BERWICK BANK WIND FARM
OFFSHORE ENVIRONMENTAL IMPACT ASSESSMENT

APPENDIX 11.4, ANNEX G: EVIDENCE AND JUSTIFICATION FOR THE DEVELOPER APPROACH

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Sarah Edwards	SEdwards	14 November 2022

Prepared by:	**SSE and Royal Haskoning DHV**
Prepared for:	**SSE Renewables**
Checked by:	**Emily Nelson**
Accepted by:	**James Orme**
Approved by:	**Sarah Edwards**

Note: This section is authored by the Applicant with support from Murray Grant Royal Haskoning DHV

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1. INTRODUCTION

1. The Applicant has for the most part adopted the advice on ornithological assessment parameters advised in the Scoping Opinion for the purposes of conducting an assessment of displacement and barrier effects on offshore ornithology for the EIA. Nevertheless, there are some parameters advised in the Scoping Opinion which the Applicant considers to be over-precautionary and a departure from standard advice/practice. As such, the Applicant has presented an assessment of likely significant effects based on:

- The Scoping Opinion Approach (noting that in some cases this is further split out to reflect advice given); and
- The Developer Approach.

2. This section presents the evidence base for the Developer Approach for the displacement assessment, including a review of scientific literature, to identify and justify any instances where this diverges from the Scoping Opinion Approach.

3. In addition to presenting the evidence base for the Developer Approach, a summary of an independent review of the SeabORD tool (volume 3, appendix 11.4, annex H) is also presented here. During the Road Map process, NatureScot and Marine Scotland Science advised that higher displacement mortality rates than precedent were required for the assessment of displacement since the SeabORD outputs show consistently higher displacement mortality rates than those based on expert judgement (volume 3, appendix 11.8). The summary presented here outlines the key findings of the independent review, including conclusions as to why it is not currently considered appropriate to interpret the SeabORD outputs in this way.

2. CONSIDERATION OF DISPLACEMENT RATE AND MORTALITY RATE BY SPECIES

2.1. GANNET

2.1.1. SUMMARY

Table 2.1: Summary of displacement and mortality rates chosen for gannet in the Developer Approach

Gannet	Displacement Rate	Mortality Rate – Breeding season	Mortality Rate – Non-breeding Seasons
Scoping Approach A	70%	1%	1%
Scoping Approach B	70%	3%	3%
Developer Approach	70%	1%	1%

2.1.2. PRECEDENT

4. For previous Forth and Tay Section 36 EIA ornithology assessments, the Scottish Ministers advised that gannet did not need to be considered in the displacement assessment (e.g. Marine Scotland, 2017a, Marine Scotland, 2017b). It is worth noting that both NatureScot and RSPB agreed with this approach in the 2017 Scoping Opinions.

5. However, there is evidence that gannets show a high degree of avoidance of offshore wind farms. A detailed study (Krijgsveld *et al.*, 2011) using radar and visual observations to monitor the post-construction effects of the Egmond aan Zee Windpark (OWEZ) established that 64% of gannets avoided entering the wind farm (macro-avoidance) and a similar result (80% macro avoidance) was also observed during a study at the Thanet offshore wind farm (Skov *et al.*, 2018). Leopold *et al.*, (2013) reported that the majority of gannets avoided Dutch offshore wind farms and did not forage within these. Dierschke *et al.*, (2016) concluded that gannets show high avoidance of offshore wind farms despite showing little avoidance of ships.

Displacement Rate

6. For the current Berwick Bank application, Scoping Opinion advice stated that a displacement rate of 70% should be used. In light of the above evidence the Developer Approach agrees with this displacement rate and uses 70%.

Mortality Rate

7. The Scoping Opinion states mortality rates of 1% and 3% should be applied in both the breeding and non-breeding seasons.

8. Based on the evidence set out below, the Applicant has considered the advised displacement mortality rates in the context of the very large foraging range and diverse diet of the species, as well as tracking data from breeding gannets on the Bass Rock, and has concluded that a mortality rate of 1% is sufficiently precautionary, with no evidence found in support of using the higher rate of 3%.

9. Mean maximum foraging range plus 1 standard deviation (SD) is 509.4 km, and the maximum known foraging range is 709 km (Woodward *et al.*, 2019). In addition, the species feeds on a wide variety of prey species, for example sandeels, mackerel, whiting and herring (Forrester *et al.*, 2007). None of these prey species have restricted distributions and all occur widely across the potential foraging range of gannet. If displacement occurs at the Proposed Development and the other Forth and Tay offshore wind farms, it is considered that there will be sufficient alternative prey sources and feeding areas elsewhere within foraging range of the Bass Rock.

10. An analysis of available GPS tracking data of adult gannets from the Bass Rock in the breeding season was undertaken to investigate the proportion of foraging trips that enter the Proposed Development (volume 3, appendix 11.4, annex E), in order to identify whether the amount of time that adult gannets spent inside the Proposed Development differed from time spent outside it. Data were collected from 682 foraging trips from adult breeding gannets on the Bass Rock over eight years between 2010 and 2019. Using statistical analysis, the tracking data was broken down into three behaviour types: resting, foraging and transiting from colony to foraging sites. Full details of the approach undertaken is presented in volume 3, appendix 11.4, annex E.

11. Overall, the Proposed Development comprises a very small component (0.7% of the size of the full home range estimated from all tracks pooled together) of the range of gannets foraging from the Bass Rock. Out of a total of 682 gannet tracks, 503 (74%) did not enter the Proposed Development at all. Of the remaining 179 tracks where gannets did enter the Proposed Development, between 94% and 100% included transiting behaviour (depending on sex). From these data, the Proposed Development does not appear to be a key foraging site for adult gannets breeding on the Bass Rock.

12. The potential effect that an offshore wind farm acting as a barrier would have on flight distances and durations depends on how far the destination areas lie beyond the barrier (Masden *et al.*, 2010). Results from tagging studies on gannets breeding on the Bass Rock show that they forage over a considerable area of the northern North Sea. The average foraging distance recorded from tagged gannets from the Bass Rock varies between years, depending on food availability, but ranges between 170 km and 363 km (Hamer *et al.*, 2000; Hamer *et al.*, 2011). Data presented in in volume 3, appendix 11.4, annex E show that the median home range size of gannets breeding on the Bass Rock between 2010 and 2019 was 3,909 km^2. It is therefore reasonable to assume that likely destinations of gannet flights potentially affected by barrier effects due to the Proposed Development will be at a range of distances beyond the Proposed Development, and commonly many tens of kilometres beyond.

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

14. It was agreed between all parties at Road Map 6 that barrier effects on gannets in the non-breeding season were not required to be assessed (volume 3, appendix 11.8).

15. Based on the above, it is considered that a displacement rate of 70% and a mortality rate of 1% for both the breeding and non-breeding seasons is suitably precautionary for an assessment of displacement effects from the Proposed Development on gannets. This has therefore been applied as the Developer Approach for the assessment.

2.2. KITTIWAKE

2.2.1. SUMMARY

Table 2.2: Summary of displacement and mortality rates chosen for kittiwake in the Developer Approach

Kittiwake	Displacement Rate	Mortality Rate – Breeding season	Mortality Rate – Non-breeding Seasons
Scoping Approach A	30%	1%	1%
Scoping Approach B	30%	3%	3%
Developer Approach (breeding season only)	30%	2%	Not assessed

2.2.2. PRECEDENT

16. For previous Forth and Tay Section 36 EIA ornithology assessments, the Scottish Ministers advised that a displacement rate of 30% and a mortality rate of 2% should be used for kittiwake in the breeding season, and that a qualitative assessment was sufficient for the non-breeding season (e.g. Marine Scotland, 2017a, Marine Scotland, 2017b).

17. In addition, in the Scoping Opinion for the Neart na Gaoithe project, NatureScot stated that kittiwake did not need to be considered for displacement effects, as the data available from post-construction monitoring indicated no significant avoidance behaviour by this species (Marine Scotland, 2017a).

18. Similarly, in the SNCBs (2017) advice note on displacement, kittiwake is not listed among the priority species for displacement assessment, as it falls below the threshold of disturbance sensitivity used to determine which species should be taken forward for displacement assessment. Based on the above SNCBs (2017) guidance, in England, there is no requirement to undertake an assessment of displacement effects on kittiwake as part of EIAR assessments.

19. The Applicant is not aware of any more recent post-construction monitoring research that contradicts the evidence from operating offshore wind farm projects that kittiwake displacement is not likely to occur to any significant level.

20. The change in precedent in the Scoping Opinion regarding the requirement for an assessment of kittiwake displacement during the non-breeding season was queried by the Applicant in Road Map 6 (volume 3, appendix 11.8). Marine Scotland Science stated as the scale of development increases across the North Sea, the cumulative effects may be great and there was therefore a requirement to consider potential displacement during the non-breeding season for this species.

Displacement rate

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

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

23. For the current Berwick Bank application, Scoping Opinion advice stated that a displacement rate of 30% should be used for kittiwake. Although there is evidence from operating offshore wind farm projects that kittiwake displacement is not likely to occur to any significant level, the Applicant has applied the 30% rate, with the proviso that it is considered suitably precautionary.

Mortality rate

24. For the current Berwick Bank application, Scoping Opinion advice stated that mortality rates of 1% and 3% should be applied in both the breeding and non-breeding seasons for kittiwake. This differs from advice received for previous assessments as described above. At Road Map 5 (volume 3, appendix 11.8), NatureScot and Marine Scotland Science stated that higher mortality rates were advised given that SeabORD outputs (e.g. Searle *et al.*, 2020) indicate that displacement mortality is greater than previously considered. As described above, the Applicant has commissioned an independent investigation into the operation and sensitivity of a comparable, publicly available version of SeabORD (Searle *et al.*, 2018) and presents evidence as to why it is not appropriate to use these theoretical outputs to inform the higher mortality rates requested for use in the matrix method assessment in the Scoping Opinion.

25. The Applicant considers that a mortality rate of 3% is overly precautionary in light of the available evidence as described below, and therefore has applied a 2% mortality rate for the breeding season, based on an evaluation of the published literature and in line with values used previously for other Forth and Tay offshore wind farm displacement assessments. It is considered that using a mortality rate of 2% is suitably precautionary for the following reasons:

- During the breeding season, kittiwakes feed primarily on sandeels which occur widely across the region. Tracking data from three breeding colonies: Fowlsheugh, St Abb's Head and the Isle of May indicate that over 80% of the breeding season foraging range lies outwith the footprint of the Proposed Development (Bogdanova *et al.*, 2022). Consequently, any kittiwakes that are displaced from the Proposed Development and other offshore wind farms in the vicinity, will be able to forage over an extensive area beyond that potentially affected by the Proposed Development; and
- Similarly, there is evidence from tracking studies involving tagged kittiwakes from the Isle of May colony between 2010 and 2021 that demonstrate that the extent of foraging areas varies between breeding seasons (Figure 2.1). Since foraging distribution can be considered a reflection of prey distribution, then typically, a more restricted foraging distribution around a breeding colony would indicate that prey availability is good in that area, for that breeding season. Potential implications of this when prey availability is poor are discussed below.

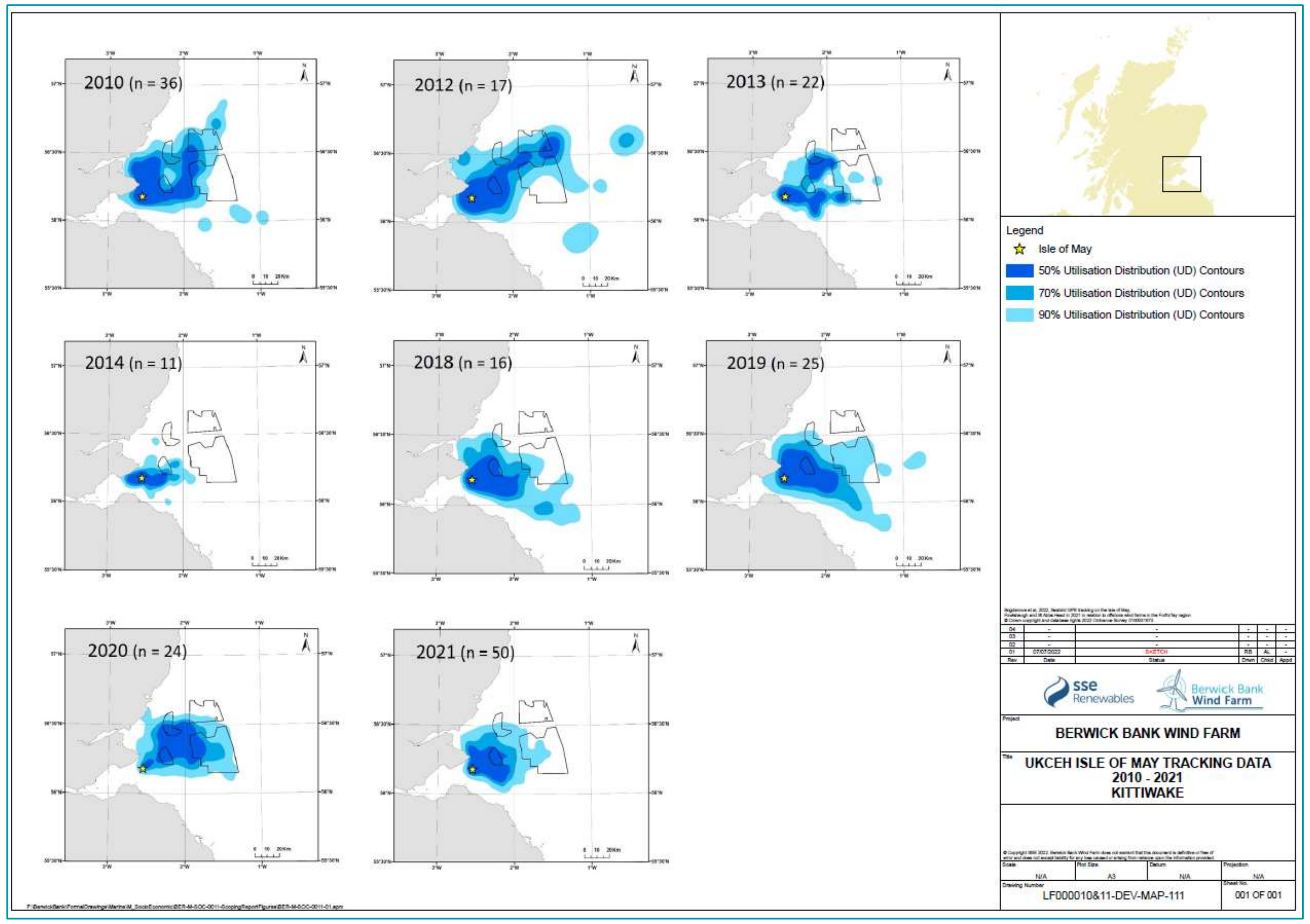

Figure 2.1: UKCEH Kittiwake Breeding Season Tracking Data from the Isle of May between 2010 and 2021 (from Bogdanova *et al.*, 2022).

26. For context, in the 2014 breeding season, no tagged kittiwakes were recorded within the Proposed Development. In the 2018, 2019 and 2021 breeding seasons, the core foraging area for kittiwakes did not overlap with the Proposed Development, while in the remaining breeding seasons, foraging kittiwakes were more widespread. This indicates that the Proposed Development is not a key foraging area used in every breeding season for the majority of kittiwakes predicted to use the Proposed Development array area (see volume 3, appendix 11.4), but that in some seasons, birds do forage within the Proposed Development.

27. Baseline digital aerial surveys for the Proposed Development were conducted between March 2019 to April 2021, and therefore covered the 2019 and 2020 breeding seasons. Based on the UKCEH tracking data presented in Figure 2.1, in both these seasons, kittiwake foraging areas within the Proposed Development were more extensive than in other breeding seasons, with the 50% utilization contour extending across almost all of the Proposed Development in the 2019 season. This indicates that kittiwake densities within the Proposed Development as recorded on baseline surveys in these breeding seasons are likely to be higher than in other breeding seasons, with a more restricted foraging distribution. On this basis, it could be considered that as the assessment has been based on these data, then the resulting conclusions are likely to be precautionary, as more birds will have been recorded in the Proposed Development than in years when prey is concentrated closer to the breeding colony.

28. As presented above, available evidence from post-construction studies and previous reviews indicates that displacement of kittiwakes by offshore wind turbines is not likely to occur to any significant extent. It is therefore considered that 30% displacement with a mortality rate of 2% for the breeding season is suitably precautionary for an assessment of displacement effects from the Proposed Development on kittiwakes. This has therefore been applied as the Developer Approach for the assessment.

29. For the Developer Approach, it was also considered that displacement mortality is not likely to occur in the non-breeding season, therefore no displacement assessment was undertaken for the non-breeding season for the Developer Approach. This approach was based on the following considerations:

- In the non-breeding season, as adult kittiwakes are not attached to a breeding colony, there are no restrictions on where they can forage, therefore if birds are displaced from the Proposed Development, or other offshore wind farms in the region, then they will be able to move to other foraging areas;
- This approach is supported by a comment from Marine Scotland Science in the Scoping Opinion for the original Berwick Bank project, which states that "due to their physiology in terms of flight efficiency and additionally their wide-ranging ecology, displacement impacts to kittiwake should be considered only during the breeding season when they function as central-place foragers" (Marine Scotland, 2021);
- Current and planned offshore wind farm development in the North Sea represents 2.2% of Scottish waters available to this species (Figure 2.2; noting that kittiwakes will range further than Scottish waters during the non-breeding season), thus potential cumulative effects from expansion of offshore wind development are likely to be small relative to the species non-breeding season range;
- In addition, in the Scoping Opinion for the original Berwick Bank project, NatureScot did not advise that an assessment of displacement in the non-breeding season was required for kittiwake (Marine Scotland, 2021).

2.3. GUILLEMOT AND RAZORBILL

2.3.1. SUMMARY

Table 2.3: Summary of displacement and mortality rates chosen for guillemot and razorbill in the Developer Approach

Guillemot and Razorbill	Displacement Rate	Mortality Rate – Breeding season	Mortality Rate – Non-breeding Seasons
Scoping Approach A	60%	3%	1%
Scoping Approach B	60%	5%	3%
Developer Approach	50%	1%	1%

2.3.2. PRECEDENT

30. For previous Forth and Tay Section 36 EIA ornithology assessments, the Scottish Ministers advised that a displacement rate of 30% and a mortality rate of 2% should be used for kittiwake in the breeding season, and that a qualitative assessment was sufficient for the non-breeding season (e.g. Marine Scotland, 2017a, Marine Scotland, 2017b).

Displacement rate

31. For the current Berwick Bank application, Scoping Opinion advice states that a displacement rate of 60% should be used for guillemot and razorbill displacement assessments. However, there is evidence from offshore wind farm post-construction studies that indicate that these displacement rates are overly precautionary.

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

33. Robin Rigg offshore wind farm, in the Solway Firth, is within foraging range of breeding guillemots and razorbills from Cumbria and Mull of Galloway. Evidence from five years of post-construction monitoring at Robin Rigg offshore wind farm, suggests that neither species has been displaced from the Robin Rigg offshore wind farm during operation, as birds were present within the Robin Rigg offshore wind farm during all five years of operational monitoring. For both guillemot and razorbill, mean densities of birds on the sea declined during the construction phase, before returning to preconstructions levels during operation. Although there was an indication of a slight decrease in guillemot abundance for birds on the sea across the four operational years, this was not statistically significant, and there were no significant changes in distribution during operation. It was concluded that changes in guillemot and razorbill abundance and distribution were likely to be due to changes in prey distribution resulting from sedimentary movement, rather than being an effect of the offshore wind farm. This explanation is supported by similar patterns in distribution being predicted for both species across the five operational years (Nelson *et al.*, 2015).

34. A study at the operational Westermost Rough offshore wind farm investigated evidence of displacement for kittiwakes and auks and recorded high variability in overall mean densities of both guillemots and razorbills, calculated for the entire offshore wind farm and the surrounding buffer zone, suggesting no evidence of displacement. There were variations in mean densities of these species across the buffer zone but these differences were not statistically significant (APEM, 2017).

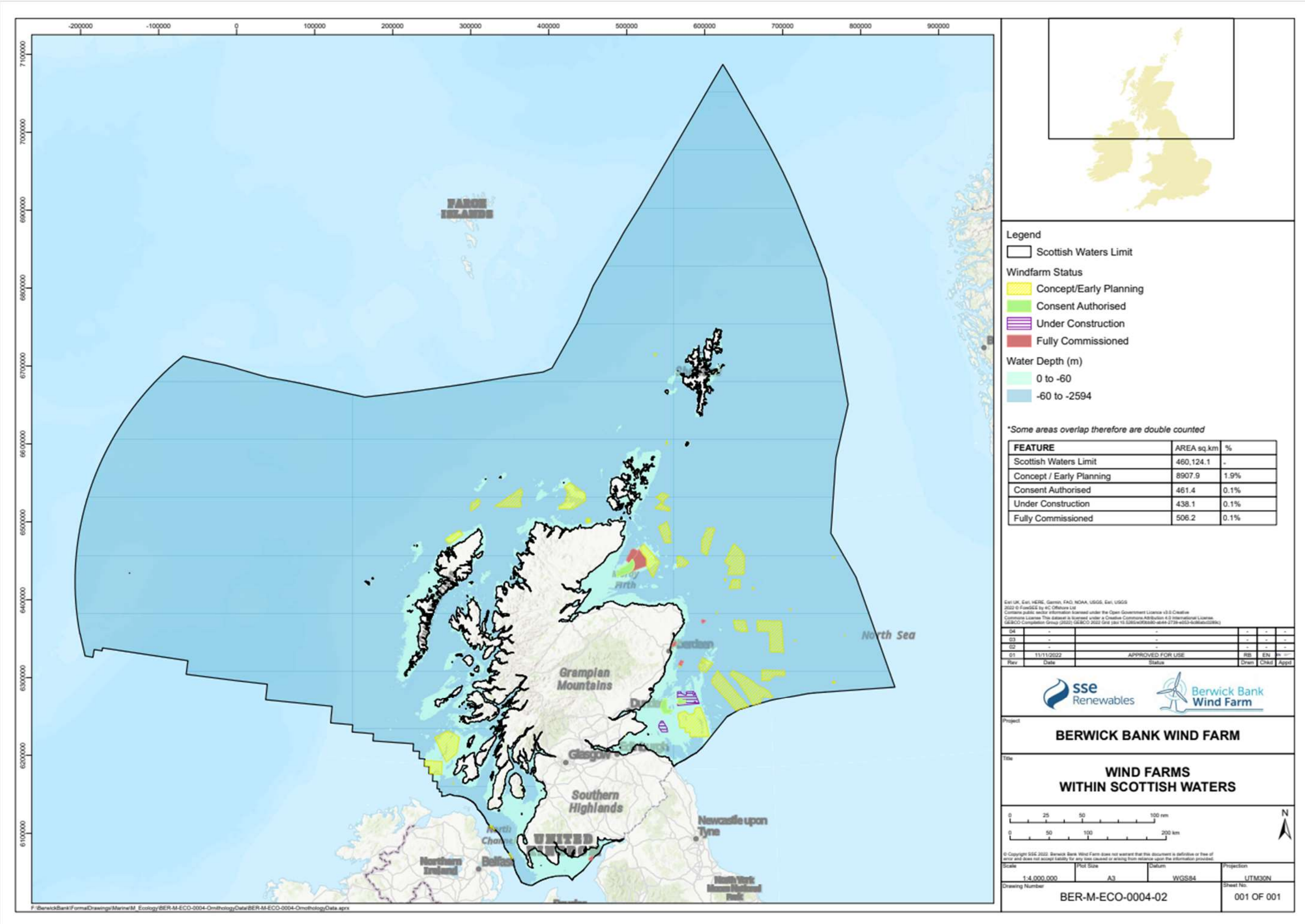

Figure 2.2: Windfarms within Scottish Waters

35. A recent review of post-construction displacement at offshore wind farms showed that guillemots and razorbills are not completely displaced from offshore wind farms. The strongest displacement effects were reported for Thorntonbank and Bligh Bank offshore wind farms in Belgian waters, with reductions in density of 68% and 75% for guillemot respectively at these two offshore wind farms. Reported razorbill displacement at these two offshore wind farms was slightly lower, with reductions in density of 55% and 67% respectively (Dierschke *et al.*, 2016).

36. A subsequent review found that on average, the densities of birds within offshore wind farms were approximately 50% of the densities in the wider area around these sites. Where it has been measured, densities within 2 km of offshore wind farms, within the buffer zone were reduced by less than 30%, with most studies reporting no significant reduction in density (MacArthur Green, 2019). This review also concluded that there was evidence in support of using a precautionary displacement rate of 50% within the wind farm, 30% within the 1 km buffer and 0% beyond 1 km, together with a 1% mortality rate for guillemot and razorbill (MacArthur Green 2019a).

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

38. After examining the analysis methods used in these different studies, the APEM (2022) review suggested that not all predicted displacement effects were equally robust, as there were many sites where high displacement rates were predicted that had low or very low auk abundance. The review suggested that for sites with high numbers of zero counts, prediction of likely displacement rates is highly problematic, given the natural spatial and temporal variation in auk abundance and distribution. The review concluded that at such sites, the reported displacement effects are most likely unreliable. One example of this is from the Prinses Amalia and Egmond aan Zee offshore wind farms off the coast of the Netherlands, where significant displacement effects were previously reported. Independent re-analysis of the post-construction data using the statistical package R-INLA did not detect a statistically significant effect (Zuur, 2018). The same study also concluded that previously reported displacement effects at Alpha Ventus, Blighbank, Thorntonbank and Horns Rev offshore wind farms, may also be misleading since there were high numbers of zero observations of guillemots in their datasets which is a major challenge for statistical analysis, requiring advanced statistical methods (Zuur, 2018). These studies make up the majority of reported auk displacement rates of up to 75%. The APEM (2022) review recommended that results from these studies should be regarded with caution and not presented as strong evidence in support of high displacement effects, following the work undertaken by Zuur (2018). Results from the various studies as presented in the APEM (2022) review, including revised results following re-analysis of original datasets are summarised in Table 2.4.

39. The APEM (2022) review concludes that offshore wind farm sites that have moderate to high auk abundance (e.g. densities of $\geq 5/km^2$), tend to have reported displacement effects that are non-significant or weak (Table 2.4). This is based on analysis of post-construction data from offshore wind farm projects such as Beatrice, Robin Rigg, Westermost Rough, North Hoyle, Lincs and Thanet. As discussed above, where higher and more variable displacement rates have been reported, these appear to be a result of there being many instances of low or zero abundances of guillemots and razorbills within the study site which cause subsequent issues with the analysis method used in these studies.

40. The Year 1 post-construction study report for Beatrice offshore wind farm reported that both guillemots and razorbills were more abundant within the wind farm on post-construction surveys than on pre-construction surveys. Results showed that there was a significant increase in the overall guillemot and razorbill abundance post-construction, but found that the spatial component of this relationship was not significant. No regions of the study area were found to have significant reductions, but the southern half of the study area had significant increases. Overall, the report concluded that for both guillemot and razorbill, the displacement rates of 30-70% currently used in wind farm assessments are considerably over-estimated, at least in the breeding season for similar wind farms (MacArthur Green, 2021). Results from Year 2 post-construction analyses corroborate the findings of Year 1 (M.Trinder, pers.comm). As the Proposed Development has similar turbine spacing to Beatrice offshore wind farm (where spacing is approximately 1,170 m), it is considered that these conclusions would also be applicable for the Proposed Development.

41. Similarly, a post-construction displacement study in the Belgian offshore wind farm zone recorded higher densities of razorbills and slightly higher densities of guillemots within the turbine array compared to outside, on a survey conducted in February 2021. Within the turbine area, the peak recorded density of razorbills was 4.59 birds/km^2, compared to 2.36 birds/km^2 outside the turbine area. For guillemot, densities inside and outside the turbine area were more similar, yet still slightly higher within the turbines (1.18 birds/km^2 inside compared to 1.03 birds/km^2 outside) (Vanerman *et al.*, 2021).

42. The APEM (2022) review concluded that a precautionary approach would be to use a displacement rate of up to 50% for guillemots and razorbills. The higher displacement rates reported from German and Belgium post-construction studies where numbers of guillemots and razorbills were low and poor displacement rate accuracy was correspondingly poor would not be suitable sites for predicting auk displacement rates. It is therefore concluded that a displacement rate of 50% for guillemots and razorbills is the most applicable and suitably precautionary rate to use for the Developer Approach for the Proposed Development and a 2 km buffer.

Table 2.4: Summary results of displacement analysis for guillemot and razorbill and their predicted effects/rates from the most recent monitoring report or published studies (based on APEM, 2022)

Offshore Wind Farm	Number of Years Pre-Construction Data	Number of Years Operational Data	Analysis Period	Post-construction Guillemot and Razorbill Mean Peak Density (n/km^2) within the Wind Farm	Predicted Displacement Rate
Beatrice	1	1	May to July	Guillemot = 100 Razorbill = 6.0	Guillemot = NSE[1] Razorbill = NSE
Thanet	1	3	October to March	Guillemot = 11.6 Razorbill = 2.6	Guillemot = NSE
Westermost Rough	N/A	2	July	Combined Guillemot/Razorbill = 10.5	Combined Guillemot/Razorbill = NSE
North Hoyle	<1(winter)	3	All months	Guillemot = 8.9 Razorbill = 4.8	Combined Guillemot/Razorbill = Positive effect Razorbill = <25%
Robin Rigg	2	3	All months	Guillemot = 5.1 Razorbill = 4.1	Guillemot = NSE
Prinses Amalia	1.5	3	Sept to Mar	Guillemot = 4.1 Razorbill = 1.9	Guillemot = NSE
Egmond aan Zee	1.5	4	Sept to Mar	Guillemot = 4.1 Razorbill = 1.9	Guillemot = NSE
London Array	2	3	Nov to Feb	Combined Guillemot/Razorbill = 5.58	Combined Guillemot/Razorbill = 68%
Lincs	3	3	All months	Combined Guillemot/Razorbill = 5.0	Combined Guillemot/Razorbill = NSE
Thornton Bank Phase I, II, III	2-10	6	All months	Guillemot = 3.0 Razorbill = 1.0	Guillemot = 60%
Bligh Bank (Belwind)	2-10	4.5	All months	Guillemot = 2.0 Razorbill = 2.5	Guillemot = 75%
BARD 1	2	1	All months	Guillemot = 2.5	Combined Guillemot/Razorbill = not specified
Alpha Ventus	N/A	3	All months	Combined Guillemot/Razorbill = <2	Combined Guillemot/Razorbill = 75%
Helgoland Cluster & Butendiek	14	3	All months	Guillemot = 0.23-1.58 Guillemot = 0.3-0.83	Guillemot (non-breeding season) = 63% Guillemot (breeding season) = 44%
Kentish Flats	3	2	All months	Combined Guillemot/Razorbill <1.0	Combined Guillemot/Razorbill = NSE
Gunfleet Sands	1	1	Oct to Mar	Guillemot <1.0	Combined Guillemot/Razorbill = not specified
Horns Rev 1	N/A	1	Jan to Apr	Combined Guillemot/Razorbill <1.0	Combined Guillemot/Razorbill = not specified
Horns Rev 2	2	1	Oct to Apr	Combined Guillemot/Razorbill <1.0	Combined Guillemot/Razorbill = not specified

1 NSE = No statistically significant effect

Mortality rate

43. For the current Berwick Bank application, advice in the Scoping Opinion stated that mortality rates of 3% and 5% in the breeding season and 1% and 3% in the non-breeding season should be used for the guillemot and razorbill displacement assessments. This differs from advice received for previous assessments as described above. At Road Map 5 (volume 3, appendix 11.8) NatureScot and Marine Scotland Science stated that higher mortality rates were advised given that SeabORD outputs (e.g. Searle *et al.*, 2020) indicate that displacement mortality is greater than previously considered. As described above, the Applicant has commissioned an independent investigation into the operation and sensitivity of a comparable, publicly available version of SeabORD (Searle *et al.*, 2018) and presents evidence as to why it is not appropriate to use these theoretical outputs to inform the higher mortality rates requested for use in the matrix method assessment in the Scoping Opinion.

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

45. Two theoretical studies have attempted to predict the fate or population consequence of displaced seabirds, including auks, from offshore wind farms (Searle *et al.*, 2014 and 2018, and van Kooten *et al.*, 2019).

46. The work of Searle *et al.*, (2014, 2018) is reviewed and discussed separately in volume 3, appendix 11.4, annex H. The study conducted by van Kooten *et al.*, (2019) involved assessments for guillemots and razorbills in the non-breeding season and included existing and planned North Sea offshore wind farms as presented in Van der Wal *et al.*, (2018). The analysis consisted of habitat quality maps based on seabird distribution data and determining the cost of habitat loss using an individual based energy-budget model. Displacement rates were set at a realistic maximum of 50% based on Dierschke *et al.*, (2016) or an overly precautionary 100% in order to understand the consequences of complete displacement. Two mortality rates were tested; the first based on the Individual Based Model (IBM), using an energy budget approach to quantify this effect, while the second was based on a precautionary 10% mortality rate. The study estimated an additional non-breeding season mortality rate for displaced guillemots and razorbills of 0.1% for a 50% displacement rate and 0.4% for a 100% displacement rate.A review undertaken by Norfolk Vanguard (MacArthur Green 2019) included an investigation on the likely consequences of displacement at the population level. This review concluded that displacement of guillemots and razorbills by offshore wind farms is likely to be incomplete, may reduce with habituation, and that in the long term there may be increased food availability to guillemots and razorbills through providing enhanced habitat for fish populations around offshore wind farms. These factors, together with the very low level of natural mortality of adult guillemots and razorbills (approximately 6% and 10% per annum respectively; Horswill and Robinson, 2015), suggest that impacts of displacement from offshore wind farms are unlikely to represent levels of mortality anywhere close to the 6% or 10% total annual mortality that occurs due to the combination of many natural factors plus existing human activities (MacArthur Green, 2019).

47. For context, there is also evidence from tracking studies involving tagged guillemots from the Isle of May colony between 2010 and 2021 that demonstrate that the extent of foraging areas varies between breeding seasons (Figure 2.3). Similar distributions of tagged razorbills over the same breeding seasons are presented in Figure 2.3. Since foraging distribution may be considered a reflection of prey distribution, then typically, a more restricted foraging distribution around a breeding colony would indicate that prey availability is good in that area, for that breeding season. Potential implications of this when prey availability is poor are discussed above.

48. As shown in Figure 2.3, in the 2014, 2018 and 2021 breeding seasons, no tagged guillemots were recorded within the Proposed Development. In the 2010, 2012 and 2013 breeding seasons, the core foraging area for guillemots extended close to the western edge of the Proposed Development. In the 2019 and 2020 breeding seasons, foraging guillemots were more widespread across the Proposed Development.

49. Similarly, in the 2012, 2013 and 2014 breeding seasons, no tagged razorbills were recorded within the Proposed Development (Figure 2.4). Distribution was similar in 2010, 2018, 2019 and 2021, with the core foraging area for razorbills extending into the western edge of the Proposed Development, while in the 2020 breeding season, the core foraging area for razorbills included much of the Proposed Development. These tagging results indicate that the Proposed Development is not a key foraging area used in every breeding season for either species, but that in some seasons, birds do forage within the Proposed Development.

50. Baseline digital aerial surveys for the proposed Development were conducted between March 2019 to April 2021, and therefore covered the 2019 and 2020 breeding seasons. Based on the UKCEH tracking data (Bogdanova *et al.*, 2022), in both these seasons, guillemot and razorbill foraging areas within the Proposed Development were more extensive than in other breeding seasons, with the 50% utilization contour extending across almost all of the Proposed Development in the 2020 season for razorbill. This indicates that densities for both these species within the Proposed Development as recorded on baseline surveys in these breeding seasons are likely to be higher than in other breeding seasons, with a more restricted foraging distribution. On this basis, it could be considered that as the assessment has been based on these data, then the resulting conclusions are likely to be precautionary, as more birds will have been recorded in the Proposed Development than in years when prey is concentrated closer to the breeding colony.

51. There are likely to be similar variations in foraging distributions between breeding seasons for guillemots and razorbills from other colonies in the region.

52. Based on the above evidence, it is considered that a displacement rate of 50% and a mortality rate of 1% for the breeding and non-breeding seasons is suitably precautionary for an assessment of displacement effects from the Proposed Development on guillemots and razorbills. This has therefore been applied as the Developer Approach for the assessment.

53.

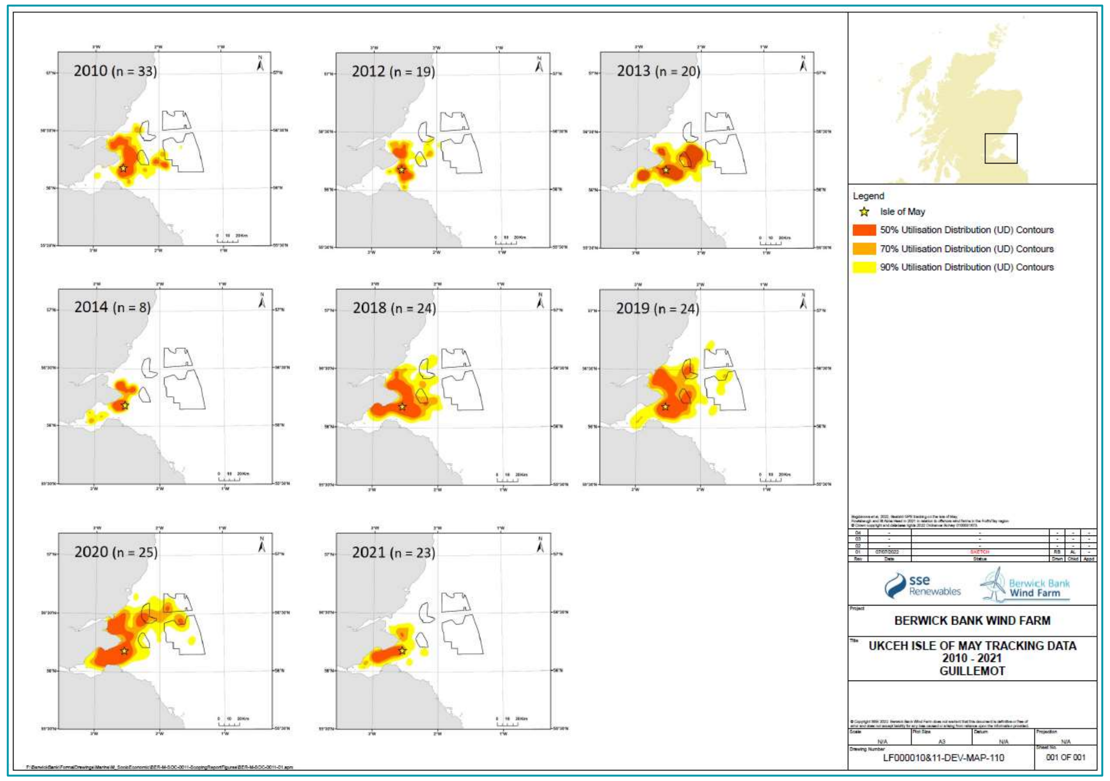

Figure 2.3: UKCEH Guillemot Breeding Season Tracking Data from Isle of May between 2010 and 2021 (from Bogdanova *et al.*, 2022).

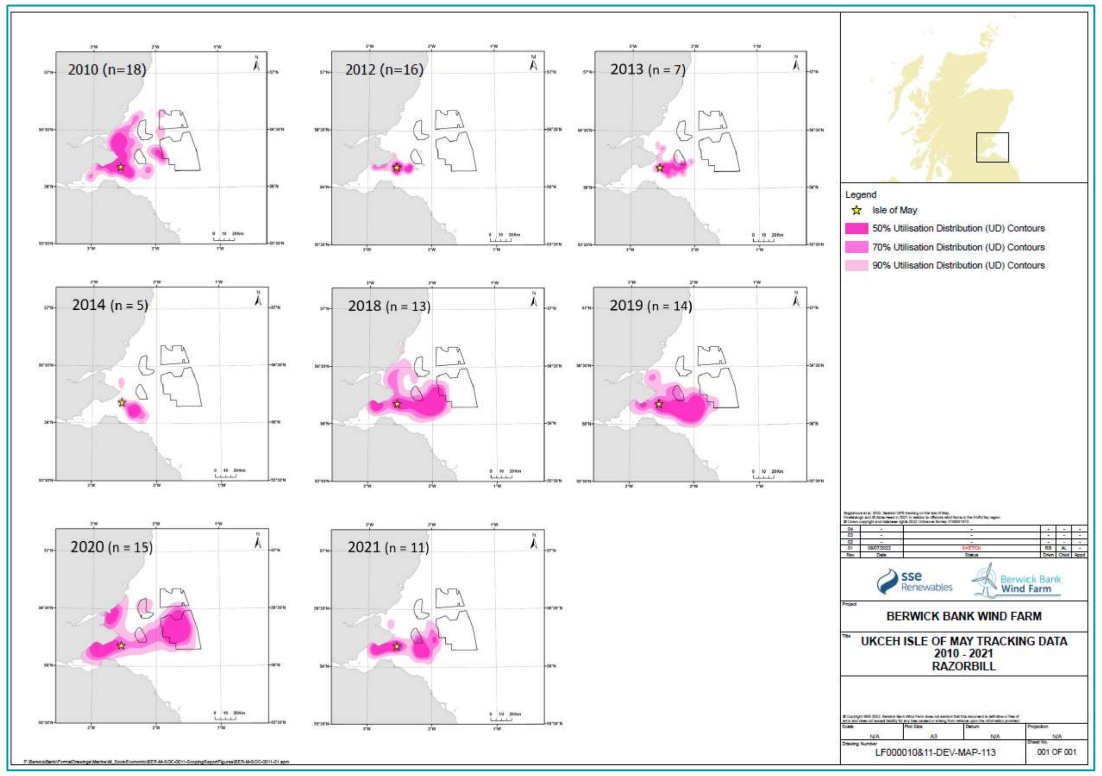

Figure 2.4: UKCEH Razorbill Breeding Season Tracking Data from Isle of May between 2010 and 2021 (from Bogdanova *et al.*, 2022).

2.4. PUFFIN

2.4.1. SUMMARY

Table 2.5: Summary of displacement and mortality rates chosen for puffin in the Developer Approach

Puffin	Displacement Rate	Mortality Rate – Breeding season	Mortality Rate – Non-breeding Seasons
Scoping Approach A	60%	3%	No assessment required
Scoping Approach B	60%	5%	No assessment required
Developer Approach	50%	1%	No assessment required

2.4.2. PRECEDENT

54. For previous Forth and Tay Section 36 EIA ornithology assessments, Scottish Ministers advised that a displacement rate of 60% and a mortality rate of 2% should be used for puffin for the breeding season only (e.g. Marine Scotland, 2017a, Marine Scotland, 2017b).

Displacement rate

55. For the current Berwick Bank application, Scoping Opinion advice stated that a displacement rate of 60% should be used for the puffin displacement assessment but that assessment of displacement during the non-breeding season was not required.

56. There is little empirical evidence on the effects on puffins from operational offshore wind farms. Occasionally puffins were recorded during Horns Rev, Egmond aan Zee and Arklow Bank post-construction monitoring but not in sufficient numbers to undertake any statistical analysis of effects (Petersen, 2006, Leopold *et al.*, 2011, Barton *et al.*, 2010).

57. A study at the operational Westermost Rough offshore wind farm investigated the degree of displacement for auks, including puffins within the wind farm. The study recorded high variability in overall mean densities of auks, including puffins, calculated for the entire offshore wind farm and the surrounding buffer zone suggesting no evidence of displacement. There were variations in mean densities of auks across the buffer zone but these differences were not statistically significant (APEM, 2017).

58. The Year 1 post-construction study report for Beatrice offshore wind farm reported that puffin was one of the species that were less abundant within the wind farm on post-construction surveys than on pre-construction surveys. However, although the study found that puffins were present in lower numbers on post-construction surveys, birds were still recorded within the wind farm. It was thought that the lower abundance may have been due to a later survey date on the pre-construction surveys coinciding with greater numbers of puffins at that time, rather than being an actual displacement effect (MacArthur Green, 2021).

59. A review of post-construction auk displacement concluded that evidence in support of using a precautionary displacement rate of 50% within the wind farm, 30% within the 1 km buffer and 0% beyond 1 km, together with a 1% mortality rate for guillemot and razorbill was also considered appropriate for puffin (MacArthur Green 2019a).

60. Similarly, a further review of post-construction auk displacement also concluded that the precautionary displacement rate of 50% and a 1% mortality rate used for guillemot and razorbill was also considered appropriate for puffin (MacArthur Green 2019b).

Mortality rate

61. For the current Berwick Bank application, Scoping Opinion advice stated that mortality rates of 3% and 5% should be applied for puffin in the breeding season but that assessment of displacement during the non-breeding season was not required. This differs from advice received for previous assessments as described above. At Road Map 5 (volume 3, appendix 11.8) NatureScot and Marine Scotland Science stated that higher mortality rates were advised given that SeabORD outputs (e.g. Searle *et al.*, 2020) indicate that displacement mortality is greater than previously considered. As described above, the Applicant has commissioned an independent investigation into the operation and sensitivity of a comparable, publicly available version of SeabORD (Searle *et al.*, 2018) and presents evidence as to why it is not appropriate to use these theoretical outputs to inform the higher mortality rates requested for use in the matrix method assessment in the Scoping Opinion.

62. In addition, there is little available evidence on mortality rates resulting from displacement impacts on puffins. However, there is some evidence from tracking studies involving tagged puffins from the Isle of May colony from 2010 and between 2018 and 2021 that demonstrate that the extent of foraging areas varies between breeding seasons (Figure 2.5). Since foraging distribution can be considered a reflection of prey distribution, then typically, a more restricted foraging distribution around a breeding colony would indicate that prey availability is good in that area, for that breeding season.

63. For context, in the 2010 and 2018 to 2019 breeding seasons, tagged puffins from the Isle of May were recorded foraging along the western edge of the Proposed Development (Figure 2.5). In the 2020 breeding season, the core foraging area for puffins extended further into the western side of the Proposed Development, while in the 2021 breeding season, the foraging range for tagged puffins from the Isle of May was more restricted than previous years, with fewer tracks recorded in the Proposed Development.

64. Baseline digital aerial surveys for the proposed Development were conducted between March 2019 to April 2021, and therefore covered the 2019 and 2020 breeding seasons. Based on the UKCEH tracking data (Bogdanova *et al.*, 2022), in both these seasons, puffin foraging areas within the Proposed Development were more extensive than in the 2010 and 2021 breeding seasons, with the 50% utilization contour extending over much of the western half of the Proposed Development in the 2020 season. This indicates that densities for puffin within the Proposed Development as recorded on baseline surveys in these breeding seasons are likely to be higher than in other breeding seasons with a more restricted foraging distribution. On this basis, it could be considered that as the assessment has been based on these data, then the resulting conclusions are likely to be precautionary, as more birds will have been recorded in the Proposed Development than in years when prey is concentrated closer to the breeding colony.

65. There are likely to be similar variations in foraging distributions between breeding seasons for puffins from other colonies in the region.

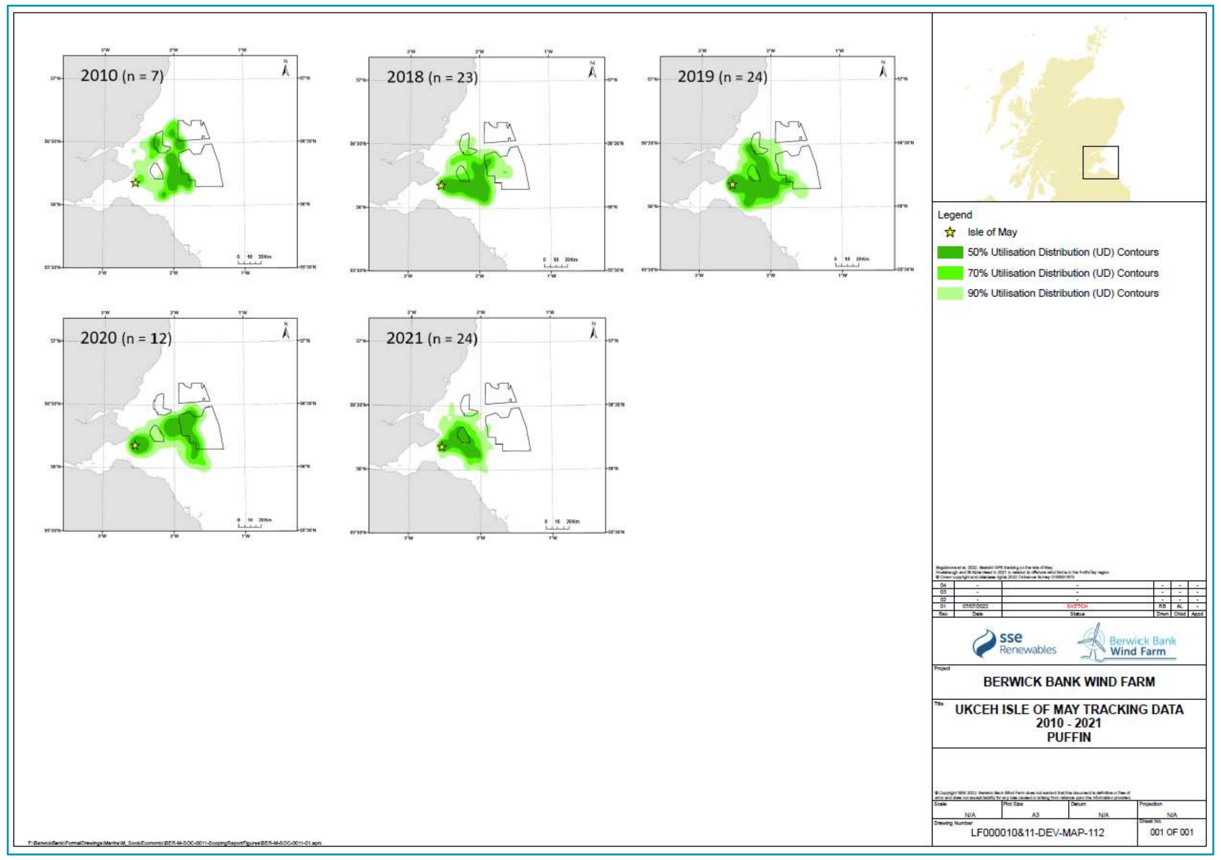

Figure 2.5: UKCEH Puffin Breeding Season Tracking Data from Isle of May in 2010 and between 2018 and 2021

66. In addition, tracking data from puffins breeding at the Isle of May indicate that there is an overlap between the Proposed Development and puffins from this colony with 17% of flights and 2% of birds flying across the Proposed Development. However, the area of the Proposed Development impacts on no more than 1.5% of the foraging and resting areas of puffins from the Isle of May recorded during this study. This suggests that the vast majority of foraging during the breeding period occurs beyond the area of possible impact arising from the Proposed Development (Bogdanova *et al.*, 2022.). Consequently, individual puffins that may be displaced by the Proposed Development and other offshore wind farms in the region will be able to relocate to an extensive surrounding area that is known to be suitable for puffins for both feeding and resting.

67. Studies using time-depth recorders indicate that puffins are capable of diving to depths of 45 m or greater (e.g. Jónsson 2003, Shoji *et al.*, 2015). Results from tracking studies also indicate that puffins have low foraging site fidelity and typically do not make repeated trips to the same foraging area (Fayet *et al.*, 2021). Consequently, their distribution is not constrained by habitat (water depth) nor are they reliant on foraging in specific areas. This strongly suggests that any puffins that may be displaced from the Proposed Development and other offshore wind farms in the region would be able to find alternative foraging locations in the vicinity.

68. Based on the above, it is considered that a displacement rate of 50% and a mortality rate of 1% for the breeding season is suitably precautionary for an assessment of displacement effects from the Proposed Development on puffins. This has therefore been applied as the Developer Approach for the assessment.

3. SUMMARY OF INDEPENDENT REVIEW AND SENSITIVITY ANALYSIS OF THE SEABORD TOOL

69. The SeabORD tool uses complex individual-based modelling to simulate the energetic consequences of birds foraging elsewhere due to displacement from an offshore wind farm site and/or having to travel further to their foraging locations to avoid offshore wind farms due to barrier effects. This is intended to be more biologically realistic than the currently used matrix approach (Searle *et al.*, 2018).

70. It is widely acknowledged that the matrix approach is simplistic and that the displacement mortality rates used are based solely on expert judgement. In contrast, SeabORD is extremely complicated and inaccessible, and there are concerns that the drivers underlying survival and reproductive rates predicted by the model are not fully understood. Furthermore, SeabORD often predicts much higher rates of mortality (by an order of magnitude) than is expected from expert judgement (Searle *et al.*, 2020). However, the outputs from SeabORD are now being used as a basis to inform SNCB advice on displacement mortality rates for use with the matrix approach (e.g. Road Map 5; volume 3, appendix 11.8). This has clear implications for assessments of the ecological impact of consented and proposed projects.

71. The authors of SeabORD recommend that the SeabORD outputs; "should be used to revise mortality rates used in the displacement matrix, and to quantify the uncertainty associated with these rates." (Searle *et al.*, 2020).

72. At Roadmap Meeting 5 (volume 3, appendix 11.8) NatureScot and Marine Scotland Science stated that higher mortality rates were advised given that SeabORD outputs indicate that displacement mortality is greater than previously considered. This was confirmed in further communication from Marine Scotland Licensing Operations Team in response to Scoping Opinion queries (K. Bell; email 02/03/2022).

73. The Applicant's position is that it is not appropriate to use the SeabORD outputs to inform the higher mortality rates requested for use in the matrix method assessment in the Scoping Opinion for the reasons outlined below.

3.2. INADEQUATE ASSESSMENT OF SENSITIVITY AND CONFIDENCE OF OUTPUTS PRIOR TO CONCLUDING FROM OUTPUTS

74. To date, the confidence in the outputs from SeabORD are not fully quantified and there is no comprehensive sensitivity study published to quantify the level of uncertainty in the outputs created by varying key input parameters and relationships (Searle *et al.*, 2014, 2018, 2020). It is therefore the Applicant's position that it is not appropriate to draw conclusions and apply these higher rates for use in EIA prior to the sensitivity and confidence being properly understood.

75. To improve understanding of this issue, Natural Power were commissioned by the Applicant to undertake a sensitivity analysis of the SeabORD model. The aim of this work is to assess the key uncertainties and sensitivities associated with the model and in that light, understand the extent to which the model is fit for purpose to be used in the assessment of predicted displacement mortality at this time. This was achieved by (1) a review of the model to identify underlying parameters and assumptions, (2) determining a level of confidence in each parameter/assumption based on the supporting evidence provided by the tool authors and additional evidence identified during a literature review and (3) testing the sensitivity of key parameters and assumptions to understand the potential consequences of adjusting individual parameters within a range of realistic values.

3.3. SEABORD OUTPUTS ARE HIGHLY SENSITIVE TO THE MULTIPLE INSTANCES OF PROFESSIONAL JUDGEMENT USED WITHIN THE MODEL

76. The model is described by its authors as more biologically realistic than the matrix method (Searle *et al.*, 2018, 2020), and whilst it provides a very useful exercise to understand complex relationships in seabird ecology, the investigation and sensitivity analysis undertaken by in volume 3, appendix 11.4, annex H shows that the outputs are extremely sensitive to a number of parameters in which there is little certainty and in fact many instances of parameters which are unsubstantiated professional judgement.

3.4. SOME HIGHLY SENSITIVE SEABORD PARAMETERS ARE KNOWN TO BE DEFICIENT

77. Some of the parameters to which SeabORD is very sensitive are known to be based on proxy data. For example, the parameter used to assess the degree to which adult mass influences overwintering survival is currently based on a study of puffins in northern Norway where puffins are generally larger and likely to experience more severe over-winter conditions (Erikstad *et al.*, 2009; Daunt *et al.*, 2018). Daunt *et al.* (2018) found support for a relationship of mass with overwinter survival of Scottish puffins in the Forth and Tay region based on good sample sizes and data collected over a number of years. It is understood that the use of the more spatially relevant data collected by Daunt *et al.*, (2018) would reduce the additional mortality predicted by the model (Road Map 5, volume 3, appendix 11.8; volume 3, appendix 11.4, annex H). However to date, it is understood that these parameters have not been updated.

3.5. THE METHOD OF ASSOCIATING SEABORD OUTPUTS WITH THE MATRIX APPROACH IS NOT DIRECTLY COMPARABLE

78. As described above, outputs from SeabORD are being used to inform SNCB advice on displacement mortality rates for use with the matrix approach (Road Map 5, volume 3, appendix 11.8; Searle *et al.*, 2020). In order to produce displacement mortality rates that are directly comparable with those applied in

the matrix method, there must be a method of linking SeabORD outputs with the at-sea snapshot survey data used to generate displacement matrices.

79. SeabORD therefore incorporates the ability to simulate snapshot at-sea surveys like those generally used as a basis for the displacement matrix approach. However, although these derived “matrix-comparable” mortality rates will vary more or less proportionately to the other metrics produced by SeabORD, the absolute difference among the rates will be much larger due to the relatively small number of birds detected within the simulated snapshot surveys (other metrics relate to entire population sizes). In addition, there are a number of considerations which mean that mortality rates derived from the SeabORD simulated snapshot surveys are not directly comparable to those that should be used with the at-sea survey abundances that feed into the displacement matrix. These are further outlined in volume 3, appendix 11.4, annex H, but typically result in an underestimate of the number of birds in the simulated snapshot, which leads to an over-estimate of the mortality rate.

3.6. THE USE OF CUMULATIVE PRECAUTION WITHIN THE MODEL

80. The model is based around the principles underlying the ecology and behaviour of seabirds and where possible, parameter values are taken from publicly available literature or from data accessible to the authors. However, the model necessarily incorporates a number of simplifications in order to keep the run-time down and a number of assumptions where evidence to support a more refined mechanism is unavailable. Where simplifications or assumed parameters are used, a precautionary approach is generally taken. This occurs at a number of points during the modelling process, for example:

- that adults do not change their feeding location within time steps even if the foraging conditions are poor;
- that habituation or learned avoidance of the wind farm area at a large spatial scale, i.e. a change in forage location choice based on having previously encountered the wind farm, is assumed not to occur;
- that birds are not able to accrue more energy within a time step than is required to replace the energy used in the previous timestep, i.e. no adult mass gain;
- that adults are not able to compensate for time unattended, or deficit in energy provided to their chick by their partner.

81. It is considered that in each of these assumptions, the result will be additional precaution added into the model, even though such outcomes appear biologically unlikely.

82. The user-defined input parameter values recommended by regulators and their advisors, for example, for displacement rates and the proportion of displaced birds barriered, are already subject to precaution. Additional precaution from the model as highlighted above, will result in an accumulation of precaution such that while each individual assumption may make a small impact on the outcomes of the model, the cumulative impact of these simplifications will be much greater.

83. The more complex the modelling approach used to make such assessments, the more opportunities there are for accumulation of conservatism to become an issue, and an understanding of the magnitude and potential impacts of this conservatism on model outputs is necessary to fully understand results. The lack of thorough sensitivity and confidence analysis undertaken to date means that this context is not yet properly understood

3.7. PREY QUANTITY SENSITIVITY AND UNCERTAINTY

84. As has been noted by Searle *et al.*, (2018), the default scenario of the SeabORD model is extremely sensitive to the prey quantities specified, even when these fall within the range of values that result in a “moderate” baseline scenario. The high sensitivity of the model to prey abundance is understandable since prey availability will be a key determinant of adult mass loss and reproductive success in any given year. However, it is problematic, due to the need to conduct lengthy calibration runs prior to running final models to identify prey values that will result in “moderate” baseline scenarios.

85. A significant question with respect to the validity of this calibration approach is that the model must be re-run for each colony to be included in the model with prey values re-calibrated for that colony, i.e. different values for each colony are required to be used. This reduces confidence in the extent to which the tool is able to replicate the real-world conditions experienced by the birds, as in reality birds from all colonies will experience the same set of conditions. Given the sensitivity of the model to these assumptions, it also reduces confidence in the validity of the outputs.

3.8. BIRD AND PREY DISTRIBUTION ISSUES

86. It has been noted that mortality rates predicted by SeabORD for displaced individuals vary significantly depending on the underlying data used in the modelling (e.g. ICOL, 2018; King, 2021). This highlights the need for data that accurately reflect reality, particularly regarding the underlying bird and prey distribution, as these will, both in the model and in the real world, have significant impacts on mortality levels.

87. The initial model developed by Searle *et al.*, (2014) was based on bird distributions derived from low sample sizes, especially for some combinations of species and colonies, collected during a short period of the chick-rearing season and over just a few years. New maps have been generated based on larger sample sizes from the chick-rearing period for more recent iterations of the model (Searle *et al.*, 2018, 2020), but there is a large degree of variation among these maps, demonstrating that there is substantial uncertainty associated with them.

88. The uncertainty around the data underlying these two inputs is acknowledged by the authors of the tool (Searle *et al.*, 2018, 2020) and further work is ongoing to provide more robust bird and prey density data for the Forth and Tay region (e.g. via the Marine Scotland led PrePARED research programme). However, on this basis, it appears that the use of the existing outputs for decision making is not easily defensible given the fact that predictions may change substantially with the use of more robust datasets.

89. In the model, where data to derive distribution maps are not available, or have not been modelled, an alternative approach can be implemented in which a distance decay function is used to model the distribution of bird foraging locations, with a uniform (even) prey distribution used to feed into the intake rate at any given foraging location and determine new foraging locations of displaced birds. Note that this method was advised by Marine Scotland Science in Road Map 5 (volume 3, appendix 11.8) for use with seabORD to provide contextual displacement mortality estimates from the Proposed Development.

90. With distance decay, the majority of birds are predicted to forage close to the colony. This will often result in much lower predictions of the effects of offshore wind farms than would be expected to be generated using a density map, as most offshore wind farm will not be built in very close proximity to seabird colonies. In addition, the distance-decay relationship cannot account for the effect of prey abundance which will generally cause hotspots of bird density beyond those where they would be expected to be when only considering distance to the colony (as acknowledged in Searle *et al.*, 2018).

91. The distance decay method will likely be required for most commercial wind farm assessments, as the colony-specific tracking data required to generate appropriate bird distribution maps for use with SeabORD are either not available or not accessible to wind farm developers. There is considerable uncertainty

surrounding how well distance decay maps approximate the realised distribution of foraging seabirds and the high sensitivity associated with this assumption, with distance decay estimates 100% and 75% lower than estimates using distribution maps for chicks and adults respectively. It is therefore considered that SeabORD is not an appropriate method for predicting the impacts of displacement and barrier effects using the distance decay relationship, and thus is unlikely to be suitable for most commercial wind farm assessments.

3.9. INCORPORATION OF UNCERTAINTY WITHIN THE MODEL

92. When run as intended for assessment, impact metrics generated by SeabORD include a measure of uncertainty surrounding them. This uncertainty captures the intrinsic stochastic variability within the model and the uncertainty associated with specification of the prey density values. However, it should be noted that that while the uncertainty associated with specification of the prey density values captures uncertainty around what may happen in a moderate year, it does not consider good or poor prey scenarios (as is the case for the part of the simulation relating to winter), thus under-representing uncertainty even within this parameter. A range of additional sources of uncertainty also remain unquantified, including the uncertainty associated with parameter estimation, the structural uncertainty associated with the model, and the uncertainty associated with the spatial distributions of birds and prey (Searle *et al.*, 2018). As recognised by the model developers, these sources of uncertainty are likely to be large.

93. It is considered that the true uncertainty associated with the model will be much higher, and the total uncertainty inherent within the model is not accurately represented by the output. Therefore, despite openness by the developers regarding this issue, the confidence intervals provided are misleading and may provide false confidence when comparing scenarios against one another.

3.10. CONCLUSION ON THE USE OF SEABORD TO INFORM MATRIX DISPLACEMENT MORTALITY RATES

- The SeabORD model has been promoted as a favourable alternative to the displacement matrix due to the simplicity of the matrix approach relative to the process that it represents, the difficulty in determining connectivity of birds within a offshore wind farm footprint to different colonies, and the reliance of the matrix approach upon expert judgement for mortality rates. Whilst the matrix approach is simplistic, it does provide mortality estimates in a straightforward and transparent format. The matrix approach provides an indication of likely mortality rates given our current understanding, and in a way that allows ease of interpretation by industry and academia alike. This is in contrast to the SeabORD model which is extremely complex and opaque in terms of which factors are driving predicted additional mortality, meaning that critical evaluation of the outputs is extremely difficult.
- The SeabORD model incorporates a vast range of parameters and assumptions, many of which are based on little or no real-world evidence but rather on simplifications, calibration or expert judgement.
- In addition, the sensitivity of the SeabORD model to some key parameters, including those based entirely on professional judgement, suggests that the outputs are unlikely to be more reliable than those from the matrix approach with the added disadvantage that the sources and magnitude of uncertainty are not transparent.
- Several assumptions underlying the SeabORD model are precautionary such that combined with precautionary displacement and barrier rates, impacts may be substantially over-estimated.
- Some parameters to which SeabORD is very sensitive are based on proxy data where more relevant data exist, which would reduce overestimation of adult mortality.
- The output of the SeabORD model is extremely sensitive to the prey distribution and bird density maps underlying the algorithms thus it does not seem appropriate to reply on simplifications such as the distance-decay assumption and the assumption of uniform prey. Outputs generated using the existing bird and prey distribution maps should also be treated with caution due to the level of uncertainty associated with these inputs and the fact that no attempt is currently made to incorporate an estimate of this uncertainty into the model.
- The snapshot functionality of the tool, designed to provide a mechanism for translating at-sea survey data from offshore wind farm footprints into population-level demographic consequences as predicted by SeabORD, does not currently accurately reflect the method used to derive the numbers that feed into the displacement matrices and would over-estimate mortality rates to be used in the displacement matrix if used as is.
- The SeabORD model is still under development, with work currently ongoing to better understand key input parameters (e.g. the Cumulative Effects Framework (CEF), the ORJIP project "Quantifying Mortality Rates" project and the Marine Scotland led "PrePARED" project). It therefore seems inappropriate to draw strong conclusions from the outputs at this stage.
- Although a measure of uncertainty is provided with the model, this only reflects a small portion of the total uncertainty inherent within the modelling process. Additional sources of uncertainty, such as uncertainty associated with parameter estimation, the structural uncertainty associated with the model, and the uncertainty associated with the spatial distributions of birds and prey are not incorporated, thus providing outputs that inaccurately represent the true uncertainty associated with the modelling process. While the authors are clear that this is the case, the outputs are misleading and suggest a lot more confidence than can truly be attributed.
- The SeabORD model is a complex and intricate model for which it is currently impossible to assess correct levels of uncertainty, to derive generally applicable sensitivities or to understand the specifics of the interplay of the different components giving rise to the outputs for any given scenario. However, it is clear that the model is associated with a large amount of uncertainty and that the model can be highly sensitive to certain key input parameters. Given this, it does not appear to be the correct tool to provide the concise, transparent and comparable predictions required for general use for impact assessment at this time. Also given the lack of sensitivity assessment to date, and complexity of generating comparable values for the matrix approach it is not considered appropriate to use SeabORD outputs to inform an increase in the mortality rates used in EIAs for offshore wind farms at this time.

4. OVERALL CONCLUSIONS

94. As explained above, for the most part, the Developer Approach follows the Scoping Opinion Approach, except as presented and justified in the preceding sections.

95. The diverging approach relates only to parameters advised in the Scoping Opinion which the Applicant considers to be over-precautionary and a departure from standard advice/practice.

96. The Applicant considers the Developer Approach to be scientifically robust, suitably precautionary and reflective of current methods of assessment and recommends that it can and should be reasonably relied upon by the decision maker for the purposes of assessment. The Applicant has therefore provided the necessary information to support a decision based on the Developer Approach.

97. Nevertheless, cognisant of the advice given in the Scoping Opinion, the Applicant has also provided all necessary information to support a decision based on the Scoping Opinion Approach should the decision maker be minded to do so.

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