LLŶR FLOATING OFFSHORE WIND PROJECT

Llŷr 1 Floating Offshore Wind Farm

Environmental Statement

Volume 6: Appendix 22D, Annex C – SeabORD Displacement Modelling

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Prepared by: Llŷr Floating Wind Ltd

FLOVENTIS ENERGY

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Acronyms and abbreviations

Acronym or Abbreviation	Definition	Acronym or Abbreviation	Definition
%	Percentage	km	Kilometre
CEH	Centre for Ecology and Hydrology	NRW (A)	Natural Resources Wales Advisory
DEE	Daily Energy Expenditure	ORDs	Offshore Renewable Energy Developments
DER	Daily Energy Requirements	SD	Standard deviation
g	Grams	SPA	Special Protection Area
GPS	Global Positioning System	SSSI	Sites of Special Scientific Interest
HiDef	HiDef Aerial Surveying Ltd	SSSP	Skomer, Skokholm and the Seas off Pembrokeshire
JNCC	Joint Nature Conservation Committee		

Glossary of project terms

Term	Definition
Barrier effects	The impact of the offshore windfarm on the flight paths of individual seabirds. For example, a barrier-effected seabird will navigate around the windfarm to avoid travelling through the development.
Baseline survival	The average number of adults simulated to survive the chick-rearing period when no windfarms are present.
Daily Energy Expenditure (DEE)	Energy expended by an individual over a 24 hour period (kJ/day).
Daily Energy Requirement (DER)	Energy required by an individual over a 24 hour period to maintain health (kJ/day).
Distance decay	A type of function, in this case used to generate seabird densities, which assumes that as the distance from the colony increases the density of seabirds decreases.
Standard Deviation (SD)	A measure of the amount of variation or dispersion of a set of values.
Windfarm border	An area surrounding the wind farm which birds impacted by barrier effects will not be able to fly through.
Windfarm buffer	An area surrounding the windfarm which displaced seabirds will forage within of their original foraging location is within the windfarm footprint.
Windfarm footprint	The area containing the proposed development.
The Applicant	The developer of the Project, Llŷr Floating Wind Ltd.
Array	All wind turbine generators, inter array cables, mooring lines, floating sub-structures and supporting subsea infrastructure within the Array Area, as defined, when considered collectively, excluding the offshore export cable(s).
Array Area	The area within which the wind turbine generators, inter array cables, mooring lines, floating sub-structures and supporting subsea infrastructure will be located.
Floventis Energy	A joint venture company between Cierco Ltd and SBM Offshore Ltd of which Llŷr Floating Wind Limited is a wholly owned subsidiary.

Term	Definition
Landfall	The location where the offshore export cable(s) from the Array Area, as defined, are brought onshore and connected to the onshore export cables (as defined) via the transition joint bays.
Llŷr 1	The proposed Project, for which the Applicant is applying for Section 36 and Marine Licence consents. Including all offshore and onshore infrastructure and activities, and all project phases.
Marine Licence	A licence required under the Marine and Coastal Access Act 2009 for marine works which is administered by Natural Resources Wales (NRW) Marine Licensing Team on behalf of the Welsh Ministers.
Offshore Development Area	The footprint of the offshore infrastructure and associated temporary works, comprised of the Array Area and the Offshore Export Cable Corridor, as defined, that forms the offshore boundary for the S36 Consent and Marine Licence application.
Offshore Export Cable	The cable(s) that transmit electricity produced by the WTGs to landfall.
Offshore Export Cable Corridor (OfECC)	The area within which the offshore export cable circuit(s) will be located, from the Array Area to the Landfall.
Onshore Development Area	The footprint of the onshore infrastructure and associated temporary works, comprised of the Onshore Export Cable Corridor and the Onshore Substation, as defined, and including new access routes and visibility splays, that forms the onshore boundary for the planning application.
Onshore Export Cable(s)	The cable(s) that transmit electricity from the landfall to the onshore substation.
Onshore Export Cable Corridor (OnECC)	The area within which the onshore export cable circuit(s) will be located.
proposed Project	All aspects of the Llŷr 1 development (i.e. the onshore and offshore components).
Onshore Substation	Located within the Onshore Development Area, converts high voltage generated electricity into low voltage electricity that can be used for the grid and domestic consumption.
Section 36 consent	Consent to construct and operate an offshore generating station, under Section 36 (S.36) of the Electricity Act 1989. This includes deemed planning permission for onshore works.

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22. APPENDIX 22D: ANNEX C – SEABORD DISPLACEMENT MODELLING

22.1 Introduction

1. This **Appendix 22D: Annex C – SeabORD Displacement Modelling** presents results from SeabORD modelling undertaken for the three auk species (guillemot, razorbill and puffin) being assessed for displacement, as well as for kittiwake for Joint Nature Conservation Committee's (JNCC) information (as requested during pre-application discussion; please see **Table 22-5** of **Chapter 22: Marine Ornithology**).
2. SeabORD is an individual-based modelling method created by the Centre for Ecology and Hydrology (CEH) to model the energetic consequences to seabirds from displacement and / or barrier effects occurring in relation to offshore renewable energy developments (ORDs). SeabORD investigates these energetic consequences by simulating bird flight paths of individual birds from focal breeding colonies (usually Special Protection Areas (SPAs) or Sites of Special Scientific Interest (SSSIs)), in response to the presence of single or multiple wind farms located within each species foraging range (Searle *et al.,* 2014; 2018; 2019).
3. The information from these simulations is then used in bioenergetic equations which estimate the percentage body mass loss of the birds and therefore their survival.

22.1.1. Scope of Work

4. SeabORD has been used to model two scenarios for the proposed Project (i) Llŷr Project-alone and (ii) Llŷr, in combination with Erebus and White Cross wind farms. All three wind farms in the latter scenario may be anticipated to have potential impacts on the guillemot, razorbill, puffin and kittiwake populations at Skomer, Skokholm and the Seas off Pembrokeshire (SSSP) SPA, as well as in relation to guillemot at Castlemartin Range SSSI. In this respect, Erebus is consented, the White Cross consent application has been submitted for determination and Llŷr is the subject of this report due for submission.
5. This SeabORD modelling has been undertaken voluntarily by HiDef Aerial Surveying Ltd ('HiDef') on behalf of the Applicant to explore the potential risk from the three small-scale demonstrator projects noted, lying in relative proximity to each other off the Pembrokeshire coast (Llŷr and Erebus) and in the Bristol Channel (White Cross). In this regard the modelling acts as a 'trial run' to familiarise Natural Resources Wales Advisory (NRW (A)) and JNCC with the method and so they can consider whether it would be worth recommending it for the future offshore wind proposals upcoming in this area (part of the Round 4 commercial leasing round).
6. This focus has been kept because the apportioning weightings indicate that the majority of displacement impact arising from these three projects (when assessed using displacement matrices) would be assigned against SSSP SPA (for the four species being modelled) and Castlemartin SSSI (for its designated guillemot feature) (**Appendix 22B: Marine Ornithology Colony Apportioning**).
7. As SeabORD has a maximum number of SPAs (six) and wind farms (six) that can be encompassed in any scenario, it is not clear what benefit there would be in widening the scope beyond what has been undertaken. The aim of the work is to explore whether the upper range of mortality rates (5-10%) recommended for use in displacement matrices by NRW (A) and JNCC are representative of likely impact.

22.1.2. Context for the Modelling

8. Note that the non-designated guillemot, razorbill and puffin populations at Castlemartin Range SSSI have also been included in the modelling to make it more representative. Increased

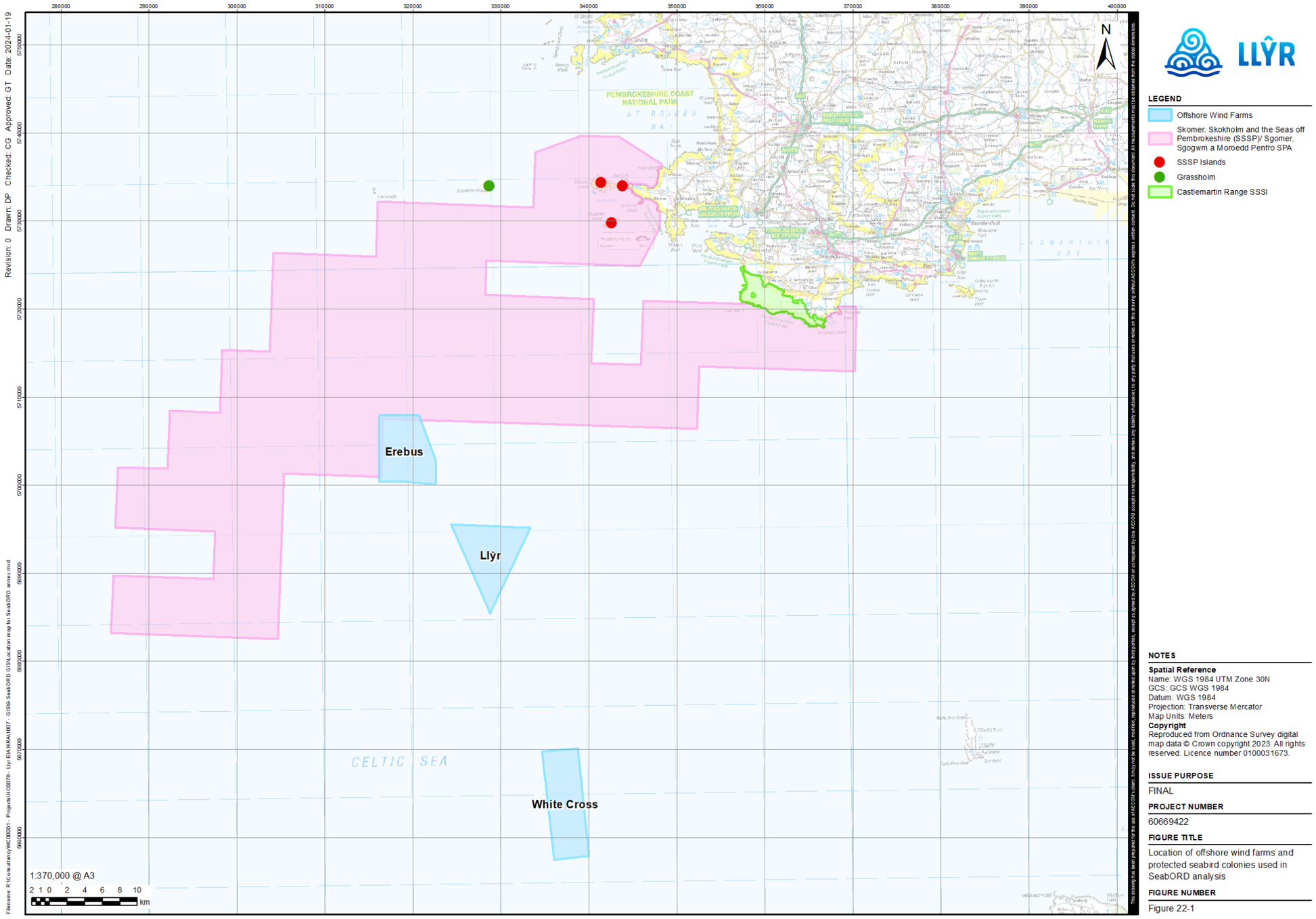
competition between individuals as a result of displacement is one aspect addressed under SeabORD, where such competition may affect the bioenergetics of the individuals modelled.

9. **Annex** C, Figure 22D-1 illustrates the location of the focal wind farms and the respective seabird colonies. Note that Grassholm SPA is included on the map solely for contextual information (as gannet are not a species currently addressed by the SeabORD model).

10. For each species and colony, 'single' simulations were run to determine the correct prey range to be used in the final 'paired' simulations and the same input values were used for both Llŷr Project-alone and the in combination simulations, with the only difference being the number of wind farms included in simulations.

11. Following the available guidance, once these 'single' simulations have been undertaken, two sets of 10 'paired' simulations are run to model the displacement and barrier impacts, one set for each wind farm scenario modelled; Project-alone and cumulative (Mobbs *et al.,* 2018, Searle *et al.,* 2018).

12. Further detail on modelling method is provided in **Section 22.2** with all model outputs and a summary of the results presented in **Section 22.3**.



Annex C, Figure 22D-1. Location of offshore wind farms and protected seabird colonies modelled in the SeabORD analysis.

22.2 Methods

13. The seabORD model operates by simulating each adult individually to determine whether or not they will survive the chick-rearing period of the breeding season. Annual adult mortality can then be determined using the condition of adults at the end of the breeding season to ascertain their likelihood of survival. Each 'paired' simulation allows the user to simulate two breeding seasons with only one difference – the presence or absence of wind farm(s) – which allows for a comparison between both scenarios and an estimate of the possible impact of the proposed developments.

14. Each colony included in the simulation was represented by the mid-point of coastline at the colony and all individuals from each colony were simulated to start flight paths from these points. For island colonies a point on the side closest to the nearest wind farm was selected. The points used for each colony and the number of pairs of each species present at each colony are presented in **Table 22D-1**.

15. The most recent colony counts were used to calculate the total number of pairs for each species at each colony. For all species, Skomer and Skokholm colony counts were collected in 2021 and Middleholm colony counts were collected in 2022. The colony counts most contemporaneous with the survey data for guillemot and razorbills at Castlemartin were collected in 2021 – 2022, whereas puffin colony counts at Castlemartin were collected 2021.

Table 22D-1. Colony coordinates and the number of pairs of each species used during simulations

Colony	Longitude	Latitude	Number of pairs			
			Guillemot	Razorbill	Kittiwake	Puffin
Skomer	-5.29553	51.72895	18,128	5,473	1439	10,848
Skokholm	-5.27044	51.69567	3,394	2,248	0	5,622
Middleholm	-5.26296	51.73373	528	729	0	339
Castlemartin	-5.00330	51.60764	11,296	1,001	0	7

22.2.3. Model Assumptions

16. SeabORD provides two options for predicting seabird abundance and distributions. The first option uses Global Positioning System (GPS) tracking data to determine distributions, whereas the second option uses a distance decay function. Insufficient GPS data is available for these species at either the SSSP SPA colonies or at Castlemartin Range SSSI, therefore, the distance decay function was the option chosen for this study. This function relies on generic information related to foraging range (see **Table 22D-2**) with modelled 'distance decay' assuming that the larger the distance from the colony, the lower the density of foraging birds.

- Prey distribution was assumed to be uniform as the second option to model these distributions requires GPS data, which was unavailable.
- It was also assumed that all individuals that are susceptible to displacement are also impacted by barrier effects.
- The model also assumed that each breeding pair had one chick during the chick-rearing period. This is likely for auk species, however kittiwake are expected to have more than one chick. This could lead to an underestimation of the effort required by adults during the simulation and an overestimation of the prey provided to each chick during the simulation. Thus, the model may be underestimating adult and chick mortality for kittiwakes.

22.2.4. Input Variables

17. The input values used within the SeabORD modelling are shown in **Table 22D-2**. The same values were used for both wind farm scenarios to ensure any differences in results can be attributed to the combination of wind farms present.

18. The area used within the simulation is referred to as the 'region'. During the simulations, individuals will only be able to travel and forage within the boundaries of the region. To determine the region for each species, a buffer around each colony point was created using the mean maximum ('mean max') foraging range plus one standard deviation (SD) plus 5% to account for individuals who may be foraging out with this range (**Table 22D-2**). The limits were then set to the most northern, southern, eastern and western points across the colony buffers for each species to create a species-specific region (**Table 22D-3**).

19. Each 'paired' simulation runs the same breeding season twice, once with and once without selected wind farms present, which allows for a comparison between the two scenarios. For simulations which include wind farm presence, each individual (bird) is assigned to either be unaffected or to be susceptible to impacts (displacement and barrier effects) by wind farms (termed 'offshore renewables development' or ORDs in the modelling). The model also has the ability to assign a third status of susceptibility to displacement but not to barrier effects, however, it was assumed that all displaced birds would also be susceptible to barrier effect (as 'worst-case').

20. The wind farm footprint is surrounded by two separate areas - the border and the buffer. The border is the area directly surrounding the edge of the wind farm footprint. If individuals are susceptible to barrier effects, they will not be able to travel through this area, and therefore through the wind farm footprint. Barrier-affected individuals are modelled to navigate around the border using the navigation method set by the user. The buffer on the other hand relates to modelling displacement impacts; whereby if a displaced individual is assigned a location within the wind farm footprint, they will be reassigned to a foraging location within the buffer. The width of the border and buffer are each set by the user (**Table 22D-2**).

21. Flight paths can be simulated using either perimeter or A* path finding. A* path finding allows individuals to fly the shortest path from the colony to their selected foraging locations, whereas perimeter flight paths allow for travel in a straight line until an area individuals cannot travel through (the wind farm border) is encountered. If one of the wind farm borders is encountered, the susceptible individual will follow the perimeter of the obstacle until they can travel in a straight line again. In this case, the perimeter method was used, following available examples (Searle *et al.,* 2018; Mobbs *et al.,* 2018). Upon encountering land all individuals used A* path finding.

22. Following the generation of flight paths for all individuals, the bioenergetics of each individual were calculated.

Table 22D-2. The proposed input parameter values to be used during SeabORD modelling for both wind farm scenarios (Llŷr Project-alone and in combination with Erebus and White Cross)

Parameter	Guillemot	Razorbill	Puffin	Kittiwake
Mean max foraging range + 1SD (km)[1]	95.2	122.2	265.4	300.6
Proportion of individuals within foraging range	0.975	0.975	0.975	0.975
Forage site selection method	Distance decay	Distance decay	Distance decay	Distance decay
% of population susceptible to displacement	70	70	70	30
% of displaced birds also susceptible to barrier effects	100	100	100	100
Barrier navigation	Perimeter	Perimeter	Perimeter	Perimeter
Wind farm border (km)	2	2	2	2
Wind farm buffer (km)	5	5	5	5
Prey distribution	Uniform	Uniform	Uniform	Uniform
% of population to include in 'single' simulations (calibration)[2]	10	10	10	10
% of population to include in 'paired' simulations[3]	30	100	60	100

[1]From Woodward et al. (2019), for guillemot and razorbill the figures used are those which exclude Fair Isle.

[2]10% is used for calibration as recommended in available guidance (Searle et al., 2014; 2018; 2019).

[3] Where populations are large, they may need to be reduced in order to run the 'paired' simulations; in this case it was necessary for both guillemot and puffin.

Table 22D-3.The north, south, east and west limit used to define the region used during SeabORD simulation for each species.

Species	North limit	South limit	East limit	West limit
Guillemot	53.18388	50.15717	-2.67259	-7.63081
Razorbill	53.28671	50.05429	-2.50726	-7.79633
Puffin	54.23756	49.10285	-0.97864	-9.32718
Kittiwake	54.56958	48.77056	-0.44362	-9.86231

22.2.5. Calibration ('Single' Simulations)

23. Firstly, the model was calibrated for each species, at each colony. To do this 'single' simulations, which simulate breeding seasons with no wind farm(s) present, were run. The only input altered during this process was the prey quantity (g per unit volume) being simulated.

24. The point of calibration was to find the prey range which was expected to occur during 'moderate' breeding seasons. This was determined by comparing the change in body mass of adults (%) and chick survival (%) from the 'single' simulations to values from Mobbs *et al.* (2018) shown in **Table 22D-4**.

Table 22D-4.The lower and upper boundary of adult mass loss (%) and lower boundary for chick survival (%) used within SeabORD (v1.3) to determine the year type (poor, moderate or good)

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

25. If the average adult mass loss (%) was found to be equal or fall between the lower and upper boundaries and the chick survival was equal or higher than the lower boundary presented in **Table 22D-4,** then the prey value used was expected to result in a moderate breeding season. The prey value was then altered to find the lowest and highest values that fell within these conditions for each species at each colony.

22.2.6. 'Paired' Simulations

26. Once the appropriate upper and lower prey quantities were determined, those values were used as the prey quantity range for 'paired' simulations. Once the prey range was set, each paired simulation was assigned a prey quantity value using random stratified sampling (Searle *et al.,* 2018). This method divides the range into ten subgroups or 'strata' and selects a value from each. Each value was then used to simulate one breeding season with no wind farms present and one breeding season with wind farm(s) present, to allow for a comparison between both scenarios. Therefore, for each 'paired' simulation, two chick-rearing periods are simulated. The prey ranges used for paired simulations are shown in **Table 22D-5**.

Table 22D-5. The lower and upper prey ranges (g per unit volume) used in each paired simulation.

Species	Skomer		Skokholm		Middleholm		Castlemartin[1]	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Guillemot	340	422	340	420	351	421	353	436
Razorbill	222	281	220	279	227	285	-	-
Puffin	263	322	264	322	267	323	-	-
Kittiwake	208	274	-	-	-	-	-	-

[1]*Castlemartin razorbill and puffin populations were included in the modelling purely in relation to potential competition with SSSP SPA birds, therefore they did not require any separate Castlemartin-specific prey ranges to be calculated. This was only a requirement for guillemot as a designated interest of the SSSI and therefore a focus for assessment.*

22.2.7. Bioenergetics of the Model

27. During each timestep of the 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.

28. 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 foraging needed to meet individuals' Daily Energy Requirements (DER) and the time spent flying for each

individual were generated by SeabORD. A minimum of one hour was assigned to time spent on the sea surface for each timestep. The remaining time was assigned to time spent at the colony. Both these assumptions are set by the model and cannot be altered. Once the time spent carrying out each activity was generated, the DEE for the timestep could be calculated.

29. The DER of each adult was then calculated by combining the energy expended (DEE divided by an assimilation efficiency) and half of the DEE of chicks, as it was assumed that both parents contribute equally. If DEE was greater than DER, then adults would lose body mass.

30. At the end of each timestep the current mass of each individual was compared to their mass at the beginning of the seasons. This information was used to determine the behaviours carried by both adults and chicks as shown in **Table 22D-6**.

Table 22D-6. Behaviours of each individual at the beginning of each timestep determined by body mass within SeabORD (v1.3)

Species	Age class	% of initial mass	Behaviour for next timestep
All	Adult	>90	Stays at nest for the next timestep.
All	Adult	80-90	Leaves chick unattended to reach DER.
All	Adult	<80	Abandon chick[1]
All	Adult	<60	Assumed to have died.
Puffin	Chick	60-80	Chick will go to the opening of the burrow, increasing the likelihood of death due to predation or harsh environmental conditions.
Guillemot and razorbill	Chick	<60	Assumed to have died.

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

31. Chick mortality can also 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 increases until a specified threshold for each species.

22.2.8. Annual Adult Mortalities Predicted by SeabORD

32. To determine the annual survival of adults, the mass at the end of the chick-rearing period of each individual was used. SeabORD assumed 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 required 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 were set by SeabORD.

33. The baseline survival was equal to the mean value of annual adult survival from sites with observed data curated by the creators of SeabORD. Likewise, the shape of the logistic curve, which explains the relation between survival probability and body weight, was set by the creators of SeabORD.

22.3 Results

22.3.1. Summary of Annual Mortalities Predicted by SeabORD

34. **Table 22D-7** and **Table 22D-8** provide a summary of the overall adult and chick mortalities predicted by SeabORD for each species at SSSP SPA, and for guillemot at Castlemartin SSSI. These numbers are derived by summing the predicted additional mortalities caused by the

wind farm(s) for each SPA sub-colony and separately for Castlemartin (all for 'moderate' conditions).

35. 'Moderate' conditions are the baseline set in the modelling, informed by empirical evidence of adult body mass loss during the chick rearing period; these are the conditions more likely to be observed / more typical. The 'good' and 'poor' conditions are extrapolated from the 'moderate' ones to represent the extremes which may occur. Under poor conditions a higher percentage of birds will lose more body mass and under good conditions fewer birds will lose less body mass.

36. For these reasons, the SeabORD outputs under 'moderate' conditions are the which have been taken forward in assessment as they are the most robust. If SeabORD modelling is undertaken for any future offshore wind projects in the Celtic Sea, then the 'moderate' figures are the best to use for any cross-comparisons.

37. Note that for guillemot and for puffin where the paired model simulations used less than 100% of the population, it is the scaled values which are adopted for assessment. These values are calculated using a scaling factor of 1/proportion of the population modelled. This method assumes that the number of mortalities scales linearly with increasing population size.

Table 22D-7. Number of additional annual adult mortalities predicted to be caused by the presence of wind farm(s) for Llŷr Project-alone and cumulative impact scenarios.

Species	Llŷr Project-alone		Cumulative (Llŷr, Erebus and White Cross)	
	SSSP SPA[1]	Castlemartin	SSSP SPA[1]	Castlemartin
Guillemot	16.333	10.000	27.000	11.667
Razorbill	7.500	-	15.200	-
Puffin	20.333	-	37.167	-
Kittiwake	0.100	-	0.900	-

For SSSP SPA, the predicted sub-colony adult mortalities during 'moderate' conditions were summed (cells shaded grey in the results tables).

Table 22D-8. Number of additional chick mortalities during the chick-rearing period predicted to be caused by the presence of wind farm(s) for Llŷr Project-alone and cumulative impact scenarios.

Species	Llŷr Project-alone		Cumulative (Llŷr, Erebus and White Cross)	
	SSSP SPA[1]	Castlemartin	SSSP SPA[1]	Castlemartin
Guillemot	5.400	3.000	15.400	5.900
Razorbill	6.500	-	19.700	-
Puffin	9.300	-	17.400	-
Kittiwake	2.700	-	4.600	-

For SSSP SPA, the predicted sub-colony chick mortalities during 'moderate' conditions were summed (cells shaded grey in the results tables).

22.3.2. Full SeabORD Outputs

38. SeabORD model outputs for SSSP SPA sub-colonies - Skomer, Skokholm, Middleholm – and for Castlemartin Range SSSI are presented as follows:

- Guillemot; **Table 22D-9** to **Table 22D-12**;
- Razorbill; **Table 22D-13** to **Table 22D-15**;

- Puffin; **Table 22D-16** to **Table 22D-18**; and
- Kittiwake; **Table 22D-19** to **Table 22D-21**.

Guillemot

Table 22D-9. Guillemot predicted annual adult mortalities for Llŷr Project-alone and cumulative scenarios during 'poor', 'moderate' and 'good' environmental conditions at Skomer, Skokholm and Seas Off Pembrokeshire SPA

Site (scenario)	Environmental Conditions	Annual adult mortality						Difference in scaled mortalities between scenarios	Additional mortalities from wind farm presence (%)
		Baseline (no wind farm(s))			Wind farm(s) present				
		Mean	SD	Scaled mortalities[1]	Mean	SD	Scaled mortalities[1]		
Skomer (Llŷr only)	Poor	2,325.500	21.819	7,751.667	2,328.400	21.573	7,761.333	9.667	0.027
	Moderate	1,121.500	9.733	3,738.333	1,125.200	9.875	3,750.667	12.333	0.034
	Good	921.300	9.799	3,071.000	924.000	9.821	3,080.000	9.000	0.025
Skokholm (Llŷr only)	Poor	404.400	2.951	1,348.000	405.200	3.645	1,350.667	2.667	0.039
	Moderate	217.500	2.877	725.000	218.700	2.669	729.000	4.000	0.059
	Good	160.400	3.893	534.667	160.500	4.403	535.000	0.333	0.005
Middleholm (Llŷr only)	Poor	64.300	1.160	214.3333	64.400	0.843	214.667	0.333	0.032
	Moderate	24.500	1.354	81.667	24.500	1.354	81.667	0.000	0.000
	Good	31.300	1.494	104.333	31.300	1.494	104.333	0.000	0.000
Skomer (All windfarms)	Poor	2,325.500	21.819	7,751.667	2,332.700	22.809	7,775.667	24.000	0.066
	Moderate	1,121.500	9.733	3,738.333	1,128.600	10.987	3,762.000	23.667	0.065
	Good	921.300	9.799	3,071.000	925.100	10.450	3,083.667	12.667	0.035
Skokholm (All windfarms)	Poor	404.400	2.951	1,348.000	405.800	4.662	1,352.667	4.667	0.069
	Moderate	217.500	2.877	725.000	218.500	2.718	728.333	3.333	0.049
	Good	160.400	3.893	534.667	160.600	4.274	535.333	0.667	0.010
Middleholm (All windfarms)	Poor	64.300	1.160	214.333	65.000	1.414	216.667	2.333	0.222
	Moderate	24.500	1.354	81.667	24.500	1.354	81.667	0.000	0.000
	Good	31.300	1.494	104.333	31.300	1.494	104.333	0.000	0.000

[1] *Values calculated using a scaling factor of 1/proportion of the population modelled. (The method assumes that the number of mortalities scales linearly with increasing population size.)*

Table 22D-10. Guillemot predicted annual adult mortalities for Llŷr Project-alone and cumulative scenarios during 'poor', 'moderate' and 'good' environmental conditions at Castlemartin SSSI

Site (scenario)	Environmental Conditions	Annual adult mortality						Difference in scaled mortalities between scenarios	Additional mortalities from wind farm presence (%)
		Baseline (no wind farm(s))			Wind farm(s) present				
		Mean	SD	Scaled mortalities[1]	Mean	SD	Scaled mortalities[1]		
Castlemartin Range (Llŷr only)	Poor	1,620.200	8.561	5,400.667	1,623.000	7.703	5,410.000	9.333	0.041
	Moderate	858.400	5.296	2,861.333	861.400	5.296	2,871.333	10.000	0.044
	Good	628.100	8.185	2,093.667	631.000	10.646	2,103.333	9.667	0.043
Castlemartin Range (All windfarms)	Poor	1,620.200	8.561	5,400.667	1,626.500	7.367	5,421.667	21.000	0.093
	Moderate	858.400	5.296	2,861.333	861.900	6.332	2,873.000	11.667	0.052
	Good	628.100	8.185	2,093.667	633.200	11.153	2,110.667	17.000	0.075

[1] *Values calculated using a scaling factor of 1/proportion of the population modelled. (The method assumes that the number of mortalities scales linearly with increasing population size.)*

Table 22D-11. Guillemot SeabORD outputs for the modelled Llŷr Project-alone scenario during 'moderate' conditions

Output Variable	Scenario (wind farm present / not present)	Skomer		Skokholm		Middleholm		Castlemartin Range	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	10,876	-	2,036	-	316	-	6,778	-
Adult survival at end of breeding season (%)[1]	Not present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	Not present	920.364	0.000	919.450	0.000	921.540	0.000	918.766	0.000
	Present	920.364	0.000	919.450	0.000	921.540	0.000	918.766	0.000
Final adult body mass (g)	Not present	863.679	15.885	862.897	15.582	864.956	13.866	861.971	15.811
	Present	863.549	15.869	862.710	15.560	864.868	13.791	861.788	15.784
Difference between total distance flown with and without windfarm (km)	-	15.869	1.149	1.880	0.220	1.285	0.420	1.815	0.285
Difference in the total number of trips with and without windfarm	-	-0.002	0.002	-0.001	0.007	-0.001	0.008	-0.001	0.004
Chicks not surviving the season	Not present	931.400	646.630	170.400	124.685	23.200	15.697	586.600	398.501
	Present	934.800	648.466	171.900	124.859	23.700	15.945	589.600	399.851
	Difference	3.400	-	1.500	-	0.500	-	3.000	-
Additional mortality of chicks with windfarm present (%)	-	0.063	0.063	0.147	0.155	0.316	0.334	0.089	0.101
Number of adults directly impacted by the windfarms (displaced or barriered)[2]	Present	1,973	-	461	-	57	-	1,433	-

[1] *This reference to breeding season means only the chick-rearing period.*

[2] *Impacted adults refer to any adult that were displaced at least once during the simulation.*

Table 22D-12. Guillemot SeabORD outputs for the modelled cumulative impact scenario (Llŷr, Erebus and White Cross) during 'moderate' conditions

Output Variable	Scenario (wind farms present / not present)	Skomer		Skokholm		Middleholm		Castlemartin Range	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	10,876	-	2,036	-	316	-	6,778	-
Adult survival at end of breeding season (%)[1]	Not present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
	Present	100.000	0.000	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	Not present	920.364	0.000	919.450	0.000	921.540	0.000	918.766	0.000
	Present	920.364	0.000	919.450	0.000	921.540	0.000	918.766	0.000
Final adult body mass (g)	Not present	863.679	15.885	862.897	15.582	864.956	13.866	861.971	15.811
	Present	863.354	15.850	862.474	15.452	864.588	13.818	861.602	15.750
Difference between total distance flown with and without windfarms (km)		3.593	0.641	5.292	0.823	2.942	0.778	3.227	0.580
Difference in the total number of trips with and without windfarms		0.001	0.005	0.006	0.010	-0.006	0.024	-0.008	0.005
Chicks not surviving the season	Not present	931.400	646.630	170.400	124.685	23.200	15.697	586.600	398.501
	Present	942.400	652.592	173.900	128.477	24.100	15.878	592.500	403.325
	Difference	11.000	-	3.500	-	0.900	-	5.900	-
Additional mortality of chicks with windfarms present (%)		0.202	0.144	0.344	0.415	0.570	0.467	0.204	0.162
Number of adults directly impacted by the windfarms (displaced or barriered)[2]	Present	4,121	-	893	-	121	-	2,625	-

[1] *This reference to breeding season means only the chick-rearing period.*

[2] *Impacted adults refer to any adult that were displaced at least once during the simulation.*

Razorbill

Table 22D-13. Razorbill predicted annual adult mortalities for Llŷr Project-alone and cumulative scenarios during 'poor', 'moderate' and 'good' environmental conditions

Site (scenario)	Environmental Conditions	Adult annual mortality				Difference in mortalities between scenarios	Additional mortalities from wind farm presence (%)
		Baseline (no wind farm(s))		Wind farm(s) present			
		Mean	SD	Mean	SD		
Skomer (Llŷr only)	Poor	2,614.800	6.812	2,621.700	11.156	6.900	0.063
	Moderate	1,448.800	8.108	1,453.600	7.806	4.800	0.044
	Good	797.100	9.960	800.100	11.958	3.000	0.027
Skokholm (Llŷr only)	Poor	296.500	4.743	299.400	5.016	2.900	0.252
	Moderate	165.900	4.175	167.900	5.466	2.000	0.174
	Good	88.800	2.860	89.700	2.312	0.900	0.078
Middleholm (Llŷr only)	Poor	370.400	2.757	371.200	2.150	0.800	0.055
	Moderate	198.500	3.979	199.200	4.050	0.700	0.048
	Good	114.300	1.889	114.700	1.703	0.400	0.027
Skomer (All windfarms)	Poor	2,614.800	6.812	2,632.800	8.854	18.000	0.164
	Moderate	1,448.800	8.108	1,457.700	8.590	8.900	0.081
	Good	797.100	9.960	804.200	11.163	7.100	0.065
Skokholm (All windfarms)	Poor	1,031.600	12.149	1,037.300	12.347	5.700	0.127
	Moderate	591.800	7.391	597.300	6.273	5.500	0.122
	Good	331.900	7.249	335.100	6.674	3.200	0.071
Middleholm (All windfarms)	Poor	370.400	2.757	371.500	2.369	1.100	0.075
	Moderate	198.500	3.979	199.300	3.974	0.800	0.055
	Good	114.300	1.889	115.000	1.764	0.700	0.048

Values calculated using a scaling factor of 1/proportion of the population modelled. (The method assumes that the number of mortalities scales linearly with increasing population size.)

Table 22D-14. Razorbill SeabORD outputs for the modelled Llŷr Project-alone scenario during 'moderate' conditions

Output Variable	Scenario (wind farm present / not present)	Skomer		Skokholm		Middleholm	
		Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	10,946	-	4,496	-	1,458	-
Adult survival at end of breeding season (%)[1]	Not present	100.000	0.000	100.000	0.000	100.000	0.000
	Present	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	Not present	582.919	0.000	582.485	0.000	582.585	0.000
	Present	582.919	0.000	582.485	0.000	582.585	0.000
Final adult body mass (g)	Not present	547.504	10.791	546.323	10.945	548.273	10.856
	Present	547.388	10.773	546.183	10.937	548.171	10.846
Difference between total distance flown with and without windfarm (km)	-	1.284	0.343	1.770	0.476	0.992	0.586
Difference in the total number of trips with and without windfarm	-	-0.006	0.004	-0.003	0.003	-0.004	0.005
Chicks not surviving the season	Not present	771.900	550.416	314.400	248.622	84.000	59.003
	Present	777.500	553.399	315.000	249.617	84.300	59.619
	Difference	5.600	-	0.600	-	0.300	-
Additional mortality of chicks with windfarm present (%)	-	0.102	0.096	0.027	0.064	0.041	0.093
Number of adults directly impacted by the windfarm (displaced or barriered)[2]	Present	2,408	-	1,149	-	314	-

[1] *This reference to breeding season means only the chick-rearing period.*

[2] *Impacted adults refer to any adult that were displaced at least once during the simulation.*

Table 22D-15. Razorbill SeabORD outputs for the modelled cumulative impact scenario (Llŷr, Erebus and White Cross) during 'moderate' conditions

Output Variable	Scenario (wind farms present / not present)	Skomer		Skokholm		Middleholm	
		Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	10,946	-	4,496	-	1,458	-
Adult survival at end of breeding season (%)[1]	Not present	100.000	0.000	100.000	0.000	100.000	0.000
	Present	100.000	0.000	100.000	0.000	100.000	0.000
Initial adult body mass (g)	Not present	582.919	0.000	582.485	0.000	582.585	0.000
	Present	582.919	0.000	582.485	0.000	582.585	0.000
Final adult body mass (g)	Not present	547.504	10.791	546.323	10.945	548.273	10.856
	Present	547.222	10.746	545.988	10.914	547.983	10.848
Difference between total distance flown with and without windfarms (km)	-	3.979	0.883	5.639	1.404	3.503	0.895
Difference in the total number of trips with and without windfarms	-	-0.009	0.006	0.003	0.011	0.001	0.010
Chicks not surviving the season	Not present	771.900	550.416	314.400	248.622	84.000	59.003
	Present	786.200	562.234	319.100	252.778	84.700	59.105
	Difference	14.300	-	4.700	-	0.700	-
Additional mortality of chicks with windfarms present (%)	-	0.261	0.240	0.209	0.224	0.096	0.159
Number of adults directly impacted by the windfarms (displaced or barriered)[2]	Present	4,943	-	2,203	-	637	-

[1] *This reference to breeding season means only the chick-rearing period.*

[2] *Impacted adults refer to any adult that were displaced at least once during the simulation.*

Puffin

Table 22D-16. Puffin predicted annual adult mortalities for Llŷr Project-alone and cumulative scenarios during 'poor', 'moderate' and 'good' environmental conditions

Site (scenario)	Environmental Conditions	Adult annual mortality						Difference in scaled mortalities between scenarios	Additional mortalities from wind farm presence (%)
		Baseline (no wind farm(s))			Wind farm(s) present				
		Mean	SD	Scaled mortalities[1]	Mean	SD	Scaled mortalities[1]		
Skomer (Llŷr only)	Poor	2,471.400	11.510	4,119.000	2,480.500	10.223	4,134.167	15.167	0.700
	Moderate	1,773.800	7.495	2,956.333	1,782.200	7.269	2,970.333	14.000	0.065
	Good	980.400	8.030	1,634.000	982.400	8.208	1,637.333	3.333	0.015
Skokholm (Llŷr only)	Poor	1,265.800	9.151	2,109.667	1,270.000	10.011	2,116.667	7.000	0.062
	Moderate	939.100	5.259	1,565.167	942.700	7.646	1,571.167	6.000	0.053
	Good	519.500	3.440	865.833	521.200	4.077	868.667	2.833	0.025
Middleholm (Llŷr only)	Poor	78.800	1.687	131.333	78.900	1.524	131.500	0.167	0.025
	Moderate	58.400	2.459	97.333	58.600	2.119	97.667	0.333	0.049
	Good	32.200	1.751	53.667	32.900	1.912	54.833	1.167	0.172
Skomer (All windfarms)	Poor	2,471.400	11.510	4,119.000	2,491.300	10.393	4,152.167	33.167	0.153
	Moderate	1,773.800	7.495	2,956.333	1,790.200	9.259	2,983.667	27.333	0.126
	Good	980.400	8.030	1,634.000	987.900	6.757	1,646.500	12.500	0.058
Skokholm (All windfarms)	Poor	1,265.800	9.151	2,109.667	1,277.400	11.768	2,129.000	19.333	0.172
	Moderate	939.100	5.259	1,565.167	945.500	8.810	1,575.833	10.667	0.095
	Good	519.500	3.440	865.833	521.900	4.228	869.833	4.000	0.036
Middleholm (All windfarms)	Poor	78.800	1.687	131.333	79.400	1.897	132.333	1.000	0.148
	Moderate	58.400	2.459	97.333	57.900	1.969	96.500	-0.833[2]	-0.123*
	Good	32.200	1.751	53.667	33.200	2.044	55.333	1.667	0.246

[1] Values calculated using a scaling factor of 1/proportion of the population modelled. (The method assumes that the number of mortalities scales linearly with increasing population size.) [2]It cannot be confirmed why this negative additional mortality value has occurred without access to the code underlying SeabORD. However, it is reasonable to assume that when estimated impacts are so low, the allowance for randomness within the model can give a negative result by chance.

Table 22D-17. Puffin SeabORD outputs for the modelled Llŷr Project-alone scenario during 'moderate' conditions

Output Variable	Scenario (wind farm present / not present)	Skomer		Skokholm		Middleholm	
		Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	13,018	-	6,746	-	406	-
Adult survival at end of breeding season (%)[1]	Not present	99.998	0.004	99.999	0.000	100.000	0.000
	Present	99.997	0.004	99.999	0.000	100.000	0.000
Initial adult body mass (g)	Not present	392.761	0.000	392.286	0.000	392.511	0.000
	Present	392.761	0.000	392.286	0.000	392.511	0.000
Final adult body mass (g)	Not present	369.489	7.508	368.858	7.391	368.890	6.839
	Present	369.353	7.353	368.740	7.422	368.747	6.962
Difference between total distance flown with and without windfarm (km)	-	10.090	0.732	10.181	0.908	9.041	2.744
Difference in the total number of trips with and without windfarm	-	-0.003	0.009	-0.004	0.011	-0.008	0.031
Chicks not surviving the season	Not present	608.400	218.001	272.700	118.879	15.800	6.233
	Present	614.000	223.505	275.900	121.901	16.300	6.800
	Difference	5.600	-	3.200	-	0.500	-
Additional mortality of chicks with windfarm present (%)	-	0.086	0.089	0.095	0.103	0.246	0.419
Number of adults directly impacted by the windfarm (displaced or barriered)[2]	Present	8,125	-	3,904	-	240	-

[1] *This reference to breeding season means only the chick-rearing period.*

[2] *Impacted adults refer to any adult that were displaced at least once during the simulation.*

Table 22D-18. Puffin SeabORD outputs for the modelled cumulative impact scenario (Llŷr, Erebus and White Cross) during 'moderate' conditions

Output Variable	Scenario (wind farms present / not present)	Skomer		Skokholm		Middleholm	
		Mean	SD	Mean	SD	Mean	SD
Number of adult birds in simulation	Both	13,018	-	6,746	-	406	-
Adult survival at end of breeding season (%)[1]	Not present	99.998	0.004	99.999	0.005	100.000	0.000
	Present	99.997	0.004	99.997	0.009	100.000	0.000
Initial adult body mass (g)	Not present	392.761	0.000	392.286	0.000	392.511	0.000
	Present	392.761	0.000	392.286	0.000	392.511	0.000
Final adult body mass (g)	Not present	369.489	7.508	368.858	7.391	368.890	6.839
	Present	369.214	7.573	368.592	7.462	368.676	6.896
Difference between total distance flown with and without windfarms (km)	-	23.189	0.792	25.654	1.283	21.606	3.496
Difference in the total number of trips with and without windfarms	-	-0.005	0.014	-0.002	0.012	0.002	0.038
Chicks not surviving the season	Not present	608.400	218.001	272.700	118.879	15.800	6.233
	Present	619.800	228.478	278.200	125.000	16.300	6.945
	Difference	11.400	-	5.500	-	0.500	-
Additional mortality of chicks with windfarms present (%)	-	0.175	0.164	0.163	0.188	0.246	0.479
Number of adults directly impacted by the windfarms (displaced or barriered)[2]	Present	8,997	-	4,672	-	299	-

[1] *This reference to breeding season means only the chick-rearing period.*

[2] *Impacted adults refer to any adult that were displaced at least once during the simulation.*

Kittiwake

Table 22D-19. Kittiwake predicted annual adult mortalities for Llŷr Project-alone and cumulative scenarios during 'poor', 'moderate' and 'good' environmental conditions

Site (Scenario)	Environmental Conditions	Annual adult mortality				Difference in mortalities between scenarios (No.)	Additional mortalities from wind farm(s) presence (%)
		Baseline (no wind farm(s))		Wind farm(s) present			
		Mean	SD	Mean	SD		
Skomer (Llŷr only)	Poor	1,108.500	4.116	1,107.200	4.050	-1.300[1]	-0.045[1]
	Moderate	751.000	3.887	751.100	4.067	0.100	0.003
	Good	472.900	5.021	471.400	4.812	-1.500[1]	-0.052[1]
Skomer (All windfarms)	Poor	1,108.500	4.116	1,108.700	4.218	0.200	0.007
	Moderate	751.000	3.887	751.900	3.957	0.900	0.031
	Good	472.900	5.021	471.400	4.881	-1.500[1]	-0.052[1]

It cannot be confirmed why these negative additional mortality values have occurred without access to the code underlying SeabORD. However, as this has happened only for values derived for 'poor' or 'good' years, it will relate to the way that the outputs for a 'moderate' breeding season are simulated by the model to reflect these other conditions.

Values calculated using a scaling factor of 1/proportion of the population modelled. (The method assumes that the number of mortalities scales linearly with increasing population size). Note also that the estimated adult mortalities for the Llŷr 'Project-alone' scenario are unexpectedly higher during 'good' conditions compared to 'moderate'. This may be due to the conversion method and/or randomness in the model which can lead to negative values by chance when dealing with such low levels of impact.

Table 22D-20. Kittiwake SeabORD outputs for the modelled Llŷr Project-alone scenario during 'moderate' conditions

Output Variable	Scenario (wind farm present/not present)	Skomer	
		Mean	SD
Number of adult birds in simulation	Both	2,878	-
Adult survival at end of breeding season (%)[1]	Not present	100.000	0.000
	Present	100.000	0.000
Initial adult body mass (g)	Not present	373.628	0.000
	Present	12.393	5.556
Final adult body mass (g)	Not present	373.628	0.000
	Present	347.309	5.569
Difference between total distance flown with and without windfarm (km)	-	-1.599	1.934
Difference in the total number of trips with and without windfarm	-	-0.054	0.021
Chicks not surviving the season	Not present	777.500	199.243
	Present	780.200	198.322
	Difference	2.700	-
Additional mortality of chicks with windfarm present (%)	-	0.188	0.139
Number of adults directly impacted by the windfarm (displaced or barriered)[2]	Present	745	-

[1] *This reference to breeding season means only the chick-rearing period.*

[2] *Impacted adults refer to any adult that were displaced at least once during the simulation.*

Table 22D-21. Kittiwake SeabORD outputs for the modelled cumulative impact scenario (Llŷr, Erebus and White Cross) during 'moderate' conditions

Output Variable	Scenario (wind farms present / not present)	Skomer	
		Mean	SD
Number of adult birds in simulation	Both	2,878	-
Adult survival at end of breeding season (%)[1]	Not present	100.000	0.000
	Present	100.000	0.000
Initial adult body mass (g)	Not present	373.628	0.000
	Present	373.628	0.000
Final adult body mass (g)	Not present	347.280	5.556
	Present	347.272	5.564
Difference between total distance flown with and without windfarms (km)	-	1.399	1.801
Difference in the total number of trips with and without windfarms	-	-0.069	0.019
Chicks not surviving the season	Not present	777.500	199.243
	Present	782.100	199.026
	Difference	4.600	-
Additional mortality of chicks with windfarms present (%)	-	0.320	0.114
Number of adults directly impacted by the windfarms (displaced or barriered)[2]	Present	822	-

[1] *This reference to breeding season means only the chick-rearing period.*

[2] *Impacted adults refer to any adult that were displaced at least once during the simulation.*

22.4 References

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