BERWICK BANK WIND FARM
OFFSHORE ENVIRONMENTAL IMPACT ASSESSMENT

APPENDIX 11.3: ORNITHOLOGY COLLISION RISK MODELLING TECHNICAL REPORT

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1. INTRODUCTION

1. Berwick Bank Wind Farm Limited (BBWFL) is a wholly owned subsidiary of SSE Renewables Limited and will hereafter be referred to as 'the Applicant'. The Applicant is developing the Berwick Bank Wind Farm (hereafter referred to as 'the Project') located in the outer Forth and Tay region (Figure 1.1).

2. The Project is located adjacent to the consented Forth and Tay offshore wind farms (OWFs) consisting of Seagreen to the north, Inch Cape to the northwest and Neart na Gaoithe to the west (Figure 1.1).

3. The Project will, if consented, provide an estimated 4.1 GW of renewable energy. Given the anticipated operational life span of 35 years, the Project will make a critical contribution to Scotland's renewable energy target of 11 GW of new offshore wind by 2030.

4. Turbine capacity is predicted to be 14 MW to 24 MW per wind turbine generator (WTG), with the number of turbines on site to be 179 to 307. Importantly, the minimum lower blade tip height has been increased from 22 m to 37 m (LAT) as an engineering design measure to increase the air gap and reduce potential collision risk to seabirds. The effectiveness of this is demonstrated in Annex A.

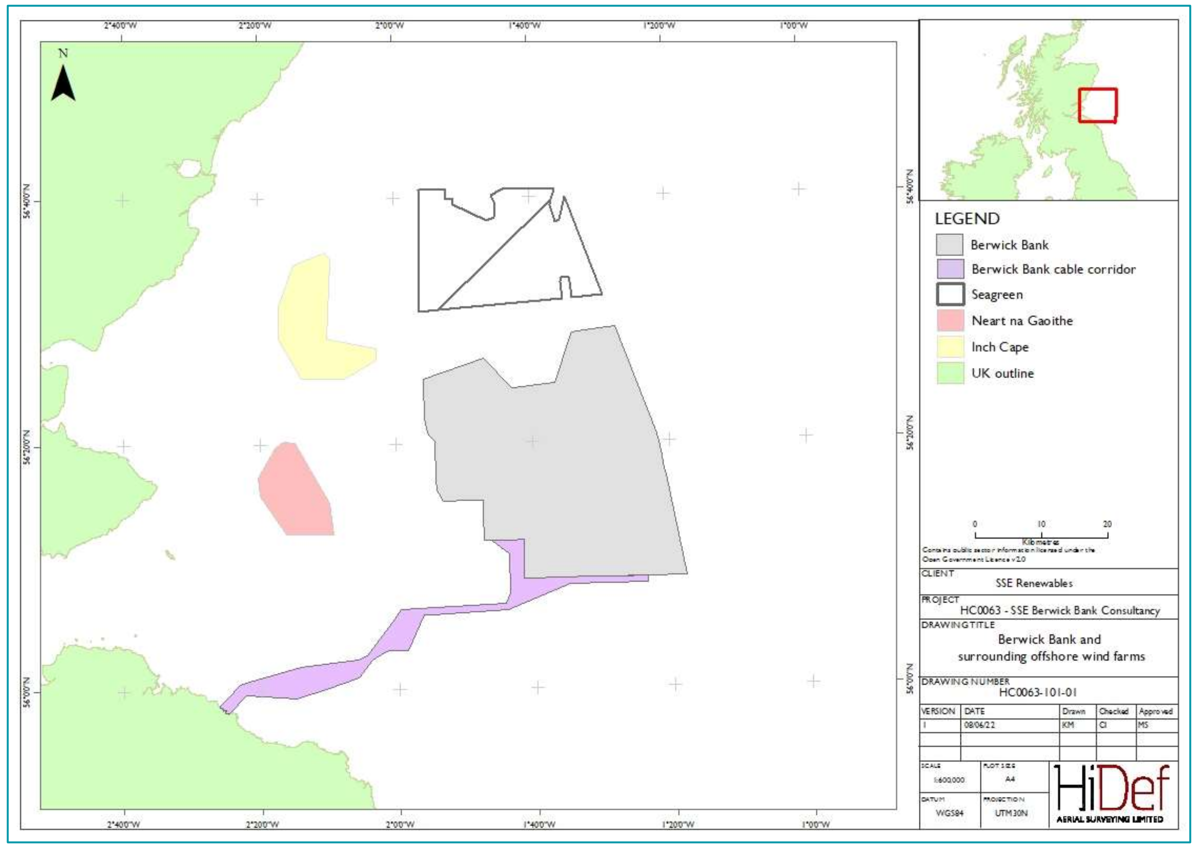


Figure 1.1: Boundaries for all consented and proposed offshore wind farms currently within the Outer Firth of Forth.

2. PURPOSE OF THE REPORT

5. This Technical Report provides estimates of collision risk for eight seabird species (Section 3.3) in relation to the Project.

6. Two approaches to collision risk modelling (CRM) were used:

- Deterministic offshore Band CRM (Band, 2012); and
- Stochastic CRM (sCRM) (Masden, 2015; McGregor *et al.,* 2018).

7. The deterministic Band model was used following the advice issued in the Scoping Opinion (4 February 2022) and provides the primary estimates for assessment of collision risk within the Proposed Development Array area, with these outputs used in the Population Viability Analyses (Technical Appendix 11:6: Ornithology Population Viability Analysis Technical Report). The sCRM approach, which takes account of the variability around input parameters, is used only for comparative purposes because the avoidance rates for use with this model (Bowgen and Cook, 2018), are not currently endorsed by NatureScot or Marine Scotland Science. This was agreed via the Ornithology Road Map process and follows the Scoping Opinion.

3. METHODS

3.1. OVERVIEW OF METHODS

8. The method for estimating the number of collisions can be simply expressed as:

$$FoT\ x\ Q2r\ x\ probability\ of\ collision$$

where

FoT = Flux rate multiplied by the operational time of the wind farm,

Q2r = Proportion of flying birds at collision risk height

Probability of collision = the probability of a single bird colliding with a turbine assuming no avoidance behaviour

9. Band (2012) and the sCRM make use of two model frameworks; a basic model which uses a straightforward calculation of Q2r from either site-based flight height estimates or generic flight height distributions, and an extended model which uses a flight height distribution but assumes that risk varies over the area of the turbine blades. As guidance, Band (2012) suggests that collision risk estimates get presented using three Options:

- Option 1 – Basic model: Proportion of birds at collision height (calculated manually) based on site-based flight height data, which assumes a uniform distribution of risk over the extent of the rotor swept area.
- Option 2 – Basic model: Proportion of birds at collision risk height (calculated automatically), based on a generic flight height distribution, also assuming a uniform distribution of risk over the rotor swept area.
- Option 3 – Extended model: Proportion of birds at collision height calculated by integrating risk across a turbine blade at different points along a generic flight height distribution.

10. Estimates using the Band model were generated using the Excel spreadsheet tool accompanying the Band (2012) publication. Estimates using the sCRM were generated using the underlying R code from the web-

based sCRM tool[1] so that multiple scenarios could be run more efficiently. Code can be made available on request.

11. The three model Options are equivalent between the Band (2012) spreadsheet implementation and the sCRM tool.

12. The estimates from using the Band and sCRM approaches are broadly similar, prior to application of the respective avoidance rates (see Table 3.6 and Table 3.7). However, the sCRM integrates stochasticity by way of random sampling from statistical distributions of input parameters.

3.2. OVERVIEW OF MODELLED SCENARIOS

13. The expected installation date for the Project means that it is anticipated that new technological advancements in turbine technology may occur between the consent application and the installation of turbines.

14. For this reason, physical parameters for future possible turbines have been determined by the Applicant's engineering team through an assessment of existing technology and research into turbine Developer plans and expectations with respect to future models. This exercise identified five potential turbine ratings to be considered in the Project Design Envelope (PDE) and determined likely worst-case parameters for each. The engineering team identified two potential variations of each of the three larger future turbine ratings with different rotor design concepts, resulting in eight types in total (Section 3.4.1).

15. The scenarios for the Band (2012) model included the eight turbine types and Options 2 (basic model) and 3 (extended model) only, with Option 3 limited to the large gull species following SNCBs guidance (SNCBs, 2014).

16. Model Options 2 and 3 make use of the generic flight height data of Johnston *et al.* (2014a; 2014b) as advised in the Scoping Opinion (4 February 2022). In addition, collision estimates for kittiwakes were modelled using Option 1 of the basic Band model, using site-based specific flight heights gathered during boat-based surveys, as advised in the Scoping Opinion and presented in Annex B (Technical Appendix 11.7: Comparison of boat-based and digital video aerial survey methods for seabirds).

17. It was agreed through the Ornithological Road Map process (RM2, 9 August 2021) that scenarios for all turbine types would be modelled to determine which represents the worst-case for each species considered in terms of predicted collision mortality.

18. The turbine and biological parameters of the worst-case scenario from the Band (2012) model for each species, were also modelled using the sCRM and provided for context (Annex C).

19. The Applicant has for the most part adopted the advice on ornithological assessment parameters advised in the Scoping Opinion (Volume 3, Appendix 11.8), for the purposes of conducting a CRM assessment on offshore ornithology for the EIA. Nevertheless, the Applicant considers elements of the Scoping Opinion to be over-precautionary and a departure from standard advice/practice. As such, the Applicant determined to undertake a 'dual assessment' approach of the collision risk posed by the proposed Development:

- The 'Scoping Approach'; and
- The 'Developer Approach'.

20. With respect to estimating collision risk, the two approaches differ only in their use of input monthly density estimates of flying birds of the assessed species within the proposed Development.

[1] https://dmpstats.shinyapps.io/avian_stochcrm/

21. The Scoping Approach is based on the Scoping Consultation responses from NatureScot and Marine Scotland Science (Volume 3, Appendix 11.8) which advised the use of monthly maximum density of relevant seabird species within the proposed Development Array area in the CRMs.

22. However, guidance on the use of the CRM suggests that model predictions should be based upon the mean monthly densities of flying birds estimated within the array area (Band 2012)[2] and, to the best of the Applicant's knowledge, this approach has been applied in all recent UK offshore wind farm assessments (i.e. from at least the Round 3 and Scottish territorial waters leasing rounds onwards).

23. Despite this, the Scoping Opinion advised that the CRMs for the Proposed Development should use the maximum monthly densities of flying birds within the array area. In part at least, this advice appeared to derive from a decision that it was not possible to use the stochastic version of the CRM (sCRM; McGregor *et al.,* 2018) due to an absence of recommended avoidance rates, meaning that the resultant collision estimates for the proposed Development (as generated from the deterministic CRM) would not account for variation and uncertainty in input information, including baseline densities (K. Bell, email 02/03/2022; Volume 3, Appendix 11.8). Further advice in the Scoping Opinion was that sCRM outputs should just be presented for context. However, the use of the maximum monthly densities does not actually address this issue since a full measure of uncertainty would be limited to differences between the two density calculations (i.e. mean density and maximum density). Furthermore, it is also the case that guidance from Natural England accepts that option 2 of the sCRM can be used with the same species-specific avoidance rates as for option 2 of the deterministic CRM (Parker *et al.,* 2022).

24. The Developer Approach follows that recommended in the industry guidance (Band, 2012) and as undertaken in all recent UK offshore wind farm assessments that the Applicant is aware of. This approach uses the monthly mean of the relevant two annual estimates of the density of flying birds within the proposed Development Array area. The Applicant is unaware of any change to the evidence base to support a change from this approach, noting that in their advice for the revised designs of the Forth and Tay projects Marine Scotland Science stated that an approach of using the maximum monthly density values within the CRM "runs the very high risk of producing an estimated effect that is highly likely to be unreasonable and unrealistically high." (Marine Scotland, 2017a, Marine Scotland, 2017b).

25. 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.

26. 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

3.3. SPECIES FOR MODELLING

27. Collision risk estimates are presented for eight seabird species considered to be vulnerable to collision at OWFs (Furness *et al.,* 2013): kittiwake *Rissa tridactyla*, herring gull *Larus argentatus*, lesser black-backed gull *Larus fuscus*, gannet *Morus bassanus*, Arctic tern *Sterna paradisaea*, common tern *Sterna hirundo*, little gull *Hydrocoloeus minutus* and great skua *Stercorarius skua*.

28. Auks *Alcidae* and fulmar *Fulmaris glacialis* were not considered as they generally fly at low altitudes, well below the minimum height of turbine rotor blades (Cook *et al.,* 2012; Johnston *et al.,* 2014a; 2014b; Jongbloed, 2016). The list of seabird species taken forward for CRM was discussed and agreed through the Ornithology Road Map process.

[2] A minimum 24-month programme of baseline offshore ornithology surveys (as undertaken for the Proposed Development) is considered a standard requirements for UK offshore wind farm assessments, providing (at least) two density estimates for each calendar month for use as inputs to the CRM (e.g. Parker *et al*., 2022).

3.4. PARAMETERISING THE COLLISION RISK MODELS

3.4.1. WIND FARM AND TURBINE PARAMETERS

29. Turbine and wind farm parameters were provided to HiDef from the Applicant within the PDE. Five different potential turbine designs, each of differing size, are being considered as part of the PDE: 14 MW, 15 MW, 18 MW, 21 MW and 24 MW.

30. Information on the 14 MW turbine is based on that provided by Siemens Gamesa Renewable Energy (SGRE) and GE's 14 MW Haliade X model. The parameters for the 15 MW turbine are based on the Vestas V236 turbine design parameters.

31. The larger rated turbines (18 – 24 MW) are of two different rotor design types, reflecting two possible future design pathways; (A) wide chord and slower rotational speed and (B) narrower chord and faster rotational speed.

32. The parameters for all turbine scenarios (rating and type) which are relevant to the CRM are given in Table 3.1.

33. The monthly wind availability is given in Table 3.2 and was calculated using the following cut-in/cut-out assumptions:

- 14 MW: 4 – 28 ms^{-1}
- 15 MW: 3 – 30 ms^{-1}
- 18 MW: 3 – 30 ms^{-1}
- 21 MW: 3 – 30 ms^{-1}
- 24 MW: 3 – 30 ms^{-1}

34. A mean monthly downtime of 3% was assumed for all turbine scenarios. The monthly time operational was calculated as the monthly wind available (%) minus 3% (Table 3.2). Estimates of collision are provided based on the application of the large array correction factor.

Table 3.1: Wind farm and turbine specifications for collision risk modelling for the Proposed Development.

Parameter	14 MW	15 MW	18 MW	21 MW	24 MW
Latitude (°)	56.1	56.1	56.1	56.1	56.1
Wind farm width (km)	48	48	48	48	48
Tidal offset (m)	-2.5	-2.5	-2.5	-2.5	-2.5
Maximum number of turbines	307	287	239	205	179
Number of blades	3	3	3	3	3
Rotor radius (m)	111	118	132.5	145	155
Hub height relative to LAT (m)	148	155	169.5	182	192
Chord width (m): Type A	7	5.2	8.4	9.1	9.8
Chord width (m): Type B	7	5.2	6.1	6.7	7.2
Rotation Speed (RPM): Type A	7.81	8.40	6.49	5.93	5.55
Rotation Speed (RPM): Type B	7.81	8.40	7.90	7.51	7.39
Pitch (°)	10	10	10	10	10
Mean wind speed at hub height (ms^{-1})	10.29	10.33	10.39	10.43	10.51

Table 3.2: Monthly wind availability (%) (WA) and operational time (%) (OT) for turbines being considered for the Proposed Development.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14 MW (WA)	96.15	94.57	92.42	90.29	87.41	88.30	86.58	87.16	91.27	94.44	95.07	95.42
14 MW (OT)	93.15	91.57	89.42	87.29	84.41	85.30	83.58	84.16	88.27	91.44	92.07	92.42
15 MW (WA)	98.12	97.27	95.69	95.07	93.00	93.89	92.59	92.93	95.80	97.29	97.59	97.87
15 MW (OT)	95.12	94.27	92.69	92.07	90.00	90.89	89.59	89.93	92.80	94.29	94.59	94.87
18 MW (WA)	98.14	97.33	95.85	95.23	93.18	94.05	92.64	93.13	96.08	97.31	97.53	97.85
18 MW (OT)	95.14	94.33	92.85	92.23	90.18	91.05	89.64	90.13	93.08	94.31	94.53	94.85
21MW (WA)	98.09	97.34	95.77	95.10	93.15	94.06	92.60	93.01	95.90	97.36	97.50	97.76
21 MW (OT)	95.12	94.34	92.81	92.14	90.14	91.01	89.47	90.05	93.01	94.33	94.48	94.81
24 MW (WA)	98.09	97.34	95.77	95.09	93.15	94.05	92.61	93.00	95.88	97.36	97.50	97.76
24 MW (OT)	95.09	94.34	92.77	92.10	90.15	91.06	89.60	90.01	92.90	94.36	94.50	94.76

3.4.2. SEABIRD DENSITIES

35. The monthly densities of flying birds in the Development Array only (excluding the 16 km buffer of the Offshore Ornithology Study Area; Figure 3.1) were estimated using design-based strip transect methods from the HiDef digital aerial surveys conducted between March 2019 – April 2021. The estimates for all species were based on counts that had been apportioned for non-identified birds during the surveys; detail is provided in Technical Appendix 11.2: Ornithology Baseline Technical Report.

36. Estimates of mean (Developer Approach) and maximum (Scoping Approach) monthly densities and pooled standard deviations (the latter only required for sCRM) for flying birds only have been used as input to the CRMs (Table 3.3 and Table 3.4).

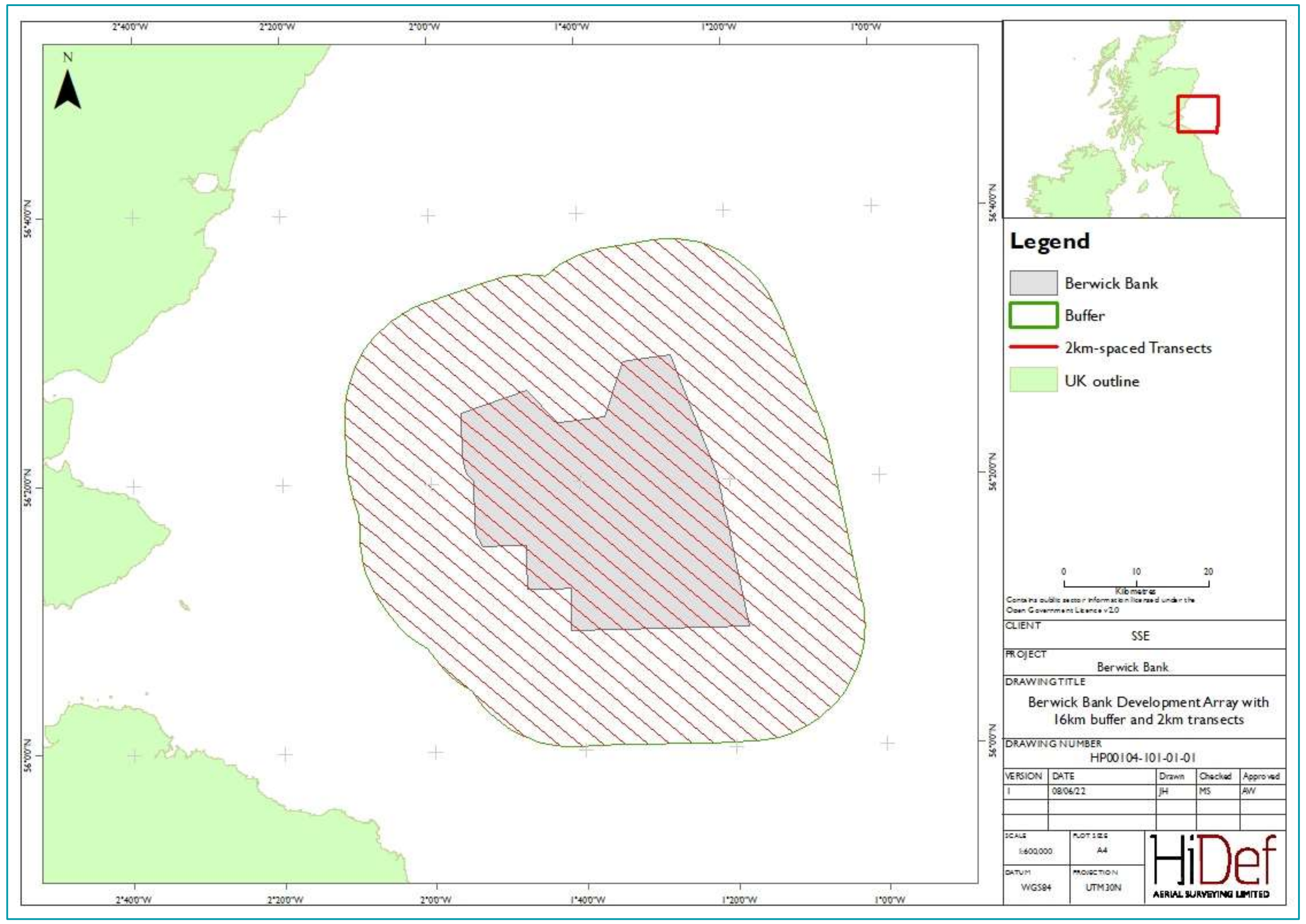


Figure 3.1: Offshore Ornithological Study Area comprising the proposed Berwick Bank Development Array and 16 km buffer flown using digital video strip transects by HiDef March 2019 – April 2021.

Table 3.3: Developer Approach: Mean monthly densities and pooled standard deviation (SD) of flying birds for eight species in the Proposed Development Array area only estimated from 25 months of baseline data collection.

	Kittiwake		Herring gull		Lesser black-backed gull		Gannet	
Month	Density of flying birds (n/km^2)	Pooled SD	Density of flying birds (n/km^2)	Pooled SD	Density of flying birds (n/km^2)	Pooled SD	Density of flying birds (n/km^2)	Pooled SD
January	1.10	0.21	0.02	0.01	0.00	0.00	0.03	0.02
February	0.54	0.17	0.00	0.00	0.00	0.00	0.02	0.02
March	3.14	1.07	0.01	0.01	0.00	0.00	0.17	0.05
April	5.11	1.67	0.00	0.00	0.00	0.00	0.44	0.18
May	4.91	0.86	0.00	0.00	0.00	0.00	0.57	0.11
June	4.38	0.53	0.16	0.05	0.02	0.02	0.84	0.18
July	1.91	0.20	0.32	0.10	0.13	0.03	1.51	0.23
August	3.53	0.58	0.03	0.02	0.00	0.00	1.04	0.16
September	2.14	0.43	0.00	0.00	0.00	0.00	1.70	0.32
October	0.84	0.25	0.00	0.00	0.00	0.00	0.41	0.07
November	1.85	0.58	0.03	0.03	0.00	0.00	0.46	0.10
December	0.50	0.16	0.04	0.02	0.00	0.00	0.01	0.01
	Arctic tern		**Common tern**		**Little gull**		**Great skua**	
Month	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
February	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
April	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
May	0.06	0.04	0.01	0.01	0.00	0.00	0.01	0.01
June	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00
July	0.56	0.22	0.07	0.04	0.01	0.01	0.01	0.01
August	1.57	0.35	0.45	0.13	0.07	0.04	0.00	0.00
September	0.01	0.01	0.03	0.04	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
November	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00

Table 3.4: Scoping Approach: Maximum monthly densities of flying birds for eight species in the proposed Development Array area only estimated from 25 months of baseline data collection.

	Kittiwake		Herring gull		Lesser black-backed gull		Gannet	
Month	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**
January	1.13	0.21	0.04	0.02	0.00	0.00	0.05	0.02
February	0.59	0.15	0.00	0.00	0.00	0.00	0.04	0.02
March	3.55	0.97	0.01	0.01	0.00	0.00	0.19	0.02
April	7.29	1.87	0.00	0.00	0.00	0.00	0.58	0.22
May	6.73	1.06	0.00	0.00	0.00	0.00	0.72	0.13
June	8.01	0.73	0.32	0.05	0.03	0.03	0.88	0.10
July	2.12	0.17	0.48	0.12	0.18	0.04	1.53	0.17
August	4.45	0.69	0.03	0.02	0.00	0.00	1.39	0.15
September	3.59	0.55	0.00	0.00	0.00	0.00	2.46	0.29
October	1.29	0.34	0.00	0.00	0.00	0.00	0.48	0.07
November	3.47	0.81	0.05	0.03	0.00	0.00	0.79	0.14
December	0.80	0.21	0.06	0.02	0.00	0.00	0.02	0.01
	Arctic tern		**Common tern**		**Little gull**		**Great skua**	
Month	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**	**Density of flying birds (n/km^2)**	**Pooled SD**
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
February	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00
March	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
April	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.00
May	0.07	0.03	0.01	0.01	0.00	0.00	0.01	0.01
June	0.04	0.02	0.00	0.01	0.00	0.00	0.00	0.00
July	1.09	0.22	0.07	0.05	0.01	0.01	0.01	0.01
August	2.60	0.33	0.69	0.18	0.12	0.05	0.00	0.00
September	0.02	0.01	0.06	0.06	0.00	0.00	0.00	0.00
October	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
November	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
December	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00

3.4.3. SEABIRD BIOLOGICAL PARAMETERS

37. Discussions through the Ornithology Road Map process (RM 3, 28 September 2021; NatureScot advice, 7 October 2021) were used to decide upon sources of seabird morphological and behavioural parameters for (e.g., flight speed, wingspan; Table 3.5) to parameterise the CRMs.

38. Body length, wingspan and flight speed measurements are sourced from Robinson (2005), Pennycuick (1997) and Alerstam *et al.* (2007). This information was not available for Arctic tern, so the morphological and behavioural parameters for common tern were used instead as they were considered a suitable proxy.

39. Nocturnal activity is defined over the period of nautical twilight (the time when the centre of the sun is between 6° and 12° below the horizon). Nocturnal activity is converted to a 1-5 scale in the Band spreadsheet where 1 = 0%; 2= 25%; 3 = 50%; 4 = 75%; and 5 = 100%. NatureScot provided advice for gannet based on an analysis of nocturnal activity of tagged birds which showed there to be very low levels of activity after dark (Furness *et al.,* 2018 and references therein). Furness *et al.* (2018) noted that nocturnal activity during the breeding season was 8%, and 3% during the non-breeding season; given these values, in the Band spreadsheet nocturnal activity during the breeding season is entered as 1.32, and during the non-breeding season as 1.12 following the 1-5 scale. For herring, lesser black-backed and little gulls, Arctic and common terns and great skua, the nocturnal activity scores were taken from Garthe and Hüppop (2004). The value for kittiwake is taken from the previously accepted Seagreen 1 (EIA Optimised Project Addendum 2018). All values follow the Scoping Opinion and agreement reached at the Ornithology Road Map 6 (10 May 2022) meeting.

40. Flight type was set as flapping for all species except gannet, which was set to gliding following advice from NatureScot in their Scoping Consultation response (7 December 2021).

Table 3.5: Morphological and behavioural parameters for the eight relevant species for the collision risk modelling for Berwick Bank.

Species	Body length (m)*	Wingspan (m)*	Flight speed (ms^{-1})**	Nocturnal activity (%)	Flight type (flapping or gliding)
Kittiwake	0.39	1.08	13.1	25***	Flapping
Herring gull	0.60	1.44	12.8	50†	Flapping
Lesser black backed gull	0.58	1.42	13.1	50†	Flapping
Gannet	0.935	1.72	14.9	8 (breeding season); 3 (non-breeding)‡	Gliding
Arctic tern	0.33	0.88	10.9	25†	Flapping
Common tern	0.33	0.88	10.9	25†	Flapping
Little gull	0.26	0.78	11.5	0†	Flapping
Great skua	0.585	1.5	14.9	0†	Flapping

**Robinson (2005); **Pennycuick (1997) and Alerstam et al., (2007); ***Seagreen 1 Scoping Report (EIA Optimised Project Addendum 2018); †Hüppop (2004); ‡Furness et al., (2018).*

3.4.4. AVOIDANCE RATES

41. Avoidance rates advised in the joint response of SNCBs (2014) are based on the Marine Scotland Science Avoidance Rate review (Cook *et al.,* 2014). The review included quantitative and qualitative analyses of all available evidence for five priority species: gannet, kittiwake, lesser black-backed gull, herring gull and great black backed gull. The review built upon previous work of Cook *et al.* (2012).

42. Bowgen and Cook (2018) utilise the results of the Bird Collision Avoidance (BCA) study which collected data on empirical estimates of bird behaviour at the operational Thanet Offshore Wind Farm (Skov *et al.,* 2018) to propose seabird collision and avoidance rates.

43. For the deterministic Band model, avoidance rates for all species were sourced from the SNCBs joint response on approved avoidance rates (SNCBs, 2014; Cook *et al.,* 2014; Table 3.6). Use of SNCBs (2014) avoidance rates for the primary assessment was advised in the Scoping Opinion (4 February 2022). Furthermore, a 98% avoidance rate for gannet was used following RSPB's consultation representation (Table 3.6).

44. There are no SNCBs endorsed avoidance rates for kittiwake or gannet for the extended Band model (Option 3). Therefore, avoidance rates from Bowgen and Cook (2018) were used for comparison (Table 3.7), noting that an avoidance rate for use in the extended model is not provided.

45. For the sCRM, avoidance rates for kittiwake, gannet, herring gull and lesser black-backed gull were taken from Bowgen and Cook (2018; Table 3.7). Currently SNCBs advice on preferred avoidance rates for sCRM is not available, but agreement to use Bowgen and Cook (2018) was obtained through the Ornithology Road Map process and confirmed in the Scoping Opinion 4 February 2022. Avoidance rates for sCRM for the terns, little gull and great skua were set at 0.980.

46. Avoidance rates from Cook (2021) were initially recommended for consideration during the Ornithology Road Map process (RM3, 28 September 2021). However, these avoidance rates have not been adopted by SNCBs to date, given concerns about the data sources and methodology used to produce them. Therefore, Cook (2021) avoidance rates have not been used.

Table 3.6: Avoidance rates (± 2 SD) used for the deterministic basic (Options 1 and 2) and extended (Option 3) Band model (2012) as per SNCBs advice (SNCBs, 2014). An additional avoidance rate of 98% was included for gannets. Avoidance rates used in the deterministic Band model for the terns, little gull and great skua are taken from SNCBs (2014) and were set at 0.980.

Species	Basic	Extended
Kittiwake	0.989 (0.002)	N/A
Herring gull	0.995 (0.001)	0.990 (0.002)
Lesser black-backed gull	0.995 (0.001)	0.989 (0.002)
Gannet	0.989 (0.002)	N/A
Gannet	0.980	0.980

Table 3.7: Avoidance rates for each species used in the deterministic basic (Options 1 and 2) and extended (Option 3) Band model (2012) and stochastic collision risk models (with 95% confidence intervals) as per Bowgen and Cook (2018). For terns, little gull and great skua, avoidance rates were set at 0.980.

	Band model CRM		Stochastic CRM	
Species	Basic	Extended	Basic	Extended
Kittiwake	0.990	0.980	0.994 (0.976 – 0.998)	0.970 (0.871 – 0.989)
Herring gull	0.995	0.993	0.997 (0.992 – 0.999)	0.990 (0.974 – 0.995)
Lesser black-backed gull	0.995	0.993	0.997 (0.992 – 0.999)	0.990 (0.974 – 0.995)
Gannet	0.995	N/A	N/A	N/A

3.4.5. SEABIRD FLIGHT HEIGHT

47. It was agreed through the Ornithology Road Map process (RM4, 8 December 2021) that the CRM should utilise the generic modelled flight heights from Johnston *et al.* (2014a; 2014b) for the primary assessment (Band Option 2 and 3). These flight height data were collated from seabird surveys at 32 OWFs in the UK and Europe. Most surveys were boat-based, and height measurements taken visually and assigned into height bands, to derive continuous flight height distributions for 25 seabird species. Site-specific flight height data for kittiwake collected during boat surveys within the proposed Development Array area are considered in Band Option 1 in Annex A.

3.5. SEASONAL CONSIDERATIONS

48. In this report we define biologically distinct 'bio-seasons' following those outlined in NatureScot guidance (2020).

49. Bio-seasons are defined as breeding and non-breeding:

- **Breeding season:** birds are strongly associated with a nest site, including nesting, egg-laying and provisioning young; and
- **Non-breeding season:** birds are dispersed and no longer strongly associated with colonies. This period subsumes the short 'pre-breeding' seasons defined separately in NatureScot (2020).

50. Bio-seasons for each species are given in Table 3.8 to Table 3.15. Little gulls do not breed in Scotland; hence no breeding season is defined. However, the use of NatureScot (2020) non-breeding season definitions presents issues for non-breeding season apportioning (Technical Appendix 11.5: Ornithology Apportioning Technical Report). Since non-breeding season apportioning is reliant on information for Biologically Defined Minimum Population Scales (BDMPS) (Furness, 2015), collision mortalities were also presented for the non-breeding seasons defined in Furness (2015) and used in further PVA for kittiwake and gannet, for which the autumn and spring passage and winter periods are defined within the non-breeding season (Table 3.8 and Table 3.15).

51. Estimates of the number of collisions for each bio-season were compiled from monthly estimates. Collision estimates for seasons that encompassed half-months were allocated proportionally within the season as agreed through the Ornithology Road Map process (RM3, 28 September 2021).

52. Where the NatureScot (2020) breeding season for kittiwake or gannet overlaps with the Furness (2015) BDMPS non-breeding seasons, the NatureScot (2020) breeding season took precedence rather than the non-breeding season. As an example, both the NatureScot (2020) breeding season and Furness (2015) autumn migration period for kittiwake include the month of August, however, when presenting collision for each bio-season, the August collisions were attributed to the breeding season rather than the Furness (2015) non-breeding autumn migration.

Table 3.8: Kittiwake bio-seasons based on NatureScot (2020)* and Furness (2015).**

Bio-season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Breeding season*												
Non-breeding season*												
Spring migration**												
Autumn migration**												

Table 3.9: Herring gull bio-seasons based on NatureScot (2020).

Bio-season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Breeding season												
Non-breeding season												

Table 3.10: Lesser black-backed gull bio-seasons based on NatureScot (2020).

Bio-season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Breeding season												
Non-breeding season												

Table 3.11: Gannet bio-seasons based on NatureScot (2020)* and Furness (2015).**

Bio-season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Breeding season*												
Non-breeding season*												
Spring migration**												
Autumn migration**												

Table 3.12: Arctic tern bio-seasons based on NatureScot (2020).

Bio-season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Breeding season												
Non-breeding season												

Table 3.13: Common tern bio-seasons based on NatureScot (2020).

Bio-season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Breeding season												
Non-breeding season												

Table 3.14: Little gull bio-seasons based on NatureScot (2020).

Bio-season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Non-breeding season												

Table 3.15: Great skua bio-seasons based on NatureScot (2020).

Bio-season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Breeding season												
Non-breeding season												

4. RESULTS

53. The modelled worst-case scenario for each species is summarised in Table 4.1, for both the Developer and Scoping Approaches.

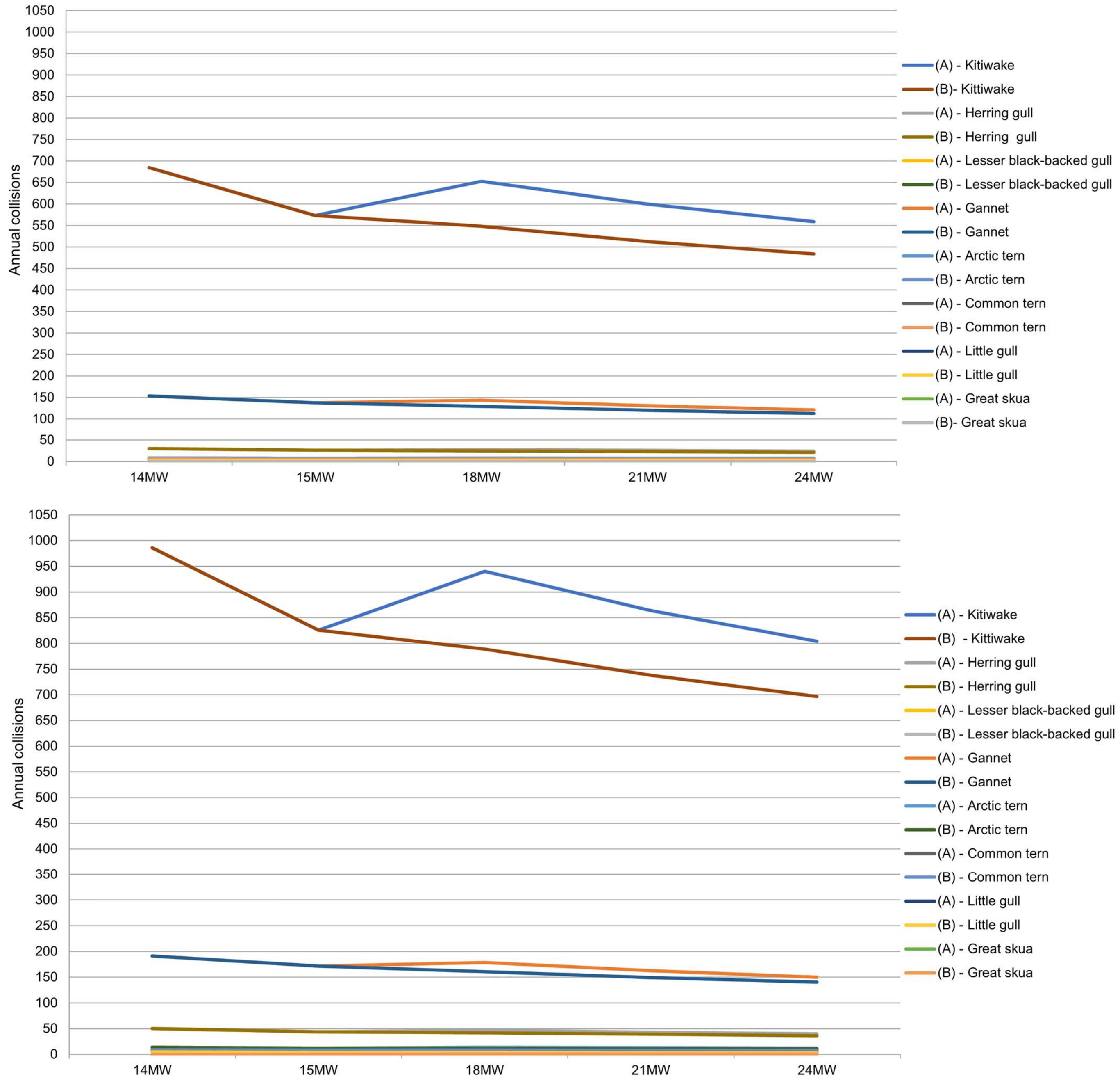
54. In all cases, the 14 MW x 307 turbines using the deterministic Band (2012) model resulted in the worst-case scenario. The view that using fewer, larger turbines as an effective measure for reducing collision (Johnston *et al.,* 2014a; 2014b) was borne out by the modelling undertaken here. For all species, the number of collisions tended to decrease with increasing turbine size and was lower for Type B turbines (narrower chord and faster rotational speed) compared to Type A turbines (wider chord and slower rotational speed) (Figure 4.1).

55. The collision mortality estimates for the 14 MW Type A turbine based on the sCRM outputs are provided for comparison in Table 4.1), noting that the scenario is not entirely equivalent to the worst case (previous paragraph 50) due to the different avoidance rates used. The full suite of collision estimates from the sCRM are provided in Annex C.

Table 4.1: Worst-case estimates for each species identified from the deterministic Band CRM using the generic flight height data (Options 2 & 3) and SNCBs (2014) avoidance rates for the Developer Approach and Scoping Approach. For sCRM, the mortality estimates for the 'equivalent' worst case scenario are provided but noting that the avoidance rates are from Bowgen & Cook (2018).

Species	CRM Option	Avoidance rate	Estimated annual collisions (SNCBs Guidance)		sCRM annual collision (95% CIs; Bowgen and Cook)	
			Developer Approach	Scoping Approach	Developer Approach	Scoping Approach
Kittiwake	2	0.989	685	986	371 (185-592)	536 (357-712)
Herring gull	2	0.995	30	50	19 (6-38)	32 (20-49)
Lesser black-backed gull	2	0.995	6	9	4 (1-10)	6 (3-11)
Gannet	2	0.989	153	191	N/A	N/A
Arctic tern	2	0.980	8	14	14 (0-84)	22 (0-127)
Common tern	2	0.980	6	9	6 (2-13)	9 (3-15)
Little gull	2	0.980	2	5	10 (0-143)	14 (0-197)
Great skua	2	0.980	0.17	0.35	1 (0-2)	1 (0-2)

Figure 4.1: Estimated numbers of annual collisions for each species, turbine rating and Type A and Type B for the Developer Approach (top) and the Scoping Approach (bottom).



4.2. KITTIWAKE

56. Monthly estimates of annual collisions for the worst-case for kittiwake are presented in Table 4.2 for both the Developer and Scoping Approaches. The total estimated annual number of collisions of kittiwake were 685 and 986 for the Developer and Scoping Approaches respectively.

57. Results from using site-specific flight heights for kittiwakes from rangefinder and visual observer data and modelled using option 1 of Band (2012) were considerably lower (Annex B, Annex B Table 36 and Annex B Table 37). Based on rangefinder data, the mean estimated annual number of collisions for kittiwake

using the Developer and Scoping Approaches were 56 and 81 birds respectively. Using the visual observer collected data, the annual mean increased to 225 and 324 kittiwakes for the Developer and Scoping Approaches respectively (Annex B Table 37).

58. The estimated number of collisions was highest during May, which coincides with the second and third peaks in mean and max monthly densities of flying kittiwakes, with 4.91 birds/km^2 (pooled SD ±0.86) and 6.73 birds/km^2 (pooled SD ±1.06) respectively (Table 3.3 and Table 3.4).

59. Combining the estimated number of collisions across bio-seasons, shows it to be highest during the breeding season (Table 4.3). However, the numbers of estimated collisions remain relatively high year-round throughout the non-breeding season.

60. The estimated number of collisions presented in Table 4.2 and Table 4.3 were used in population modelling reported in Technical Appendix 11.6: Ornithology Population Viability Analysis.

61. Annual collision estimates for kittiwakes for all turbine scenarios and avoidance rates using the Developer and Scoping Approaches are presented in Table 4.4 and Table 4.5 respectively.

Table 4.2: Monthly estimated annual collisions for kittiwake in the Proposed Development Array for the worst-case design scenario (SNCBs avoidance rates, turbine 14 MW, Option 2), based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.989) and for the mean avoidance rate ±2 standard deviations (SD) (0.002).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
- 2 SD	23.02	11.15	79.83	137.61	144.98	133.04	57.52	98.77	54.67	20.29	38.63	9.88	809.38
Estimated number of collisions	19.48	9.43	67.55	116.45	122.68	112.58	48.67	83.57	46.26	17.17	32.69	8.36	684.90
+ 2 SD	15.94	7.72	55.27	95.28	100.38	92.11	39.82	68.38	37.85	14.05	26.74	6.84	560.40
Scoping Approach													
- 2 SD	23.65	12.29	90.40	196.51	198.93	243.30	63.84	124.68	91.93	31.35	72.45	15.97	1165.30
Estimated number of collisions	20.01	10.40	76.49	166.29	168.33	205.88	54.02	105.51	77.79	26.53	61.31	13.52	986.07
+ 2 SD	16.37	8.51	62.59	136.06	137.73	168.46	44.20	86.33	63.65	21.71	50.16	11.06	806.82

Table 4.3: Estimated number of collisions for kittiwake by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2).

	Bio-season	Breeding	Spring migration*	Autumn migration*	Non-breeding**	Total
Developer Approach	Estimated collisions	425.73	154.69	104.48	259.17	684.90
Scoping Approach	Estimated collisions	616.88	190.05	179.15	369.19	986.07

**Using Furness (2015) BDMPS season definition.*

***Using NatureScot (2020) non-breeding season definition.*

Table 4.4: Summary of estimated number of annual collisions for kittiwake from the Band model using the Developer Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014) and Bowgen and Cook (2018). Estimates are rounded to the nearest whole.

	SNCBs Guidance				Bowgen & Cook			
Turbine Scenario	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3
Type A								
14MW	0.989	N/A	685	N/A	0.99	0.98	623	216
15MW	0.989	N/A	573	N/A	0.99	0.98	521	203
18MW	0.989	N/A	653	N/A	0.99	0.98	594	166
21MW	0.989	N/A	600	N/A	0.99	0.98	545	136
24MW	0.989	N/A	559	N/A	0.99	0.98	508	116
Type B								
18MW	0.989	N/A	548	N/A	0.99	0.98	498	174
21MW	0.989	N/A	513	N/A	0.99	0.98	466	149
24MW	0.989	N/A	484	N/A	0.99	0.98	440	133

Table 4.5: Summary of estimated number of annual collisions for kittiwake from the Band model using the Scoping Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014) and Bowgen and Cook (2018). Estimates are rounded to the nearest whole.

	SNCBs Guidance				Bowgen & Cook			
Turbine Scenario	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3
Type A								
14MW	0.989	N/A	986	N/A	0.99	0.98	896	311
15MW	0.989	N/A	826	N/A	0.99	0.98	751	293
18MW	0.989	N/A	940	N/A	0.99	0.98	855	238
21MW	0.989	N/A	864	N/A	0.99	0.98	785	196
24MW	0.989	N/A	804	N/A	0.99	0.98	731	168
Type B								
18MW	0.989	N/A	789	N/A	0.99	0.98	717	250
21MW	0.989	N/A	738	N/A	0.99	0.98	671	215
24MW	0.989	N/A	697	N/A	0.99	0.98	633	192

4.3. HERRING GULL

62. Monthly estimates of collisions for the worst-case scenario for herring gull are presented in Table 4.6 for both the Developer and Scoping Approaches.

63. The estimated number of collisions was highest during July, when monthly densities of flying herring gulls were at their highest, with 0.32 birds/km^2 (pooled SD ± 0.10) and 0.48 birds/km^2 (pooled SD ±0.12) used in the Developer and Scoping Approach respectively (Table 3.3 and Table 3.4).

64. Combining the estimated mortality across bio-seasons, shows that the estimated number of collisions is highest during the breeding season (Table 4.7).

65. The estimated number of collisions presented in Table 4.6 and Table 4.7 were used in population modelling reported in Technical Appendix 11.6: Ornithology Population Viability Analysis.

66. Annual collision estimates for herring gulls for all turbine scenarios, and avoidance rates using the Developer and Scoping Approaches are presented in Table 4.8 and Table 4.9 respectively.

Table 4.6: Monthly estimated collisions for herring gull in the Proposed Development Array for the worst-case design scenario (SNCBs avoidance rates, turbine 14 MW, Option 2), based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.995) and for the mean avoidance rate ±2 standard deviations (SD) (0.001).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
- 2 SD	1.08	0.00	0.29	0.00	0.00	10.05	19.77	1.51	0.00	0.00	1.32	1.84	35.84
Estimated number of collisions	0.90	0.00	0.24	0.00	0.00	8.37	16.47	1.26	0.00	0.00	1.10	1.53	29.87
+ 2 SD	0.72	0.00	0.20	0.00	0.00	6.70	13.18	1.00	0.00	0.00	0.88	1.22	23.89
Scoping Approach													
- 2 SD	2.15	0.00	0.59	0.00	0.00	20.09	30.12	1.51	0.00	0.00	2.63	3.15	60.54
Estimated number of collisions	1.80	0.00	0.49	0.00	0.00	16.74	25.10	1.51	0.00	0.00	2.19	2.62	50.45
+ 2 SD	1.44	0.00	0.39	0.00	0.00	13.39	20.08	1.21	0.00	0.00	1.75	2.10	40.36

Table 4.7: Estimated number of collisions for herring gull by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2).

	Bio-season	Breeding	Non-breeding	Total
Developer Approach	Estimated collisions	26.10	3.77	29.87
Scoping Approach	Estimated collisions	43.35	7.10	50.45

Table 4.8: Summary of estimated number of annual collisions for herring gull from the Band model using the Developer Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014) and Bowgen and Cook (2018). Estimates are rounded to the nearest whole.

	SNCBs Guidance				Bowgen & Cook			
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3
Type A								
14MW	0.995	0.99	30	18	0.995	0.993	30	13
15MW	0.995	0.99	26	17	0.995	0.993	26	12
18MW	0.995	0.99	28	14	0.995	0.993	28	10
21MW	0.995	0.99	26	11	0.995	0.993	26	8
24MW	0.995	0.99	24	10	0.995	0.993	24	7
Type B								
18MW	0.995	0.99	25	15	0.995	0.993	25	10
21MW	0.995	0.99	23	13	0.995	0.993	23	8
24MW	0.995	0.99	21	11	0.995	0.993	21	8

Table 4.9: Summary of estimated number of annual collisions for herring gull from the Band model using the Scoping Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014) and Bowgen and Cook (2018). Estimates are rounded to the nearest whole.

	SNCBs Guidance				Bowgen & Cook			
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3
Type A								
14MW	0.995	0.99	50	31	0.995	0.993	50	21
15MW	0.995	0.99	44	29	0.995	0.993	44	20
18MW	0.995	0.99	47	24	0.995	0.993	47	16
21MW	0.995	0.99	43	19	0.995	0.993	43	14
24MW	0.995	0.99	40	17	0.995	0.993	40	12
Type B								
18MW	0.995	0.99	42	25	0.995	0.993	42	17
21MW	0.995	0.99	39	21	0.995	0.993	39	15
24MW	0.995	0.99	36	19	0.995	0.993	36	13

4.4. LESSER BLACK-BACKED GULL

67. Monthly estimates of collisions for the worst-case for lesser black-backed gull are presented in Table 4.10 for both the Developer and Scoping Approaches.

68. The estimated number of collisions was highest during July, when monthly densities of flying lesser black-backed gulls were at their highest, with 0.13 birds/km^2 (pooled SD ±0.03) and 0.18 birds/km^2 (pooled SD ±0.04) respectively (Table 3.3 and Table 3.4).

69. Combining the estimated mortality across bio-seasons, shows that collisions are exclusive to the breeding season (Table 4.11).

70. The estimated number of collisions presented in Table 4.10 and Table 4.11 were used in population modelling reported in Technical Appendix 11.6: Ornithology Population Viability Analysis.

71. Annual collision estimates for lesser black-backed gulls for all turbine scenarios and avoidance rates using the Developer and Scoping Approaches are presented in Table 4.12 and Table 4.13 respectively.

Table 4.10: Monthly estimated collisions for lesser black-backed gull in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2), based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.995) and for the mean avoidance rate ±2 standard deviations (SD) (0.001).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
- 2 SD	0.00	0.00	0.00	0.00	0.00	1.02	6.60	0.00	0.00	0.00	0.00	0.00	7.62
Estimated number of collisions	0.00	0.00	0.00	0.00	0.00	0.85	5.50	0.00	0.00	0.00	0.00	0.00	6.35
+ 2 SD	0.00	0.00	0.00	0.00	0.00	0.68	4.40	0.00	0.00	0.00	0.00	0.00	5.08
Scoping Approach													
- 2 SD	0.00	0.00	0.00	0.00	0.00	1.52	9.15	0.00	0.00	0.00	0.00	0.00	10.67
Estimated number of collisions	0.00	0.00	0.00	0.00	0.00	1.27	7.62	0.00	0.00	0.00	0.00	0.00	8.89
+ 2 SD	0.00	0.00	0.00	0.00	0.00	1.02	6.10	0.00	0.00	0.00	0.00	0.00	7.11

Table 4.11: Estimated number of collisions for lesser black-backed gull by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2).

	Bio-season	Breeding	Non-breeding	Total
Developer Approach	Estimated collisions	6.35	0.00	6.35
Scoping Approach	Estimated collisions	8.89	0.00	8.89

Table 4.12: Summary of estimated number of annual collisions for lesser black-backed gull from the Band model using the Developer Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014) and Bowgen and Cook (2018). Estimates are rounded to the nearest whole.

	SNCBs Guidance				Bowgen & Cook			
Turbine Scenario	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3
Type A								
14MW	0.995	0.989	6*	4	0.995	0.993	6*	2
15MW	0.995	0.989	6*	4	0.995	0.993	6*	2
18MW	0.995	0.989	6*	3	0.995	0.993	6*	2
21MW	0.995	0.989	5	2	0.995	0.993	5	2
24MW	0.995	0.989	5	2	0.995	0.993	5	1
Type B								
18MW	0.995	0.989	5	3	0.995	0.993	5	2
21MW	0.995	0.989	5	3	0.995	0.993	5	2
24MW	0.995	0.989	5	2	0.995	0.993	5	2

**The estimated collisions for 14 MW, 15 MW and 18 MW turbines type A are 6.35, 5.57 and 6.02 per annum, respectively.*

Table 4.13: Summary of estimated number of annual collisions for lesser black-backed gull from the Band model using the Scoping Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014) and Bowgen and Cook (2018). Estimates are rounded to the nearest whole.

	SNCBs Guidance				Bowgen & Cook			
Turbine Scenario	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3
Type A								
14MW	0.995	0.989	9	5	0.995	0.993	9	3
15MW	0.995	0.989	8	5	0.995	0.993	8	3
18MW	0.995	0.989	8	4	0.995	0.993	8	3
21MW	0.995	0.989	8	3	0.995	0.993	8	2
24MW	0.995	0.989	7	3	0.995	0.993	7	2
Type B								
18MW	0.995	0.989	7	4	0.995	0.993	7	3
21MW	0.995	0.989	7	4	0.995	0.993	7	2
24MW	0.995	0.989	6	3	0.995	0.993	6	2

4.5. GANNET

72. Monthly estimates of collisions for the worst-case for gannet are presented in Table 4.14 for both the Developer and Scoping Approaches.

73. The estimated number of collisions was highest during July, which coincides with the second highest monthly densities of flying gannets, estimated at 1.51 birds/km^2 (pooled SD ±0.23) and 1.53 birds/km^2 (pooled SD ±0.17) in the Developer and Scoping Approach respectively (Table 3.3 and Table 3.4).

74. Combining the estimated mortality across bio-seasons, shows that the estimated number of collisions is highest during the breeding season (Table 4.15).

75. Estimated number of collisions presented in Table 4.14 and Table 4.15 were used in population modelling reported in Technical Appendix 11.6: Ornithology Population Viability Analysis.

76. Annual collision estimates for gannets for all turbine scenarios and avoidances rates using the Developer and Scoping Approaches are presented in Table 4.16 and Table 4.17 respectively.

77. Monthly estimates of collisions for the breeding season for gannet using an avoidance rate of 0.980 and the Band Option 2 (SNCBs, 2014) are presented for context in Table 4.18 for both the Developer and Scoping Approaches.

Table 4.14: Monthly estimated collisions for gannet in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2), based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.989) and for the mean avoidance rate ±2 standard deviations (SD) (0.002).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
- 2 SD	0.45	0.32	3.62	10.84	15.93	24.72	43.62	27.34	39.29	8.04	7.07	0.14	181.37
Estimated number of collisions	0.38	0.27	3.07*	9.17	13.48	20.92	36.91	23.13	33.24	6.80	5.99	0.12	153.48
+ 2 SD	0.31	0.22	2.51	7.50	11.03	17.11	30.20	18.93	27.20	8.04	7.07	0.14	125.58
Scoping Approach													
- 2 SD	0.74	0.65	4.17	14.45	20.30	25.89	44.34	36.53	56.85	9.41	12.15	0.27	225.75
Estimated number of collisions	0.63	0.55	3.53	12.22	17.18	21.91	37.52	30.91	48.10	7.96	10.28	0.23	191.02
+ 2 SD	0.51	0.45	2.89	10.00	14.05	17.93	30.70	25.29	39.35	6.51	8.41	0.19	156.29

Table 4.15: Estimated number of collisions for gannet by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2).

	Bio-season	Breeding	Spring migration*	Autumn migration*	Non-breeding**	Total
Developer Approach	Estimated collisions	138.43	2.30	12.79	15.05*	153.48
Scoping Approach	Estimated collisions	169.65	3.18	18.24	21.37	191.02

**Using Furness (2015) BDMPS season definition.*

***Using NatureScot (2020) non-breeding season definition.*

Table 4.16: Summary of estimated number of annual collisions for gliding gannet from the Band model Options 2 and 3 using the Developer Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014) and Bowgen and Cook (2018). Estimates are rounded to the nearest whole.

	SNCBs Guidance				Bowgen & Cook			
Turbine Scenario	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3
Type A								
14MW	0.989	N/A	153	N/A	0.995	N/A	70	N/A
15MW	0.989	N/A	138	N/A	0.995	N/A	63	N/A
18MW	0.989	N/A	144	N/A	0.995	N/A	65	N/A
21MW	0.989	N/A	131	N/A	0.995	N/A	59	N/A
24MW	0.989	N/A	121	N/A	0.995	N/A	55	N/A
Type B								
18MW	0.989	N/A	129	N/A	0.995	N/A	59	N/A
21MW	0.989	N/A	120	N/A	0.995	N/A	55	N/A
24MW	0.989	N/A	113	N/A	0.995	N/A	51	N/A

Table 4.17: Summary of estimated number of annual collisions for gliding gannet from the Band model Options 2 and 3 using the Scoping Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014) and Bowgen and Cook (2018). Estimates are rounded to the nearest whole.

	SNCBs Guidance				Bowgen & Cook			
Turbine Scenario	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3
Type A								
14MW	0.989	N/A	191	N/A	0.995	N/A	87	N/A
15MW	0.989	N/A	171	N/A	0.995	N/A	78	N/A
18MW	0.989	N/A	179	N/A	0.995	N/A	81	N/A
21MW	0.989	N/A	162	N/A	0.995	N/A	74	N/A
24MW	0.989	N/A	150	N/A	0.995	N/A	68	N/A
Type B								
18MW	0.989	N/A	161	N/A	0.995	N/A	73	N/A
21MW	0.989	N/A	150	N/A	0.995	N/A	68	N/A
24MW	0.989	N/A	140	N/A	0.995	N/A	64	N/A

Table 4.18: Monthly estimated collisions for gliding gannet in the Proposed Development Array for the worst-case scenario (mean avoidance rate of 0.980, turbine 14 MW, Option 2) during the breeding season only, based on the Developer and Scoping Approaches and generic flight height.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Breeding season total
Developer Approach								
Estimated number of collisions	5.71*	16.67	24.50	38.02	67.10	42.05	60.43	251.62
Scoping Approach								
Estimated number of collisions	6.58	22.23	31.24	39.85	68.24	56.22	87.48	308.55

**March collision estimates presented are for the entire month. Gannet breeding season is estimated to start in mid-March (NatureScot, 2020), therefore, only half of the collisions for the month of March were counted in the total breeding season collision estimates.*

4.6. ARCTIC TERN

78. Monthly estimates of collisions for the worst-case for Arctic tern are presented in Table 4.19 for both the Developer and Scoping Approaches.

79. The estimated number of collisions was highest during August, when densities of flying Artic terns were at their highest, with 1.57 birds/km^2 (pooled SD ±0.35) and 2.60 birds/km^2 (pooled SD ±0.33) used in the Developer and Scoping Approaches respectively (Table 3.3 and Table 3.4).

80. Combining the estimated mortality across bio-seasons, shows that the estimated number of collisions is highest during the breeding season Table 4.20.

81. The estimated number of collisions presented in Table 4.19 and Table 4.20 were used in population modelling reported in Technical Appendix 11.6: Ornithology Population Viability Analysis.

82. Annual collision estimates for Arctic terns for all turbine scenarios and avoidances rates using the Developer and Scoping Approaches are presented in Table 4.21 and Table 4.22 respectively.

Table 4.19: Monthly estimated collisions for Arctic tern in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2), based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.980).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
Estimated number of collisions	0.00	0.00	0.00	0.03	0.21	0.12	2.14	5.57	0.03	0.00	0.00	0.00	8.10
Scoping Approach													
Estimated number of collisions	0.00	0.00	0.00	0.07	0.26	0.15	4.17	9.25	0.07	0.00	0.00	0.00	13.97

Table 4.20: Estimated number of collisions for Arctic tern by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2).

	Bio-season	Breeding	Non-breeding	Total
Developer Approach	Estimated collisions	8.03	0.07	8.10
Scoping Approach	Estimated collisions	13.83*	0.13*	13.97*

**Collisions during the breeding and non-breeding seasons equate to 13.832 and 0.133 respectively (both rounded down to the nearest two decimal places numbers) and the total annual collisions equate to 13.965, rounded up to the nearest two decimal places number.*

Table 4.21: Summary of estimated number of annual collisions for Arctic tern from the Band model using the Developer Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014). Estimates equal or greater than 0.5 are rounded to the nearest whole.

	SNCBs Guidance			
Turbine Scenario	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3
Type A				
14MW	0.98	0.98	8*	1
15MW	0.98	0.98	7	1
18MW	0.98	0.98	8*	1
21MW	0.98	0.98	7	1
24MW	0.98	0.98	7	0.45
Type B				
18MW	0.98	0.98	7	1
21MW	0.98	0.98	6	1
24MW	0.98	0.98	6	1

**The estimated collisions for 14MW and 18MW turbines type A are 8.10 and 7.97 per annum, respectively.*

Table 4.22: Summary of estimated number of annual collisions for Arctic tern from the Band model using the Scoping Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014). Estimates are rounded to the nearest whole.

	SNCBs Guidance			
Turbine Scenario	Avoidance rate – Basic	Avoidance rate – Extended	Option 2	Option 3
Type A				
14MW	0.98	0.98	14*	2
15MW	0.98	0.98	12	1
18MW	0.98	0.98	14*	1
21MW	0.98	0.98	13	1
24MW	0.98	0.98	12	1
Type B				
18MW	0.98	0.98	12	1
21MW	0.98	0.98	11	1
24MW	0.98	0.98	11	1

**The estimated collisions for 14MW and 18MW turbines type A are 13.97 and 13.75 per annum, respectively.*

4.7. COMMON TERN

83. Monthly estimates of collisions for the worst-case for common tern are presented in Table 4.23 for both the Developer and Scoping Approaches.

84. The estimated number of collisions was highest during August, when the mean and max monthly densities of flying common terns were at their highest, with 0.45 birds/km^2 (pooled SD ±0.13) and 0.69 birds/km^2 (pooled SD ±0.18) respectively (Table 3.3 and Table 3.4).

85. Combining the estimated monthly mortality across bio-seasons shows that the estimated number of collisions is highest during the breeding season (Table 4.24).

86. The estimated number of collisions presented in Table 4.23 and Table 4.24 were used in population modelling reported in Technical Appendix 11.6: Ornithology Population Viability Analysis.

87. Annual collision estimates for common terns for all turbine scenarios and avoidance rates using the Developer and Scoping Approaches are presented in Table 4.25 and Table 4.26 respectively.

Table 4.23: Monthly estimated collisions for common tern in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2), based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.980).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
Estimated number of collisions	0.00	0.00	0.00	0.10	0.06	0.00	0.75	4.85	0.30	0.00	0.00	0.00	6.05
Scoping Approach													
Estimated number of collisions	0.00	0.00	0.00	0.21	0.11	0.00	0.81	7.43	0.59	0.00	0.00	0.00	9.15

Table 4.24: Estimated number of collisions for common tern by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2).

	Bio-season	Breeding	Non-breeding	Total
Developer Approach	Estimated collisions	5.80	0.25	6.05
Scoping Approach	Estimated collisions	8.65	0.50	9.15

Table 4.25: Summary of estimated number of annual collisions for common tern from the Band model Options 2 and 3 using the Developer Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014). Estimates equal or greater than 0.5 are rounded to the nearest whole.

SNCBs Guidance				
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3
Type A				
14MW	0.98	0.98	6*	1
15MW	0.98	0.98	5	1
18MW	0.98	0.98	6*	1
21MW	0.98	0.98	5	1
24MW	0.98	0.98	5	0.46
Type B				
18MW	0.98	0.98	5	1
21MW	0.98	0.98	5	1
24MW	0.98	0.98	5	1

**The estimated collisions for 14MW and 18MW turbines type A are 6.05 and 5.89 per annum, respectively.*

Table 4.26: Summary of estimated number of annual collisions for common tern from the Band model Options 2 and 3 using the Scoping Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014). Estimates are rounded to the nearest whole.

SNCBs Guidance				
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3
Type A				
14MW	0.98	0.98	9*	1
15MW	0.98	0.98	8	1
18MW	0.98	0.98	9*	1
21MW	0.98	0.98	8	1
24MW	0.98	0.98	8	1
Type B				
18MW	0.98	0.98	8	1
21MW	0.98	0.98	7	1
24MW	0.98	0.98	7	1

**The estimated collisions for 14MW and 18MW turbines type A are 9.15 and 8.90 per annum, respectively.*

4.8. LITTLE GULL

88. Monthly estimates of collisions for the worst-case for little gull are presented in Table 4.27 for both the Developer and the Scoping Approaches.

89. The estimated number of collisions was highest during August, when the densities of flying little gulls were at their highest, with 0.07 birds/km^2 (pooled SD ± 0.04) and 0.12 birds/km^2 (pooled SD ±0.05) respectively (Table 3.3 and Table 3.4).

90. Combining the estimated mortality across bio-seasons, shows that the estimated number of collisions is highest during the non-breeding season. This is mainly explained as little gulls do not breed in the UK and their presence and, therefore collision risk, is mainly confined to the non-breeding season (Table 4.28).

91. The estimated number of collisions presented in Table 4.27 and Table 4.28 were used in population modelling reported in Technical Appendix 11.6: Ornithology Population Viability Analysis.

92. Annual collision estimates for little gulls for all turbine scenarios and avoidance rates using the Developer and Scoping Approaches are presented in Table 4.29 and Table 4.30 respectively.

Table 4.27: Monthly estimated collisions for little gull in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2), based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.980).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
Estimated number of collisions	0.00	0.19	0.00	0.00	0.00	0.00	0.17	2.01	0.00	0.00	0.00	0.08	2.45
Scoping Approach													
Estimated number of collisions	0.00	0.38	0.00	0.00	0.00	0.00	0.35	3.71	0.00	0.00	0.00	0.16	4.60

Table 4.28: Estimated number of collisions for little gull by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 2).

	Bio-season	Summer months	Non-breeding	Total
Developer Approach	Estimated collisions	0.17	2.28	2.45
Scoping Approach	Estimated collisions	0.35	4.25	4.60

Table 4.29: Summary of estimated number of annual collisions for little gull for the five wind turbine generator sizes from the Band model Options 2 and 3 using the Developer Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014). Estimates equal or greater than 0.5 are rounded to the nearest whole.

SNCBs Guidance				
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3
Type A				
14MW	0.98	0.98	2*	0.40
15MW	0.98	0.98	2*	0.37
18MW	0.98	0.98	2*	0.31
21MW	0.98	0.98	2*	0.26
24MW	0.98	0.98	2*	0.22
Type B				
18MW	0.98	0.98	2**	0.32
21MW	0.98	0.98	2**	0.28
24MW	0.98	0.98	2**	0.25

**The estimated collisions for 14 MW; 15 MW; 18 MW; 21 MW and 24 MW turbines type A are 2.45; 2.04; 2.38; 2.19 and 2.05 per annum, respectively.*

***The estimated collisions for 18 MW; 21 MW and 24 MW turbines type B are 1.98; 1.86 and 1.77 per annum, respectively.*

Table 4.30: Summary of estimated number of annual collisions for little gull for the five wind turbine generator sizes from the Band model Options 2 and 3 using the Scoping Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014). Estimates equal or greater than 0.5 are rounded to the nearest whole.

SNCBs Guidance				
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3
Type A				
14MW	0.98	0.98	5	1
15MW	0.98	0.98	4	1
18MW	0.98	0.98	4	1
21MW	0.98	0.98	4	0.48
24MW	0.98	0.98	4	0.41
Type B				
18MW	0.98	0.98	2*	0.32
21MW	0.98	0.98	2*	0.28
24MW	0.98	0.98	2*	0.20

**The estimated collisions for 18MW; 21MW and 24MW turbines type B are 1.98; 1.86 and 1.77 per annum, respectively.*

4.9. GREAT SKUA

93. Collisions of great skua estimated by the Band method were close to zero in all of the scenarios for both the Developer and Scoping Approaches, therefore, further breakdowns beyond those given in Table 4.31 and Table 4.32 are not presented.

Table 4.31: Summary of estimated number of annual collisions for great skua for the five wind turbine generator sizes from the Band model Options 2 and 3 using the Developer Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014).

SNCBs Guidance				
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3
Type A				
14MW	0.98	0.98	0.18	0.02
15MW	0.98	0.98	0.15	0.02
18MW	0.98	0.98	0.17	0.02
21MW	0.98	0.98	0.15	0.01
24MW	0.98	0.98	0.14	0.01
Type B				
18MW	0.98	0.98	0.14	0.02
21MW	0.98	0.98	0.13	0.02
24MW	0.98	0.98	0.13	0.01

Table 4.32: Summary of estimated number of annual collisions for great skua for the five wind turbine generator sizes from the Band model Options 2 and 3 using the Scoping Approach and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from SNCBs (2014).

SNCBs Guidance				
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2	Option 3
Type A				
14MW	0.98	0.98	0.35	0.05
15MW	0.98	0.98	0.30	0.04
18MW	0.98	0.98	0.33	0.03
21MW	0.98	0.98	0.31	0.03
24MW	0.98	0.98	0.29	0.02
Type B				
18MW	0.98	0.98	0.28	0.04
21MW	0.98	0.98	0.27	0.03
24MW	0.98	0.98	0.25	0.03

5. CONCLUSION

94. For this report, the worst-case estimated number of annual collisions for each species was identified from the outputs of the deterministic Band (2012) model. The scenarios differed in the rating and type of turbine (based on chord width and rotational speed) and model Option chosen. However, we limited our search for the worst-case to scenarios that used generic flight height data of Johnston *et al.* (2014a; 2014b) only (i.e. Options 2 and 3) as this has been endorsed by SNCBs (SNCBs, 2014) and advised in the Scoping Opinion (4 February 2022); this represents the Scoping Approach for assessing collision risk for seabird species at the Proposed Development Array.

95. The results show that the worst-case ornithology collision impacts for all species modelled are predicted for the 14MW turbine and hence it is these values that are taken forward into the Population Viability Analysis (Technical Appendix 11.6) and assessed in the Environmental Statement.

96. The worst-case turbine scenario was the same (14 MW) for all species regardless of which avoidance rates or Approach was used. However, for kittiwake and gannet, estimated collisions were considerably lower when using Bowgen & Cook (2018), with a reduction of 9% and 54% respectively, when compared with outputs using SNCBs (2014) avoidance rates for both the Developer and Scoping Approaches.

97. For comparison of the worst-case scenario from the Band (2012) model, the sCRM was also used. Using the Developer Approach (which differs from the Scoping Approach by use of mean monthly densities, rather than monthly maximum densities), the results from the sCRM for kittiwake were considerably lower (-46%). For other species, sCRM estimates were also lower for lesser black-backed gull (-33%) and herring gulls (-58%) unchanged for common tern, and higher for Arctic tern (+43%), little gull (-80%) and great skua (+83%). Similar results were obtained when using the Scoping Approach. The results from the sCRM were lower for kittiwake, herring gull and lesser black-backed gull (-46%, -36%, -33% respectively). For other species, sCRM estimates were unchanged for common tern, and higher for Arctic tern (+36%), little gull (-64%) and great skua (+65%).

98. Due to its stochastic nature, estimates from the sCRM are not directly comparable with Band outputs because the output is a distribution rather than a single estimate of collisions. Recommended avoidance rates also differ between Band and sCRM methods.

99. The estimated annual number of collisions was greatest for kittiwake at 685 birds per annum using the Developer Approach and 986 using the Scoping Approach based on Band model Option 2 and using generic flight height data and SNCBs (214) avoidance rates. Use of site-specific boat-based flight height data resulted in significantly lower annual mortality estimates: based on rangefinder data, the mean estimated annual number of collisions for kittiwake using the Developer and Scoping Approaches were 56 and 81 birds respectively, and visual observer data, the annual mean was 225 and 324 kittiwakes for the Developer and Scoping Approaches respectively.

6. SUMMARY

100. Berwick Bank Wind Farm Limited (BBWFL) (the 'Applicant') is a wholly owned subsidiary of SSE Renewables Limited and is developing the Berwick Bank Wind Farm (the 'Project') located at the mouth of the North Sea's Firth of Forth.

101. Digital aerial surveys were flown March 2019 – April 2021 to provide two years of baseline data collection on the seabirds and other marine megafauna in the Offshore Ornithology Study Area (Array area and a 16km buffer). Monthly estimates of flying birds within the proposed Array area only were used in the CRM reported here.

102. Collision risk estimates are presented for eight species vulnerable to collision at OWFs: kittiwake *Rissa tridactyla,* herring gull *Larus argentatus*, lesser black-backed gull *Larus fuscus*, gannet *Morus bassanus*, Arctic tern *Sterna paradisaea*, common tern *Sterna hirundo*, little gull *Hydrocoloeus minutus* and great skua *Stercorarius skua*.

103. Two approaches to CRM have been used:

- Deterministic offshore Band CRM (Band, 2012); and
- sCRM (Masden, 2015; McGregor *et al*., 2018).

104. The results from the Band CRM will be those relied upon for further analyses (i.e. PVA) given that this Approach utilises endorsed SNCBs avoidance rates. The sCRM approach, which takes account of the uncertainty around input parameters, is used only for comparative purposes of the worst-case.

105. Only Band models 2 (basic) and 3 (extended) were used as they use the generic flight height data of Johnston *et al.* (2014a; 2014b). The models were parameterised using SNCBs (2014) advised avoidance rates; Bowgen and Cook (2018) avoidance rates; seabird morphometric data from Pennycuick (1997) and Alerstam *et al.* (2007); nocturnal activity from Garthe and Hüppop (2004), Furness *et al.* (2018) and the Seagreen EIA Optimised Project Addendum (2018); and flight speed from Pennycuick (1997).

106. The Band models were run for each of the five turbine scenarios. Additionally, scenarios for turbines 18 MW – 24 MW were of two types: Type A (wide chord and slower rotational speed) and Type B (narrower chord and faster rotational speed).

107. Estimates of collisions were calculated for each bio-season based on definitions based on NatureScot, (2020) for the breeding and non-breeding seasons. Non-breeding seasons for kittiwake and gannet were based on the spring and autumn migration periods defined by the BDMPS of Furness (2015).

108. Following the release of the Scoping Opinion and associated Consultee representations and advice, the Applicant determined to undertake a "dual assessment" of the collision risk posed by the Project:

- Scoping Approach: monthly maximum density of relevant seabird species within the Development Array area are to be used in the CRMs based on NatureScot and MSS recommendation; and
- Developer Approach: monthly mean density of relevant seabird species within the Development Array area are to be used in the CRMs based on the Applicant opinion.

109. The 14 MW turbine size resulted in the worst-case ornithology collision impacts across all species and hence it is these values that are taken forward into the PVA and assessed in the Environmental Statement. The estimated number of collisions per annum using the deterministic Band model was highest for kittiwake (685 birds for the Developer Approach and 986 birds for the Scoping Approach). Estimates were shown to be sensitive to the source of flight height data used in the Band model. Based on site-specific rangefinder data, the mean estimated annual number of collisions for kittiwake using the Developer and Scoping Approaches were 56 and 81 birds respectively. Using the visual observer collected site- data, the annual mean was 225 and 324 kittiwakes for the Developer and Scoping Approaches respectively (

Annex B Table 37 Estimated number of collisions for kittiwake by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 1) using boat-based data).

110. The annual estimate of gannet collisions was 153 birds for the Developer Approach and 191 birds for Scoping Approach.

111. For herring gull, the worst-case estimate was 30 birds per annum based on the Developer Approach and 50 for the Scoping Approach; for all other species, annual estimated collisions based on the Developer Approach were of eight birds or less, compared with 14 birds or less using the Scoping Approach. Near zero collisions for great skua were predicted using both Approaches.

112. The view that using fewer, larger turbines as an effective measure for reducing collision (Johnston *et al.,* 2014a; 2014b) was borne out by the modelling using Band Option 2 undertaken here. For all species, the number of collisions tended to decrease with increasing turbine size and (amongst the three larger turbine models which had different chord width and rotor speed Options) was lower for Type B turbines (narrower chord and faster rotational speed).

113. The embedded mitigation in the turbine design, that increases the air gap from 22 m to 37 m (LAT) results in a reduction in the estimated annual number of collisions of ~76% and 79% for kittiwake and gannet respectively.

7. REFERENCES

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ANNEX A. TO THE ORNITHOLOGY COLLISION RISK MODELING TECHNICAL REPORT: WORST CASE SCENARIO 22 M AIR GAP COLLISION ESTIMATES

1. The Applicant has chosen wind turbine generators with mitigation embedded in the design. The minimum lower blade tip height has been increased from 22 m to 37 m (LAT) as an engineering design measure to increase the lower air gap. The larger air gap was predicted to have a positive impact on reducing the number of seabirds at risk of collision with the turbines. The Scoping Opinion requires that any embedded mitigation relied upon for the purposes of the assessment should be clearly and accurately explained in detail within the EIA Report.
2. Therefore, Collision Risk Models (CRMs) were run using the deterministic Band on the worst-case scenario (SNCBs (2014) avoidance rates, turbine 14 MW, Type A) for both kittiwake (Annex A Table 33) and gannet (Annex A Table 34), for both the Developer and Scoping Approaches, but the hub height relative to LAT, reduced from 148 m to 133 m for the results presented in this Annex. All other input parameters were exactly as set out in Section 3.4.
3. The estimated number of collisions were considerably higher with a 22 m airgap compared with the larger 37 m. By using a larger airgap, the estimated number of collisions was ~76% and 79% lower for kittiwake and gannet respectively.

Annex A Table 33 Comparison of the estimated annual collisions for kittiwake in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Type A) with a 22 m and 37 m air gap, based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.989) and for the mean avoidance rate ±2 SD (0.002). Estimates are rounded to the nearest whole

	Avoidance rate (SNCBs Guidance)	Option 2	
		22 m Air Gap	37 m Air Gap
Developer Approach			
- 2 SD	0.987	3400	809
Estimated number of collisions	0.989	2877	685
+ 2 SD	0.991	2354	560
Scoping Approach			
- 2 SD	0.987	4895	1165
Estimated number of collisions	0.989	4142	988
+ 2 SD	0.991	3389	808

Annex A Table 34 Comparison of the estimated annual collisions for gannet in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Type A) with a 22 m and 37 m air gap, based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.989) and for the mean avoidance rate ±2 SD (0.002). Estimates are rounded to the nearest whole

	Avoidance rate (SNCBs Guidance)	Option 2	
		22 m Air Gap	37 m Air Gap
Developer Approach			
- 2 SD	0.987	867	181
Estimated number of collisions	0.989	734	153
+ 2 SD	0.991	600	126
Scoping Approach			
- 2 SD	0.987	1080	226
Estimated number of collisions	0.989	914	191
+ 2 SD	0.991	748	156

ANNEX B. TO THE ORNITHOLOGY COLLISION RISK MODELLING TECHNICAL REPORT: BOAT-BASED KITTIWAKE COLLISION ESTIMATES

1. Boat based surveys were undertaken from dawn until dusk on 2 – 6 July and 6 – 9 August 2020, which equated to nine days of boat-based surveys in total. ECON Ecological Consultancy Ltd and RPS surveyed short transects within the survey area and following the boat-based European Seabirds At Sea methods (ESAS, Camphuysen *et al.,* 2004) with a 300 metre transect width.
2. ESAS methods require that observers scan ahead of the boat, using binoculars on occasion, within a 90-degree arc and within a 300 m strip on one side of the ship. While a flight height will be estimated for each bird recorded, including for those flying ahead, the principal focus for the search pattern is ahead of the boat (Camphuysen *et al.,* 2004). Flying birds were estimated to be in 5m flight height bands (i.e. >0-5, >5-10, >10-15) using methods presented in (Camphuysen *et al.,* 2004). Three observers were present on board the boat; two to complete the visual surveys and one to use the rangefinder. Visual and rangefinder surveys took place on opposite sides of the observation deck.
3. The RPS boat-based visual and rangefinder surveys were conducted in tandem but using different observers on opposite sides of the observation platform. Visual estimates of flight height were recorded for every bird encountered. Estimates of flight height using the rangefinder aimed to detect every bird encountered, but during busy periods collision risk modelling target species or data-poor species were preferentially recorded.
4. The two survey methods yield different estimates of the proportion of birds at collision risk height (PCH) for both months for a wind turbine scenario of 32 – 252 m PCH relative to Mean High Water Spring (MHWS). The visual method estimates average PCH to be between 0.8% and 2.32% for kittiwakes. The rangefinder method estimates average PCH to be 0% for kittiwakes in both months (Appendix 11.7: Comparison of boat-based and digital video aerial survey methods for seabirds).
5. Using the worst-case scenario (14 MW, Type A, SNCBs avoidance rates), monthly estimates of annual collisions for kittiwake were generated using the basic Band model and Option 1, to incorporate site specific flight height information from the boat-based rangefinder (Annex B Table 35Annex B Table 37) and visual observer (Annex B Table 36 data; these are presented for both the Developer and Scoping Approaches. Estimated monthly number of collisions were also combined across bio-seasons and are presented in Annex B Table 37.
6. Compared to estimated annual number of collisions using the generic flight height data for kittiwake (Table 4.3: 685 for the Developer Approach and 986 for the Scoping Approach), the results from using site-specific flight heights from rangefinder and visual observer data were considerably lower (Annex B Table 36 and Annex B Table 37).
7. Based on rangefinder data, the mean estimated annual number of collisions for kittiwake using Developer and Scoping Approaches were 56 and 81 birds respectively. Using the visual observer collected data, the annual mean increased to 225 and 324 kittiwakes for the Developer and Scoping Approaches respectively (Annex B Table 37).

Annex B Table 35 Monthly estimated annual collisions for kittiwake in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 1), using boat-based data collected with a rangefinder and based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.989) and for the mean avoidance rate ±2 SD (0.002). Estimates equal or greater than 0.5 are rounded to the nearest whole

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
- 2 SD	2	1	7	11	12	11	5	8	4	2	3	1	67
Estimated number of collisions	2	1	6	10	10	9	4	7	4	1	3	1	56
+ 2 SD	1	1	5	8	8	8	3	6	3	1	2	1	46
Scoping Approach													
- 2 SD	2	1	7	16	16	20	5	10	8	3	6	1	96
Estimated number of collisions	2	1	6	14	14	17	4	9	6	2	5	1	81
+ 2 SD	1	1	5	11	11	14	4	7	5	2	4	1	66

Annex B Table 36 Monthly estimated annual collisions for kittiwake in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 1), using boat-based data collected visually and based on the Developer and Scoping Approaches. Estimates are presented using the mean avoidance rate (0.989) and for the mean avoidance rate ±2 SD (0.002). Estimates equal or greater than 0.5 are rounded to the nearest whole

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Developer Approach													
- 2 SD	8	4	26	45	48	44	19	32	18	7	13	3	266
Estimated number of collisions	6	3	22	38	40	37	16	27	15	6	11	3	225
+ 2 SD	5	3	18	31	33	30	13	22	12	5	9	2	184
Scoping Approach													
- 2 SD	8	4	30	65	65	80	21	41	30	10	24	5	383
Estimated number of collisions	7	3	25	55	55	68	18	35	26	9	20	4	324
+ 2 SD	5	3	21	45	45	55	15	28	21	7	17	4	265

Annex B Table 37 Estimated number of collisions for kittiwake by season in the Proposed Development Array for the worst-case scenario (SNCBs avoidance rates, turbine 14 MW, Option 1) using boat-based data

	Bio-season	Breeding	Non-breeding	Total
Developer Approach				
Rangefinder	Estimated collisions	35.01	21.31	56.33
Visual	Estimated collisions	140.05	85.26	225.31
Scoping Approach				
Rangefinder	Estimated collisions	50.73	30.36	81.10
Visual	Estimated collisions	202.94	121.45	324.39

Annex B Table 38 Proportion of birds at collision height estimated from the site-specific survey data (Option 1 sCRM)

	Percentage at collision height (%) (sample size)	
Species	**Visual**	**Rangefinder**
Kittiwake	1.2 (3710)	0.3 (599)
Herring Gull	15.5 (161)	10.5 (76)
Lesser black back gull	3.9 (76)	0 (59)
Gannet	2.3 (3892)	3 (732)

ANNEX C. TO THE ORNITHOLOGY COLLISION RISK MODELLING TECHNICAL REPORT: STOCHASTIC COLLISION RISK MODELLING

1. Stochastic Collision Risks Models were run for all species and scenarios as defined in Section 3.2 and using the input parameters defined in Section3.4.

Annex C Table 1 Summary of estimated number of annual collisions and SD for Arctic tern from the sCRM model using the Developer and Scoping Approaches and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from Bowgen and Cook (2018)

			Developer Approach		Scoping Approach	
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)
Type A						
14MW	0.980	0.980	14.14 (15.13)	2.01 (2.75)	22.05 (19.78)	2.98 (3.53)
15MW	0.980	0.980	12.15 (12.97)	1.92 (2.62)	18.97 (16.96)	2.85 (3.36)
18MW	0.980	0.980	13.79 (14.63)	1.55 (2.15)	21.55 (19.13)	2.29 (2.76)
21MW	0.980	0.980	12.75 (13.44)	1.27 (1.78)	19.94 (17.58)	1.87 (2.28)
24MW	0.980	0.980	11.94 (12.52)	1.08 (1.52)	18.69 (16.39)	1.59 (1.95)
Type B						
18MW	0.980	0.980	11.82 (12.54)	1.63 (2.25)	18.47 (16.40)	2.42 (2.89)
21MW	0.980	0.980	11.16 (11.76)	1.39 (1.94)	17.45 (15.39)	2.06 (2.49)
24MW	0.980	0.980	10.61 (11.13)	1.23 (1.73)	16.61 (14.57)	1.82 (2.22)

Annex C Table 2 Summary of estimated number of annual collisions and SD for common tern from the sCRM model using the Developer and Scoping Approaches and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from Bowgen and Cook (2018)

			Developer Approach		Scoping Approach	
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)
Type A						
14MW	0.980	0.980	6.24 (2.24)	0.89 (0.37)	8.91 (2.34)	1.27 (0.42)
15MW	0.980	0.980	5.35 (1.92)	0.85 (0.35)	7.65 (2.01)	1.21 (0.40)
18MW	0.980	0.980	6.07 (2.1)	0.69 (0.29)	8.67 (2.26)	0.98 (0.32)
21MW	0.980	0.980	5.60 (2.00)	0.56 (0.24)	8.01 (2.08)	0.80 (0.27)
24MW	0.980	0.980	5.24 (1.87)	0.48 (0.20)	7.49 (1.94)	0.68 (0.23)
Type B						
18MW	0.980	0.980	5.20 (1.86)	0.73 (0.30)	7.43 (1.94)	1.03 (0.34)
21MW	0.980	0.980	4.90 (1.75)	0.62 (0.26)	7.01 (1.82)	0.88 (0.29)
24MW	0.980	0.980	4.66 (1.66)	0.55 (0.23)	6.66 (1.72)	0.78 (0.26)

Annex C Table 3 Summary of estimated number of annual collisions and SD for great skua from the sCRM model using the Developer and Scoping Approaches and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from Bowgen and Cook (2018)

			Developer Approach		Scoping Approach	
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)
Type A						
14MW	0.980	0.980	0.52 (0.34)	0.09 (0.07)	0.66 (0.30)	0.11 (0.06)
15MW	0.980	0.980	0.44 (0.29)	0.08 (0.06)	0.56 (0.26)	0.10 (0.06)
18MW	0.980	0.980	0.49 (0.32)	0.06 (0.05)	0.62 (0.29)	0.08 (0.05)
21MW	0.980	0.980	0.45 (0.30)	0.05 (0.04)	0.57 (0.26)	0.07 (0.04)
24MW	0.980	0.980	0.42 (0.27)	0.04 (0.03)	0.53 (0.24)	0.06 (0.03)
Type B						
18MW	0.980	0.980	0.42 (0.28)	0.07 (0.05)	0.53 (0.25)	0.09 (0.05)
21MW	0.980	0.980	0.39 (0.26)	0.06 (0.05)	0.49 (0.23)	0.07 (0.04)
24MW	0.980	0.980	0.37 (0.24)	0.05 (0.04)	0.46 (0.21)	0.07 (0.04)

Annex C Table 4 Summary of estimated number of annual collisions and SD for little gull from the sCRM model using the Developer and Scoping Approaches and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from Bowgen and Cook (2018)

			Developer Approach		Scoping Approach	
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)
Type A						
14MW	0.980	0.980	10.10 (27.82)	10.02 (28.77)	13.76 (35.87)	13.54 (38.63)
15MW	0.980	0.980	10.19 (26.22)	9.25 (24.05)	13.29 (33.48)	11.67 (30.41)
18MW	0.980	0.980	10.39 (29.29)	7.79 (22.34)	14.41 (38.11)	10.62 (29.20)
21MW	0.980	0.980	10.16 (30.14)	6.69 (20.37)	13.82 (39.41)	8.87 (26.13)
24MW	0.980	0.980	7.86 (23.62)	4.90 (14.96)	11.11 (31.70)	6.53 (19.32)
Type B						
18MW	0.980	0.980	8.67 (24.43)	6.87 (19.55)	12.02 (31.78)	9.38 (25.49)
21MW	0.980	0.980	8.64 (25.63)	6.24 (18.84)	11.75 (33.52)	8.30 (24.23)
24MW	0.980	0.980	6.77 (20.33)	4.76 (14.39)	9.57 (27.30)	6.39 (18.57)

Annex C Table 5 Summary of estimated number of annual collisions and SD for kittiwake from the sCRM model using the Developer and Scoping Approaches and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from Bowgen and Cook (2018)

			Developer Approach		Scoping Approach	
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)
Type A						
14MW	0.994	0.970	371.25 (37.96)	325.36 (37.58)	536.15 (34.41)	471.14 (39.87)
15MW	0.994	0.970	310.94 (31.77)	305.79 (34.94)	449.10 (28.88)	442.72 (36.73)
18MW	0.994	0.970	354.02 (36.13)	249.40 (28.94)	511.32 (32.77)	361.20 (30.91)
21MW	0.994	0.970	325.15 (33.13)	205.31 (23.86)	469.62 (29.99)	297.36 (25.53)
24MW	0.994	0.970	302.83 (30.82)	175.28 (20.41)	437.38 (27.85)	253.87 (21.87)
Type B						
18MW	0.994	0.970	298.14 (30.43)	261.48 (29.97)	430.61 (27.60)	378.58 (31.600
21MW	0.994	0.970	278.19 (28.35)	224.52 (25.79)	401.80 (25.66)	325.09 (27.26)
24MW	0.994	0.970	261.60 (26.62)	200.41 (23.06)	377.82 (24.06)	290.19 (24.42)

Annex C Table 6 Summary of estimated number of annual collisions and SD for herring gull from the sCRM model using the Developer and Scoping Approaches and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from Bowgen and Cook (2018)

			Developer Approach		Scoping Approach	
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)
Type A						
14MW	0.997	0.99	19.34 (4.67)	21.35 (6.36)	31.60 (4.28)	35.01 (7.60)
15MW	0.997	0.99	16.97 (4.11)	20.10 (5.86)	27.73 (3.77)	32.94 (6.84)
18MW	0.997	0.99	18.14 (4.39)	16.53 (5.02)	29.64 (4.02)	27.15 (6.13)
21MW	0.997	0.99	16.50 (3.99)	13.65 (4.16)	26.95 (3.65)	22.44 (5.13)
24MW	0.997	0.99	15.22 (3.68)	11.68 (3.57)	24.87 (3.36)	19.21 (4.44)
Type B						
18MW	0.997	0.99	16.01 (3.88)	17.16 (5.02)	26.16 (3.55)	28.14 (5.92)
21MW	0.997	0.99	14.81 (3.58)	14.77 (4.33)	24.20 (3.27)	24.24 (5.13)
24MW	0.997	0.99	13.84 (3.35)	13.21 (3.87)	22.62 (3.06)	21.69 (4.59)

Annex C Table 7 Summary of estimated number of annual collisions and SD for lesser black-backed gull from the sCRM model using the Developer and Scoping Approaches and generic flight height data, for turbine Type A (wide chord and slow rotational speed) and B (narrow chord and fast rotational speed). Avoidance rates are from Bowgen and Cook (2018)

			Developer Approach		Scoping Approach	
Turbine Scenario	Avoidance rate - Basic	Avoidance rate - Extended	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)	Option 2 - Estimated collisions (SD)	Option 3 - Estimated collisions (SD)
Type A						
14MW	0.997	0.99	4.36 (1.76)	4.34 (2.33)	5.67 (1.75)	5.53 (2.52)
15MW	0.997	0.99	3.84 (1.55)	4.13 (2.15)	4.99 (1.53)	5.28 (2.31)
18MW	0.997	0.99	4.13 (1.66)	3.37 (1.82)	5.38 (1.65)	4.29 (1.96)
21MW	0.997	0.99	3.76 (1.51)	2.77 (1.50)	4.89 (1.50)	3.53 (1.62)
24MW	0.997	0.99	3.48 (1.40)	2.37 (1.29)	4.52 (1.38)	3.02 (1.38)
Type B						
18MW	0.997	0.99	3.62 (1.46)	3.52 (1.83)	4.71 (1.44)	4.49 (1.94)
21MW	0.997	0.99	3.35 (1.35)	3.03 (1.58)	4.36 (1.33)	3.86 (1.69)
24MW	0.997	0.99	3.13 (1.26)	2.71 (1.41)	4.07 (1.24)	3.46 (1.51)

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