Salamander Offshore Wind Farm

Offshore EIA Report

Volume ER.A.4, Annex 12.6: Displacement Assessment SeabORD

SALAMANDER

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Salamander Offshore Wind Farm: Annex ER.A.4.12.6: Displacement Assessment SeabORD

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Acronyms and abbreviations

Term	Definition
BOWL	Beatrice Offshore Windfarm Limited
CEH	Centre of Ecology and Hydrology
DEE	Daily Energy Expenditure
DER	Daily Energy Requirements
EOWDC	European Offshore Wind Deployment Centre
GPS	Global Positioning System
MD-LOT	Marine Directorate – Licensing Operations Team
SD	Standard Deviation
SPA	Special Protection Area

1 Introduction

1 This Annex supports the assessment of distributional responses undertaken for the proposed Salamander Offshore Wind Farm (hereafter 'the Salamander Project'). The Salamander Project is a proposed floating offshore wind farm being developed by Salamander Wind Project Company Limited (formerly called Simply Blue Energy (Scotland) Limited), a joint venture between Simply Blue Group, Ørsted and Subsea7. This annex will provide additional contextual information, produced using SeabORD, to support Annex ER.A.4.12.5: Displacement Assessment).

2 Within this annex, the term 'distributional responses' refers to two key responses assessed for seabirds in relation to the presence of offshore wind farms (OWFs): displacement and barrier effects (NatureScot 2023). More detail is provided in Annex ER.A.4.12.5: Displacement Assessment).

3 Following advice from The Marine Directorate – Licensing Operations Team (MD-LOT) and NatureScot (Scoping Opinion dated 21st June 2023 and NatureScot advice on Scoping Report dated 5th May 2023), the primary method to assess distributional responses was the matrix method presented in the joint Statutory Nature Conservation Bodies (SNCBs) (JNCC *et al.,* 2022). It was requested that SeabORD be used to provide additional contextual information, where possible.

4 SeabORD is an individual-based model developed by the Centre of Ecology and Hydrology (CEH) which assesses the bio-energetic costs of distributional responses to individual birds and specific populations, quantified by the number of estimated mortalities. Within this application, SeabORD was run using a 'distance decay' function which assumes that as the distance from the colony increases, the density of foraging birds decreases. Distributional responses were assessed using SeabORD for the following species:

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

5 Currently, these are the only species SeabORD can predict the impact of distributional responses for; each of these are a key concern to the ornithological impact assessment for the Salamander Project.

6 Estimated seabird mortalities were assessed in relation to breeding colonies within Special Protection Areas (SPAs). For each of the colonies the Salamander Project lies within the species- specific mean max foraging range ± 1 SD for the four assessed species, and so were selected based on distance to the Salamander Project. The following SPA colonies were assessed:

- Troup, Pennan and Lion's Head SPA;
- Buchan Ness to Collieston Coast SPA;
- Fowlsheugh SPA; and
- East Caithness Cliffs SPA.

7 Multiple scenarios were run through SeabORD to determine estimated seabird mortalities. The effect on seabirds was assessed first for the Salamander Project alone and secondly with the presence of other

nearby wind farms. The other offshore wind farms which were considered with the Salamander Project were:

- European Offshore Wind Deployment Centre (EOWDC);
- Moray East Offshore Windfarm, Moray West Offshore Windfarm and Beatrice Offshore Windfarm (BOWL), hereafter 'Moray Firth Wind Farms';
- Hywind Scotland Pilot Park Project, hereafter 'Hywind'; and
- Kincardine Floating Offshore Windfarm, hereafter 'Kincardine'.

8 Since the Moray Firth Wind Farms are situated alongside each other, these wind farms were run through SeabORD as one combined area (see Figure 1; Annex ER.A.4.12.5: Displacement Assessment).

2 Methods

2.1 SPA specific information

9 SeabORD requires each colony to be represented by a single point near the coastline of the UK within the simulation. The chosen point is used as the start and end point of foraging trips generated by the model. During 'single' calibration and final 'paired' simulations the same points were used for each SPA as shown in Table 1.

Table 1 SPA location and total number of pairs of key species per site

SPA	Longitude	Latitude	Guillemot (pairs)	Razorbill (pairs)	Kittiwake (pairs)	Puffin (pairs)
Troup, Pennan and Lion's Head	-2.2511	57.6821	16080	3027	10616	15
Buchan Ness to Collieston Coast	-1.8357	57.4108	19666	3901	11295	91
Fowlsheugh	-2.2003	56.9201	46785	9422	14039	89
East Caithness Cliffs	-3.3392	58.2803	99983	20172	24479	95

2.2 Calibration

10 To calibrate SeabORD for each species at each colony, 'single' simulations were run with no wind farms present. The only input values altered when running calibration simulations were the prey quantity (gram per unit volume) to produce outputs for a range of prey quantity values which can then be compared. Other values used to run calibration and final paired simulations are presented in Table 2.

11 It is crucial the model is calibrated as the breeding season outputs in the final paired simulations will only use the values from the prey quantity (gram per unit volume) range selected. Technically, within the models only the chick-rearing period is included, this will be referred to as the breeding period

throughout this annex. Therefore, to produce realistic results the prey range should be set to values expected during typical or 'moderate' breeding seasons.

Table 2 Values used for running baseline and the final paired simulations

Variable	Kittiwake	Guillemot	Razorbill	Puffin
% of populations susceptible to displacement	30	60	60	60
% of those susceptible to displacement barrier	100	100	100	100
Maximum foraging range (km)	300.6	153.7	164.6	265.4
Proportion of individuals within range	0.975	0.975	0.975	0.975
Offshore Array Area (km)	2	2	2	2
Offshore Array Area +2km buffer (km)	5	5	5	5
Fraction of population used for calibration simulations	0.1	0.1	0.1	0.1
Fraction of population used for final paired simulations	0.3	0.3	0.3	1.0

2.2.1 Model input parameters and assumptions

12 Due to a lack of Global Positioning System (GPS) tracking data for the colonies of interest, the distance decay method was used to determine the foraging sites of individuals. This assumes that as the distance from the colony increases, the density of foraging birds is expected to decrease (Searle *et al.*, 2018). For each species, the foraging range used within the model was mean max plus one standard deviation, taken from Woodward *et al.* (2019), as advised by NatureScot (NatureScot advice on Scoping Report dated 5th May 2023). The proportion of foraging occurring within this identified range was set to 0.975 (Table 2). 0.975 was used to account for the fact that only a small number of individuals would be expected to fly further than the mean max plus one SD defined foraging range. These input values were then used by SeabORD to determine the foraging location of each individual adult, at each timestep of the simulation. The model assumes that every pair has one chick, however this is incorrect for kittiwake, as they generally have two chicks to provision for. This may impact adult survival as more foraging trips will need to be made, increasing energy expenditure. Following this, it is likely that the model underestimates impacts to kittiwake.

13 The assumed percentage of the population susceptible to distributional responses was taken from NatureScot advice (NatureScot, 2023 and NatureScot advice on Scoping Report dated 5th May 2023). Displacement rates were the same as used within the matrix approach (see Annex ER.A.4.12.5: Displacement Assessment) and it was assumed that all individuals susceptible to displacement would be

barriered. The Offshore Array Area border (the area birds that are barriered will not be able to travel through) was set to 2km and the wind farm buffer (the area birds would be displaced to) set to 5km, following published SeabORD documentation (Searle *et al.*, 2018; Mobbs *et al.*, 2018).

2.2.2 Calculating prey ranges

14 To determine the prey range expected during a 'moderate' breeding season (i.e. where environmental conditions are 'moderate') calibration simulations were run (i.e. simulations with no additional wind farms present). The only input parameters in the calibration simulations which differed from those used in the final paired simulations were the upper and lower prey quantity values used to generate the uniform prey distribution. After running multiple calibration simulations, the outputs were compared to determine the appropriate lower and upper prey quantity values. The lower prey quantity value was determined by comparing the percentage adult mass loss and percentage chick survival to those expected during 'moderate' breeding seasons (Table 3).

Table 3 Adult percentage body mass loss and percentage chick survival used to determine prey values used in the final paired simulations. Values taken from Mobbs *et al.* (2018)

Species	Adult Mass Loss (%)		Chick Survival (%)
	Lower boundary	Upper boundary	Lower boundary
Kittiwake	5	15	11
Guillemot	3.5	10.5	49
Razorbill	3.5	10.5	50
Puffin	3.5	10.5	50

2.2.3 Paired simulations

15 Once the upper and lower prey quantities were determined through the calibration simulations, they were then used to run the final paired simulation for each species at each colony (Table 4). The paired simulations compare presence of the Salamander Project against baseline conditions. Each pair selected a prey quantity within the range using random stratification and then simulated the breeding season with and without the selected wind farms present, meaning that 20 breeding seasons were simulated for each final simulation. Some colonies had relatively high population sizes, which can negatively affect the run-time of simulations (SSER, 2022). To manage run times 30% of the population was simulated for guillemot (54,755 pairs), razorbill (10,957 pairs) and kittiwake (18,130 pairs). As puffin populations were smaller 100% of the population was used (290 pairs).

Table 4 Prey quantity range used for each final paired simulation

Species	Colony	Lower prey quantity (g per unit volume)	Upper prey quantity (g per unit volume)
Kittiwake	Troup, Pennan and Lion's Head SPA	167	206
	Buchan Ness to Collieston Coast SPA	163	206
	Fowlsheugh SPA	128	160
	East Caithness Cliffs SPA	170	213
Guillemot	Troup, Pennan and Lion's Head SPA	398	487
	Buchan Ness to Collieston Coast SPA	377	465
	Fowlsheugh SPA	298	380
	East Caithness Cliffs SPA	402	492
Razorbill	Troup, Pennan and Lion's Head SPA	248	311
	Buchan Ness to Collieston Coast SPA	234	296
	Fowlsheugh SPA	187	239
	East Caithness Cliffs SPA	249	316
Puffin	Troup, Pennan and Lion's Head SPA	238	291
	Buchan Ness to Collieston Coast SPA	235	280
	Fowlsheugh SPA	182	230
	East Caithness Cliffs SPA	249	302

16 Within the simulations, if individuals susceptible to distributional responses were assigned a foraging location within the Offshore Array Area they were displaced into the buffer.

17 Barrier navigation was set to 'Perimeter' for all simulations following the examples provided by Searle *et al.* (2018) and Mobbs *et al.* (2018). This assumes that displaced or barrier affected individuals will travel in a straight line until they encounter the Offshore Array Area or border and cannot travel through. Once these areas are encountered individuals will follow the perimeter of these areas until they can travel in a straight line again. All individuals that encounter land will use the A* pathfinding option to find the shortest route around the land mass.

18 For each SPA two paired simulations were run, one for each scenario. The first scenario simulated the impacts of the Salamander Project alone (hereby referred to as the 'Project Alone' scenario) and the second scenario simulated the impacts of the Salamander Project in combination with EOWDC, the Moray Firth Wind Farms, Hywind and Kincardine (hereby referred to as the 'Cumulative' scenario).

2.2.4 Bioenergetics in the model

19 During each timestep of a simulation, adult birds were assigned a Daily Energy Expenditure (DEE). For the first timestep, the DEE was selected from a normal distribution of DEE values stored within SeabORD and for subsequent timesteps the DEE was set to match the energy expended by the individual in the previous timestep. DEE of chicks was kept constant throughout the simulation.

20 The daily activity budget of each adult consisted of four behaviours – foraging, flight, time spent at the colony and time spent on the sea surface. The time spent flying and foraging to meet individuals' Daily Energy Requirements (DER) were generated by SeabORD for each individual, with a minimum of one hour assigned to time spent on the sea surface for each timestep. The remaining time was assigned to time spent at the colony. Once the time spent carrying out each activity was generated, the DEE for the timestep could be calculated. The DER of each adult was calculated by combining the energy gained (DEE divided by an assimilation efficiency) and half of the DEE of chicks, as it was assumed that both parents contributed equally. If DEE was greater than DER, then adults would lose body mass.

21 At the end of each timestep the current mass of each individual was compared to their mass at the beginning of the season. This information was used to determine the behaviours carried by both adults and chicks as shown in Table 5. Chick mortality may occur during a timestep if the time an adult spends away from the nest is greater than the threshold determined by SeabORD. Predation risk was modelled to increase as the time left unattended increased until the specified threshold for each species.

Table 5 Behaviours of each individual determined by body mass

Species	Age	% of initial mass	Behaviour for next timestep
All	Adult	>90	Stays at nest
All	Adult	80-90	Leaves chick unattended to reach DER
All	Adult	<80	Abandon chick*
All	Adult	<60	Assumed dead
All	Chick	<60	Assumed dead
Puffin	Chick	60 – 80	Chick to burrow opening, increased mortality from predation or environmental conditions

**If one parent abandons the chick, the other parent will also abandon the chick despite its own body mass.*

2.2.5 Annual mortalities predicted by SeabORD

22 To determine the annual survival of adults, the mass at the end of the breeding season of each individual is used. SeabORD assumes that there is a logistic relationship between mass at the end of the breeding season and the probability of adult survival during winter (Searle *et al.*, 2018). This requires two parameters, the 'baseline' survival and the slope associated with the impact of a change in adult mass upon the probability of survival. Both parameters are set by SeabORD.

23 The baseline survival is equal to the mean value of sites with observed data on annual adult survival and has been collated by the creators of SeabORD. Likewise, so is the shape of the logistic curve, which explains the relation between survival probability and body weight. Annual mortality is predicted by

SeabORD and results are presented in Table 6, Table 10, Table 14 and Table 18 for the Project Alone Scenario and Table 8, Table 12, Table 16 and Table 20 for the Cumulative Scenario in Section 3.

24 For species where less than 100% of the population were simulated, the number of mortalities outputted by SeabORD were scaled up to 100% using a scaling factor of 1/proportion of the population simulated. This scaling factor assumes that the number of mortalities has a linear relationship with the proportion of the population simulated.

3 Results

3.1 Kittiwake

3.1.1 Project Alone simulations

Table 6 **Modelled impacts of the Project Alone scenario on adult kittiwake during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.3**

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the Salamander Project
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Troup, Pennan and Lion's Head SPA	Poor	2730.3	25.329	9101.000	2730.5	25.242	9101.667	0.667	0.003
	Moderate	1884.5	23.764	6281.667	1884.6	23.778	6282.000	0.333	0.002
	Good	1155.1	21.398	3850.333	1155.3	21.292	3851.000	0.667	0.003
Buchan Ness to Collieston Coast SPA	Poor	2762.5	45.403	9208.333	2763.0	45.714	9210.000	1.667	0.007
	Moderate	1882.8	29.555	6276.000	1883.0	29.657	6276.667	0.667	0.003
	Good	1149.1	17.084	3830.333	1149.4	17.245	3831.333	1.000	0.004
Fowlsheugh SPA	Poor	3054.3	130.338	10181.000	3054.6	130.268	10182.000	1.000	0.004
	Moderate	2012.4	87.835	6708.000	2012.3	87.261	6707.667	-0.333	-0.001
	Good	1151.4	58.765	3838.000	1151.7	58.86	3839.000	1.000	0.004
East Caithness Cliffs SPA	Poor	6337.3	120.435	21124.33	6337.4	120.536	21124.67	0.333	0.001

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the Salamander Project
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
	Moderate	4354.7	108.281	14515.67	4354.7	108.281	14515.67	0.000	0.000
	Good	2707.8	95.701	9026.00	2707.8	95.701	9026.00	0.000	0.000

Table 7 **Kittiwake SeabORD outputs for the Project Alone scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period**

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	6370.000	-	6778.000	-	8224.000	-	14688.000	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	371.640	0.000	373.055	0.000	372.089	0.000	372.795	0.000
	Wind farm present	371.640	0.000	373.055	0.000	372.089	0.000	372.795	0.000
Final adult body mass (g)	No wind farm present	337.093	3.028	339.362	3.980	338.198	3.460	337.956	2.980
	Wind farm present	337.090	3.026	339.357	3.978	338.194	3.454	337.947	2.980
Difference between total distance flown with and without wind farms (km)	-	0.431	0.589	0.713	0.565	-0.005	0.179	-0.042	0.157

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Difference in the total number of trips carried out with and without wind farms	-	-0.003	0.007	-0.011	0.008	-0.006	0.004	-0.001	0.001
Chicks not surviving the season	No wind farm present	1807.8	914.156	1795.8	1014.138	2292.9	1128.476	4335.7	2087.354
	Wind farm present	1808.5	913.999	1797	1014.308	2294.2	1127.695	4336.4	2086.887
Additional mortality of chicks with wind farm present (%)	-	0.022	0.026	0.035	0.048	0.031	0.034	0.01	0.013
Number of adults directly impacted by the wind farm (displaced or barriered)	-	490	-	856	-	459	-	241	-

3.1.2 Cumulative simulations

Table 8 **Modelled impacts of the Cumulative Scenario on adult kittiwake during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.3**

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of wind farms
		No wind farms present			Wind farms present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Troup, Pennan and Lion's Head SPA	Poor	2730.300	25.329	9101.000	2754.200	25.477	9180.667	79.667	0.375
	Moderate	1884.500	23.764	6281.667	1903.000	22.296	6343.333	61.667	0.290
	Good	1155.100	21.398	3850.333	1160.100	20.599	3867.000	16.667	0.078
Buchan Ness to Collieston Coast SPA	Poor	2762.500	45.403	9208.333	2791.400	45.191	9304.667	96.333	0.426
	Moderate	1882.800	29.555	6276.000	1912.400	26.269	6374.667	98.667	0.437
	Good	1149.100	17.084	3830.333	1176.900	17.773	3923.000	92.667	0.410
Fowlsheugh SPA	Poor	3054.300	130.338	10181.000	3134.700	98.148	10449.000	268.000	0.954
	Moderate	2012.400	87.835	6708.000	2068.100	69.580	6893.667	185.667	0.661
	Good	1151.400	58.765	3838.000	1193.700	42.703	3979.000	141.000	0.502
East Caithness Cliffs SPA	Poor	6337.300	120.435	21124.333	6399.200	159.688	21330.667	206.333	0.421
	Moderate	4354.700	108.281	14515.667	4403.000	136.449	14676.667	161.000	0.329
	Good	2707.800	95.701	9026.000	2740.000	118.938	9133.333	107.333	0.219

Table 9 **Kittiwake SeabORD outputs for the Project alone scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period**

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	6370	-	6778	-	8424	-	14688	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	371.640	0.000	373.055	0.000	372.089	0.000	372.795	0.000
	Wind farm present	371.640	0.000	373.055	0.000	372.089	0.000	372.795	0.000
Final adult body mass (g)	No wind farm present	337.093	3.028	339.362	3980.000	338.198	3.460	337.946	2.980
	Wind farm present	336.738	2.901	338.703	3.970	337.050	2.919	337.424	2.531
Difference between total distance flown with and without wind farms (km)	-	-14.664	5.019	-79.349	21.957	114.471	12.594	55.455	21.006
Difference in the total number of trips carried out with and without wind farms	-	-0.498	0.056	-1.142	0.221	-3.077	0.146	-1.156	0.259
Chicks not surviving the season	No wind farm present	1807.800	914.156	1795.800	1014.138	2292.900	1128.476	4335.700	2087.354
	Wind farm present	1885.900	878.607	1932.300	934.336	2717.200	966.814	4736.500	1942.215

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Additional mortality of chicks with wind farm present (%)	-	2.452	1.178	4.028	2.366	10.074	4.185	5.458	2.441
Number of adults directly impacted by the wind farm (displaced or barriered)	-	1862	-	1973	-	2510	-	4369	-

3.2 Guillemot

3.2.1 Project Alone simulations

Table 10 Modelled impacts of the Project Alone scenario on adult guillemot during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.3

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the Salamander Project
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Troup, Pennan and Lion's Head SPA	Poor	2387.700	43.372	7959.000	2387.500	43.712	7958.333	-0.667	-0.002
	Moderate	1202.400	28.837	4008.000	1202.300	28.737	4007.667	-0.333	-0.001
	Good	948.300	17.410	3161.000	948.200	18.402	3160.667	-0.333	-0.001
Buchan Ness to Collieston Coast SPA	Poor	2700.800	87.930	9002.667	2704.000	87.937	9013.333	10.667	0.027
	Moderate	1336.500	47.531	4455.000	1338.400	46.600	4461.333	6.333	0.016
	Good	1064.900	34.047	3549.667	1066.600	33.669	3555.333	5.667	0.014
Fowlsheugh SPA	Poor	4165.000	148.961	13883.333	4165.500	148.074	13885.000	1.667	0.002
	Moderate	1917.500	82.357	6391.667	1917.900	82.120	6393.000	1.333	0.001
	Good	1499.900	65.431	4999.667	1500.200	65.142	5000.667	1.000	0.001
East Caithness Cliffs SPA	Poor	15472.200	159.026	51574.000	15472.100	159.045	51573.667	-0.333	0.000
	Moderate	7942.000	59.176	26473.333	7941.900	59.115	26473.000	-0.333	0.000

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the Salamander Project
		No wind farm present			Wind farm present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
	Good	6079.300	49.013	20264.333	6079.400	48.781	20264.667	0.333	0.000

Table 11 **Guillemot SeabORD outputs for the Project Alone Scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period**

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	9648.000	-	11800.000	-	28072.000	-	59990.000	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	919.644	0.000	920.297	0.000	920.037	0.000	920.153	0.000
	Wind farm present	919.644	0.000	920.927	0.000	920.037	0.000	920.153	0.000
Final adult body mass (g)	No wind farm present	852.443	14.957	851.393	14.240	855.441	14.052	850.982	14.137
	Wind farm present	853.441	14.952	851.260	14.200	855.428	14.051	850.981	14.137
Difference between total distance flown with and without wind farms (km)	-	-0.382	0.132	2.303	0.396	0.269	0.038	0.028	0.012

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Difference in the total number of trips carried out with and without wind farms	-	-0.006	0.001	0.004	0.003	0.001	0.000	0.000	0.000
Chicks not surviving the season	No wind farm present	1210.000	816.666	1613.400	1073.220	3363.600	2195.805	8444.000	5410.393
	Wind farm present	1210.400	817.348	1621.800	1075.209	3364.900	2195.212	8444.900	5410.179
Additional mortality of chicks with wind farm present (%)	-	0.008	0.042	0.142	0.098	0.009	0.013	0.003	0.003
Number of adults directly impacted by the wind farm (displaced or barriered)	-	773	-	2053	-	1039	-	330	-

3.2.2 Cumulative simulations

Table 12 Modelled impacts of the Cumulative Scenario on adult guillemot during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.3

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of wind farms
		No wind farms present			Wind farms present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Troup, Pennan and Lion's Head SPA	Poor	2387.700	43.372	7959.000	2410.300	27.949	8034.333	75.333	0.234
	Moderate	1202.400	28.837	4008.000	1216.500	30.068	4055.000	47.000	0.146
	Good	948.300	17.410	3161.000	963.600	12.703	3212.000	51.000	0.159
Buchan Ness to Collieston Coast SPA	Poor	2700.800	87.930	9002.667	2781.900	66.434	9273.000	270.333	0.687
	Moderate	1336.500	47.531	4455.000	1395.800	35.972	4652.667	197.667	0.503
	Good	1064.900	34.047	3549.667	1117.100	30.921	3723.667	174.000	0.442
Fowlsheugh SPA	Poor	4165.000	148.961	13883.333	4418.900	179.263	14729.667	846.333	0.904
	Moderate	1917.500	82.357	6391.667	2064.800	103.569	6882.667	491.000	0.525
	Good	1499.900	65.431	4999.667	1622.800	80.440	5409.333	409.667	0.438
East Caithness Cliffs SPA	Poor	15472.200	159.026	51574.000	16304.900	170.714	54349.667	2775.667	1.388
	Moderate	7942.000	59.176	26473.333	8466.300	175.840	28221.000	1747.667	0.874
	Good	6079.300	49.013	20264.333	6510.800	126.378	21702.667	1438.333	0.719

Table 13 **Guillemot SeabORD outputs for the Cumulative scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period**

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	9648.000	-	11800.000	-	28072.000	-	59990.000	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farms present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	919.644	0.000	920.297	0.000	920.037	0.000	920.153	0.000
	Wind farms present	919.644	0.000	920.297	0.000	920.037	0.000	920.153	0.000
Final adult body mass (g)	No wind farm present	852.443	14.957	851.393	14.140	855.441	14.052	850.982	14.137
	Wind farms present	851.690	14.545	849.114	13.467	851.070	13.075	845.599	12.558
Difference between total distance flown with and without wind farms (km)	-	-4.987	2.060	-12.236	5.105	63.010	10.452	107.815	23.853

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Difference in the total number of trips carried out with and without wind farms	-	-0.221	0.018	-0.582	0.037	-1.186	0.063	-0.116	0.113
Chicks not surviving the season	No wind farm present	1210.000	816.666	1613.400	1073.220	3363.600	2195.805	8444.000	5410.393
	Wind farms present	1338.600	805.787	2117.500	1001.317	4666.600	2271.287	11030.600	6065.907
Additional mortality of chicks with wind farm present (%)	-	2.666	0.375	8.544	1.278	9.283	1.085	8.623	2.704
Number of adults directly impacted by the wind farm (displaced or barriered)	-	4644.000	-	6362.000	-	15545.000	-	35917.000	-

3.3 Razorbill

3.3.1 Project Alone simulations

Table 14 Modelled impacts of the Project Alone Scenario on adult razorbill during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.3

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of the Salamander Project
		No wind farms present			Wind farms present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Troup, Pennan and Lion's Head SPA	Poor	478.800	10.633	1596.000	478.600	11.286	1595.333	-0.667	-0.011
	Moderate	282.800	9.402	942.667	283.100	9.689	943.667	1.000	0.017
	Good	170.300	4.644	567.667	170.600	4.600	568.667	1.000	0.017
Buchan Ness to Collieston Coast SPA	Poor	577.200	30.875	1924.000	577.000	30.735	1923.333	-0.667	-0.009
	Moderate	323.500	19.449	1078.333	324.500	19.716	1081.667	3.333	0.043
	Good	189.800	7.540	632.667	190.200	7.480	634.000	1.333	0.017
Fowlsheugh SPA	Poor	935.700	63.950	3119.000	935.800	63.979	3119.333	0.333	0.002
	Moderate	461.500	27.383	1538.333	461.400	27.334	1538.000	-0.333	-0.002
	Good	244.000	16.607	813.333	244.100	16.690	813.667	0.333	0.002
East Caithness Cliffs SPA	Poor	3475.500	24.587	11585.000	3475.500	24.587	11585.000	0.000	0.000
	Moderate	2037.700	15.628	6792.333	2037.700	15.628	6792.333	0.000	0.000
	Good	1096.100	24.365	3653.667	1096.000	24.290	3653.333	-0.333	-0.001

Table 15 **Razorbill SeabORD outputs for the Project Alone Scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period**

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	1816.000	-	2340.000	-	5654.000	-	12104.000	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	583.043	0.000	583.475	0.000	582.896	0.000	582.204	0.000
	Wind farm present	583.043	0.000	583.475	0.000	582.896	0.000	582.204	0.000
Final adult body mass (g)	No wind farm present	539.336	9.777	538.856	9.203	540.355	8.857	536.817	9.307
	Wind farm present	539.316	9.781	538.768	9.187	540.350	8.852	536.816	9.306
Difference between total distance flown with and without wind farms (km)	-	-0.268	0.367	2.674	0.426	0.321	0.073	0.048	0.019

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Difference in the total number of trips carried out with and without wind farms	-	-0.005	0.005	0.005	0.005	0.000	0.001	0.000	0.000
Chicks not surviving the season	No wind farm present	205.900	149.759	319.000	226.024	640.800	423.793	1693.000	1129.706
	Wind farm present	206.200	149.838	320.700	226.072	642.300	424.562	1693.100	1129.596
Additional mortality of chicks with wind farm present (%)	-	0.033	0.128	0.145	0.081	0.053	0.042	0.002	0.005
Number of adults directly impacted by the wind farm (displaced or barriered)	-	159.000	-	412.000	-	241.000	-	84.000	-

3.3.2 Cumulative simulations

Table 16 Modelled impacts of the Cumulative Scenario on adult razorbill during 'poor', 'moderate' and 'good' environmental conditions. Scaled mortalities were calculated using a scaling factor of 1/0.3

SPA	Environmental conditions	Adults not surviving the year						Difference in scaled mortalities between scenarios	Additional mortality (%) caused by the presence of wind farms
		No wind farms present			Wind farms present				
		Mean	SD	Scaled mortalities	Mean	SD	Scaled mortalities		
Troup, Pennan and Lion's Head SPA	Poor	478.800	10.633	1596.000	486.200	9.077	1620.667	24.667	0.407
	Moderate	282.800	9.402	942.667	291.800	10.250	972.667	30.000	0.496
	Good	170.300	4.644	567.667	173.200	4.417	577.333	9.667	0.160
Buchan Ness to Collieston Coast SPA	Poor	577.200	30.875	1924.000	599.800	25.407	1999.333	75.333	0.966
	Moderate	323.500	19.449	1078.333	340.100	15.531	1133.667	55.333	0.709
	Good	189.800	7.540	632.667	201.600	6.569	672.000	39.333	0.504
Fowlsheugh SPA	Poor	935.700	63.950	3119.000	1034.200	51.805	3447.333	328.333	1.742
	Moderate	461.500	27.383	1538.333	522.300	23.300	1741.000	202.667	1.075
	Good	244.000	16.607	813.333	277.500	20.463	925.000	111.667	0.593
East Caithness Cliffs SPA	Poor	3475.500	24.587	11585.000	3724.400	105.044	12414.667	829.667	2.056
	Moderate	2037.700	15.628	6792.333	2216.600	81.833	7388.667	596.333	1.478
	Good	1096.100	24.365	3653.667	1205.100	63.801	4017.000	363.333	0.901

Table 17 **Razorbill SeabORD outputs for the Cumulative Scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period**

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	1816.000	-	2340.000	-	5654.000	-	12104.000	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farms present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	583.043	0.000	583.475	0.000	582.896	0.000	582.204	0.000
	Wind farms present	583.043	0.000	583.475	0.000	582.896	0.000	582.204	0.000
Final adult body mass (g)	No wind farm present	539.336	9.777	538.475	9.203	540.355	8.857	536.817	9.307
	Wind farms present	538.511	9.521	537.359	8.802	537.008	8.074	533.173	7.973
Difference between total distance flown with and without wind farms (km)	-	-4.635	4.972	-7.375	3.896	73.218	9.424	119.180	24.933
Difference in the total number of trips carried out with and without wind farms	-	-0.236	0.038	-0.490	0.043	-1.358	0.045	-0.181	0.090

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Chicks not surviving the season	No wind farm present	205.900	149.759	319.000	226.024	640.800	423.793	1693.000	1129.706
	Wind farms present	232.700	145.691	401.700	212.790	920.500	449.008	2245.800	1275.515
Additional mortality of chicks with wind farm present (%)	-	2.952	0.646	7.068	1.316	9.894	1.767	9.134	3.109
Number of adults directly impacted by the wind farm (displaced or barriered)	-	910.000	-	1249.000	-	3108.000	-	7264.000	-

3.4 Puffin

3.4.1 Project Alone simulations

Table 18 Modelled impacts of the Project Alone scenario on adult puffin during 'poor', 'moderate' and 'good' environmental conditions

SPA	Environmental Conditions	Adults not surviving the year				Difference in mortalities between scenarios	Additional mortality (%) caused by the presence of the Salamander Project
		No wind farm present		Wind farm present			
		Mean	SD	Mean	SD		
Troup, Pennan and Lion's Head SPA	Poor	10.2	1.033	10.2	1.033	0.0	0.00
	Moderate	6.9	0.316	6.9	0.316	0.0	0.00
	Good	3.2	1.135	3.2	1.135	0.0	0.00
Buchan Ness to Collieston Coast SPA	Poor	40.6	1.350	40.4	1.265	-0.2	-0.11
	Moderate	26.5	0.972	26.5	0.972	0.0	0.00
	Good	14.4	0.966	14.4	0.966	0.0	0.00
Fowlsheugh SPA	Poor	14.5	0.972	14.5	0.972	0.0	0.00
	Moderate	9.6	0.843	9.6	0.843	0.0	0.00
	Good	3.1	1.101	3.1	1.101	0.0	0.00
East Caithness Cliffs SPA	Poor	54.8	1.033	54.8	1.033	0.0	0.00
	Moderate	27.3	2.111	27.3	2.111	0.0	0.00
	Good	21.2	1.932	21.2	1.932	0.0	0.00

Table 19 Puffin SeabORD outputs for the Project Alone Scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	30.000	-	182.000	-	178.000	-	190.000	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	395.751	0.000	392.144	0.000	395.667	0.000	393.297	0.000
	Wind farm present	395.751	0.000	392.144	0.000	395.677	0.000	393.297	0.000
Final adult body mass (g)	No wind farm present	369.135	8.906	369.585	6.391	377.273	6.601	371.073	7.407
	Wind farm present	369.125	8.916	369.548	6.382	377.265	6.615	371.067	7.410
Difference between total distance flown with and without wind farms (km)	-	2.427	1.651	3.288	1.654	1.531	1.363	0.254	0.716

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Difference in the total number of trips carried out with and without wind farms	-	0.007	0.038	-0.003	0.013	-0.006	0.011	0.000	0.007
Chicks not surviving the season	No wind farm present	1.200	0.422	4.500	1.269	3.300	2.111	2.600	1.265
	Wind farm present	1.200	0.422	4.500	1.269	3.300	2.111	2.600	1.265
Additional mortality of chicks with wind farm present (%)	-	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Number of adults directly impacted by the wind farm (displaced or barriered)	-	5.000	-	51.000	-	25.000	-	7.000	-

3.4.2 Cumulative simulations

Table 20 Modelled impacts of the Cumulative Scenario on adult puffin during 'poor', 'moderate' and 'good' environmental conditions

SPA	Environmental Conditions	Adults not surviving the year				Difference in mortalities between scenarios	Additional mortality (%) caused by the presence of wind farms
		No wind farm present		Wind farm present			
		Mean	SD	Mean	SD		
Troup, Pennan and Lion's Head SPA	Poor	10.200	1.033	11.300	0.823	1.100	3.667
	Moderate	6.900	0.316	7.300	0.483	0.400	1.333
	Good	3.200	1.135	3.500	1.080	0.300	1.000
Buchan Ness to Collieston Coast SPA	Poor	40.600	1.350	44.000	1.247	3.400	1.868
	Moderate	26.500	0.972	30.500	1.581	4.000	2.198
	Good	14.400	0.966	17.200	1.814	2.800	1.538
Fowlsheugh SPA	Poor	14.500	0.972	19.700	1.767	5.200	2.921
	Moderate	9.600	0.843	12.300	0.949	2.700	1.517
	Good	3.100	1.101	4.100	1.287	1.000	0.562
East Caithness Cliffs SPA	Poor	54.800	1.033	60.200	2.348	5.400	2.842
	Moderate	27.300	2.111	31.200	3.490	3.900	2.053
	Good	21.200	1.932	26.400	3.204	5.200	2.737

Table 21 Puffin SeabORD outputs for the Cumulative Scenario. Impacted adults refer to any adult that experienced distributional responses at least once during the simulation. Where breeding season is referenced, this applies only to the chick-rearing period

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	-	30	-	182	-	178	-	190	-
Adult survival at end of breeding season (%)	No wind farm present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Wind farms present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	No wind farm present	395.751	0.000	392.144	0.000	395.677	0.000	393.297	0.000
	Wind farms present	395.751	0.000	392.144	0.000	395.677	0.000	393.297	0.000
Final adult body mass (g)	No wind farm present	369.135	8.906	369.585	6.391	377.273	6.601	371.073	7.407
	Wind farms present	364.251	8.823	364.905	6.587	366.475	8.170	365.902	8.908
Difference between total distance flown with and without wind farms (km)	-	-4.132	78.847	-56.873	21.144	446.780	14.995	374.033	27.143

Output variable	Scenario (no wind farm present/wind farm present)	Troup, Pennan and Lion's Head SPA		Buchan Ness to Collieston Coast SPA		Fowlsheugh SPA		East Caithness Cliffs SPA	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Difference in the total number of trips carried out with and without wind farms	-	-0.947	0.936	-1.038	0.276	-4.010	0.368	-0.137	0.269
Chicks not surviving the season	No wind farm present	1.200	0.422	4.500	1.269	3.300	2.111	2.600	1.265
	Wind farms present	2.300	1.636	9.600	3.806	11.600	7.763	5.500	4.552
Additional mortality of chicks with wind farm present (%)	-	7.333	8.578	5.604	3.041	9.326	6.743	3.053	3.695
Number of adults directly impacted by the wind farm (displaced or barriered)	-	17	-	100	-	108	-	117	-

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