barrier effects arising from the Offshore Development in relation to North Caithness Cliffs SPA (Technical Appendix 12.4 Marine Ornithology: Displacement Analysis). The puffin mortality estimates thus derived from SeabORD (all breeding adults) are now taken forward into the relevant PVAs (Table 5) and do not need to be apportioned as they directly relate to the SPA.

Puffin Scenario 1.

PFOWF SeabORD
PFOWF SeabORD: 1.80 breeding adult mortalities

31 As indicated, SeabORD predicts an estimated puffin mortality at North Caithness Cliffs SPA of only 1.8 birds, significantly lower than all estimates given by use of the SNCB (2017) displacement matrices. This reflects the very high breeding season MSP calculated for puffin based on survey counts (8 June 2015 and 15 June 2021) that were a magnitude higher than for all other months. This is discussed further in Section 3.1 of Technical Appendix 12.1 Marine Ornithology: Baseline Data.

32 It should be noted that the survey estimates are only a 'snap-shot' in time, and it is not known how long any aggregations may have lasted for. It has been surmised by HiDef that they may have been associated with temporary, local foraging conditions. The aggregations were also observed in the buffer area, where it would be expected that displacement pressure is less than within the PFOWF Array Area. In this regard, all the displacement matrices undertaken for puffin at the Offshore Development significantly over-estimate the potential mortalities occurring, even at the lowest 1% mortality rate and removing the use of a 2 km buffer (Table 17, Technical Appendix 12.4 Marine Ornithology: Displacement Analysis).

33 For context, puffin impact scenario 2 (Table 5) models the displacement matrix outputs for the Offshore Development using a displacement rate of 60% and a mortality rate of 1%, applied to the PFOWF Array Area alone (i.e., without application of the 2 km buffer). For puffin the proportion of adults to immatures is derived from a stable-age population model using the PVA tool, a proportion of 0.53 adults / 0.47 immatures.

Puffin Scenario 2.

PFOWF displacement matrix (60% / 1%)
Matrix (60% / 1%), breeding: 5.07 total mortalities (2.69 adults, 2.38 immatures)

A3.2 Offshore Development and Moray Firth wind farms, puffin displacement mortalities

34 Screening for cumulative assessment indicates that it is Beatrice, Moray East and Moray West which need to be considered together with the Offshore Development for puffin breeding season impacts. The Moray West RIAA (MOWWL, 2018c) provides the most up to date, published figures for puffin MSPs in respect of the three Moray Firth wind farms; paragraphs 6.9.5.38 – 6.9.5.45 and Tables 6.9.43 and 6.9.44.

35 For the Offshore Development, the breeding season apportioning for puffin (between SPAs) has been undertaken based on NatureScot (2018) guidance (Section 3.2.1 of Technical Appendix 12.2 Marine Ornithology: Connectivity and Apportioning). In this regard, it has not been possible to reassess the puffin apportioning for the Moray Firth wind farms based on NS (2018), therefore the weightings given in the Moray West RIAA (MOWWL, 2018c) have been used for the puffin population at North Caithness Cliffs SPA (Table A3.2.1).

36 For Beatrice the apportioning weighting comes from the HRA Technical Report for that project. For Moray East it is 'obtained from information submitted as part of post-application consultation'. Calculation of the Moray West apportioning weighting is set out in Appendix 4.2 of the Moray West RIAA, Phenology and Apportioning (MOWWL, 2018c).

Table A3.2.1 Moray Firth puffin displacement mortalities, breeding taken from Moray West RIAA (MOWWL, 2018c)

Wind Farms	Puffin MSP	Puffin displacement mortalities		NCC breeding apportioning weightings	Puffin displacement mortalities apportioned against NCC	
		60%/1%	60%/2%		60%/1%	60%/2%
Moray West	1,115	6.69	13.38	0.148	0.99	1.98
Moray East	2,795	16.77	33.54	0.775	13.00	25.99
Beatrice	2,858	17.15	34.30	0.346	5.93	11.87
				Totals	19.92	39.84

37 The total estimated puffin displacement mortalities for the Moray Firth wind farms calculated in Table A3.2.1 inform impact scenarios 3, 4 and 5 for the PVA (Table 5). These are modelled at a 'more likely' 1% mortality rate, and a 'worst-case' 2% mortality rate to allow comparison with the assessment provided by Moray West. As noted above, for puffin the proportion of adults to immatures is derived from a stable-age population model using the PVA tool, a proportion of 0.53 adults / 0.47 immatures.

Puffin Scenario 3.

Moray Firth displacement matrix (60% / 1%)
Total mortalities: 10.55 adults / 9.36 immatures

Puffin Scenario 4.

Moray Firth displacement matrix (60% / 2%)
Total mortalities: 21.11 adults / 18.72 immatures

Puffin Scenario 5.

PFOWF SeaBORD
Moray Firth displacement matrix (60% / 1%)
Adding together scenario 1 plus scenario 3
Total mortalities: 12.35 adults / 9.36 immatures