Addendum to the Seagreen (2018) EIAR

Annex 2

Collision Risk Modelling

NOTE: This Annex was previously Seagreen (2018) EIAR Appendix 8B and is unchanged from the original

Collision risk modelling, methods and results

1. INTRODUCTION

1.1.1 This document details collision risk modelling (CRM) for the Seagreen Phase 1 projects (Alpha, Bravo and Alpha + Bravo). Modelling was undertaken for the three seabird species identified by MS-LOT in the Scoping Opinion (Marine Scotland 2017): Northern Gannet (hereafter Gannet), Black-legged Kittiwake (hereafter Kittiwake) and European Herring Gull (hereafter Herring Gull).

1.1.2 CRM is also presented for the nearby Scottish Territorial Waters (STW) sites of Neart na Gaoithe and Inch Cape to inform the cumulative assessment. The Seagreen data used in this analysis is an up-to-date iteration, including data from breeding season surveys in 2017. Thus, CRM to inform any cumulative assessment carried out by the STW projects will differ to that presented here.

1.1.3 The MS-LOT Scoping Opinion suggested two scenarios should be considered for the purposes of cumulative collision risk assessment:

- Scenario 1: effects of the Seagreen projects in isolation and in combination with the worst-case scenario for the 2014 consented Inch Cape and Neart na Gaoithe sites, and;
- Scenario 2: effects of the Seagreen projects in isolation and in combination with the proposed (redesigned) Inch Cape and Neart na Gaoithe projects.

1.1.4 Collision risk is estimated for all birds in flight (adults and sub-adults) during respective breeding and non-breeding seasons at all sites (i.e. Seagreen and the STW sites). Breeding season definitions followed Scottish Natural Heritage (SNH) advice (SNH 2017). For Gannet, collision estimates are presented for a breeding season running from the middle of March through to the end of September and also, as a precautionary approach, including the whole of March. The Kittiwake breeding season is defined as the middle of April to the end of August, but precautionary results are also presented including the whole of April. The breeding season for Herring Gull is considered to run from April to August inclusive.

1.1.5 Apportioning based on age structures was to be undertaken during the impact assessment. Further adjustment due to the methodological differences between Seagreen and the STW sites in relation to birds in flight (i.e. box vs radial methods) was also to be carried out within the impact assessment. Seagreen values are to be reduced by a factor of 0.7833.

2. METHODS

2.1 Collision risk modelling for the proposed Seagreen Phase 1 projects

2.1.1 Predicted mortality rates through collision with turbine blades are calculated using the extended Band model (Band 2012) that was developed through the Strategic Ornithological Support Services (SOSS) commissioned by the Crown Estate as an industry-level solution to the requirements for offshore CRM. The model provides four options with respect to different potential flight height distributions of the species concerned:

- Option 1 uses the proportion of birds at risk height based on flight heights derived from site-specific at-sea surveys and assumes a uniform distribution of flights over the extent of the swept area.
- Option 2 also assumes a uniform distribution, but is based on the proportion at risk height based on modelled flight data (Johnston *et al*. 2014).
- Option 3 is an extension of Option 2, but the full range of flight distributions between the minimum and maximum heights of the turbine blades is incorporated with calculation of the varying risk across the swept area (i.e. lowest risk towards the turbine tip and higher towards the nacelle).
- Option 4 is a bespoke interactive tool in which site-specific flight data can be fitted, with modelling then undertaken as in Option 3.

2.1.2 Following the advice of MS-LOT in the Scoping Opinion, Options 1 and 2 are considered for Kittiwake and Gannet, whilst options 2 and 3 are considered for Herring Gull (Marine Scotland 2017). Option 1 was not considered for Herring Gull, due to a lack of sufficient site-specific flight height data (see below). Also in line with SNH advice (incorporating discussion with the Royal Society for the Protection of Birds – RSPB) the following avoidance rates (ARs) with ±2 SD in parentheses were adopted:

- Gannet – 98.9% (±0.2%);
- Kittiwake – 98.9% (±0.2%), and
- Herring Gull – 99.5% (±0.1%) for Option 2 and 99.0% (±0.2%) for Option 3.

2.1.3 To avoid overestimation of birds at risk of collision, only the fractions of birds in flight were used to assess collision risk, even though birds on the water are generally likely to have flown to the site (perhaps with the exception of some individuals of strongly swimming species such as auks, that are not considered to be at risk of collision).

2.1.4 Mean monthly densities of flying birds were calculated using counts of birds in radial snapshots at defined intervals of 500 m along each transect (Table 1). Densities of birds were only considered within the predicted wind farm red-line boundary footprints (i.e. not including a 2 km buffer) for the respective projects.

2.1.5 Worst-case design scenarios of 70 wind turbine generators (WTGs) in either Alpha or Bravo projects in isolation, or 120 WTGs for a combined Alpha and Bravo area project was adopted. Given the combined Alpha and Bravo project varied from the sum of the individual projects, it is treated as a separate project.

Table 1. Unadjusted mean monthly densities (ind. km^{-2}) of flying birds, with standard deviations, used in CRM for the three species and projects. Breeding season months are shaded grey for each species and months where only the latter half is included are shaded blue. The number of surveys (n) in each month is also shown.

Species	Project	Value	Jan (n=2)	Feb (n=1)	Mar (n=2)	Apr (n=2)	May (n=4)	Jun (n=3)	Jul (n=3)	Aug (n=3)	Sept (n=2)	Oct (n=2)	Nov (n=2)	Dec (n=2)
Kittiwake	Alpha	Mean	1.397	0.591	2.696	2.187	2.687	2.382	5.431	1.455	3.602	2.467	10.230	0.617
		SD	0.476	-	3.418	1.248	2.304	1.633	5.989	1.563	5.015	1.369	14.168	0.720
	Bravo	Mean	2.434	2.133	2.560	1.413	3.271	2.449	1.273	0.904	0.402	1.523	6.961	0.715
		SD	0.630	-	1.804	1.026	1.128	1.475	0.748	0.933	0.418	1.031	8.445	0.777
	Alpha + Bravo	Mean	1.911	1.355	2.629	1.804	2.947	2.409	3.414	1.167	2.017	1.999	8.610	0.666
		SD	0.072	-	2.618	0.121	1.604	1.563	3.053	1.225	2.737	1.201	11.332	0.748
Gannet	Alpha	Mean	0.297	0.430	2.028	1.189	6.808	9.172	1.807	3.786	2.492	1.231	0.459	0.084
		SD	0.025	-	1.002	0.639	1.762	3.107	1.181	2.993	1.056	1.114	0.499	0.119
	Bravo	Mean	0.322	0.800	1.770	1.118	3.242	6.189	2.449	3.018	1.897	1.437	0.607	0.082
		SD	0.229	-	0.498	0.770	0.416	4.116	2.036	2.315	1.099	1.635	0.469	0.117
	Alpha + Bravo	Mean	0.309	0.613	1.900	1.154	4.986	7.612	2.116	3.403	2.197	1.333	0.532	0.083
		SD	0.126	-	0.752	0.704	0.932	2.809	1.454	2.653	1.078	1.372	0.485	0.118
Herring Gull	Alpha	Mean	0.159	0.161	0.248	0.055	0.083	0.110	0.038	0.000	0.028	0.114	0.053	0.196
		SD	0.146	-	0.272	0.003	0.108	0.141	0.065	0.000	0.039	0.083	0.075	0.201
	Bravo	Mean	0.081	0.053	0.131	0.000	0.076	0.147	0.000	0.000	0.029	0.028	0.000	0.275
		SD	0.114	-	0.186	0.000	0.095	0.201	0.000	0.000	0.041	0.040	0.000	0.311
	Alpha + Bravo	Mean	0.120	0.108	0.190	0.028	0.078	0.128	0.019	0.000	0.028	0.072	0.027	0.235
		SD	0.130	-	0.229	0.001	0.053	0.171	0.033	0.000	0.040	0.022	0.038	0.255

2.1.6 The latitude of the projects was set at 56.37 decimal degrees for all projects and the WTG parameters were based on the worst-case use of a 220 m rotor diameter WTG with a maximum blade width of 7.5 m (Table 2). The Hub height was calculated based on an assumed air gap of 30.18 m at mean sea level (MSL); an increase of 2.7 m relative to the specification used in the 2014 Appropriate Assessment (AA) conducted by Marine Scotland.

Table 2. WTG parameters used for collision risk modelling for all proposed Seagreen projects based on the consented and new.

Rating (MW)	Number of blades	Pitch (degrees)	Rotor radius (m)	Hub height to MSL (m)	Max blade width (m)
15	3	10	110	140.2	7.5

2.1.7 Modelled mean monthly rotor speeds were derived for indicative 9.5 MW 164 m rotor diameter WTGs based on predicted wind speeds across the project area (Table 3). These rotor speeds were assumed to provide the worst-case scenario.

2.1.8 Further estimates of the rotational speeds for the larger 220 m rotor diameter WTGs under consideration are provided (Table 3) for reference. These were used to generate comparative collision estimates for Kittiwake and Gannet. Comparative collision estimates were also produced using a smaller maximum blade width (5.4 m as consented in 2014), to illustrate the impact of this aspect of the turbine design on Kittiwake and Gannet. In both these additional scenarios the other model parameters remained as for the worst-case scenario.

Table 3. Modelled estimates of mean rotor speeds, expressed as revolutions per minute (rpm), by month based on indicative 9.5 MW V164 WTGs.

Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
164 m rotor diameter – worst case scenario	10.55	10.39	9.66	8.92	8.45	8.29	8.00	8.27	9.11	9.99	10.25	10.30
220 m rotor diameter – comparative estimates	6.83	6.80	6.54	6.27	6.07	6.03	5.90	6.01	6.37	6.72	6.76	6.76

2.1.9 The monthly operational time of the WTGs was set at 89% based on the Vortex Hindcast data modelling undertaken by Seagreen. This includes time above cut-in wind speed and predicted operations and maintenance downtime. Mean rotor speeds were used for the relevant breeding and non-breeding seasons for each of the three species (Table 4). Where the breeding and non-breeding seasons included half months, data from those months was included in the average for both periods.

Table 4. Mean estimates of rotor speeds expressed as revolutions per minute (rpm) for the breeding and non-breeding seasons for each species used in CRM. Values are shown for the worst-case (164 m rotor diameter) scenario and comparative estimates for a WTG with a 220 m rotor diameter.

Species	164 m rotor diameter - worst case		220 m rotor diameter - comparative estimates	
	Breeding	Non-breeding	Breeding	Non-breeding
Kittiwake	8.39	9.90	6.06	6.63
Gannet	8.67	10.19	6.17	6.74
Herring Gull	8.39	10.04	6.06	6.68

2.1.10 Morphological and behavioural parameters were derived from the literature (Table 5). Body length and wingspan were taken from BWPi (2004) and flight speeds from Alerstam *et al*. (2007). As a precautionary approach, the flight type was set as flapping for all species because flight behaviour in the rotor swept area is difficult to define. More recent and extensive estimates of flight speed for Kittiwake (8.71 m s^{-1}, *n*=287) and Gannet (13.33 m s^{-1}, *n*=683), derived during the Offshore Renewables Joint Industry Programme (ORJIP), were also applied for comparative purposes (Skov *et al*. 2018).

2.1.11 The first two stages of the model calculate the passage rate of the species through the rotor swept area. This is based on the density of flying birds recorded in snapshots in the breeding season. Passage rate is then scaled according to the proportion of flying birds at risk height and any nocturnal activity (see Table 5).

Table 5. Morphological and behavioural parameters of the relevant bird species used in CRM.

Parameter	Gannet	Kittiwake	Herring Gull	Source
Length (m)	0.94	0.39	0.61	BWPi 2004
Wingspan (m)	1.72	1.08	1.44	BWPi 2004
Flight speed (m sec^{-1})	14.9	13.1	12.8	Alerstam et al. 2007
Nocturnal activity	1	2	2	Scoping opinions
Flight type	flapping	flapping	flapping	

2.1.12 During the boat-based surveys in 2009-2011, surveyors recorded birds in coarse flight height categories. Birds flying at >20 m above sea level were recorded as 'potentially at risk'. This was insufficient information to provide an understanding of the flight height distribution to estimate the proportions at collision height PCH for Option 1 of the Band model and thus Option 2 using modelled data (Johnston *et al*. 2014) was previously used. However, during 2017 the surveyors recorded flight heights in 5 m bands, allowing a better understanding of the flight height distribution. In addition, a study of the reliability of surveyor's estimates of flight heights was undertaken using a low cost optical laser rangefinder (see Technical Report Appendix 1).

2.1.13 For both Kittiwake and Gannet, there was sufficient information to assess their flight height distributions within the project areas. Given the air gap at mean sea level has been set at 30.2 m, a risk height of >30 m was adopted for the estimation of PCH.

2.1.14 To make use of the 2009-11 survey data, adjustment factors were calculated based on the 2017 data by deriving the proportions of birds >20 m that would have been flying at >30 m according to the 2017 data (Table 6). The adjustment factors were used to estimate PCH values across all surveys. Mean PCH values were then calculated for each project area during the breeding and non-breeding seasons and used in the respective models (Table 7). For Kittiwake and Gannet, surveys in April and March were used to inform both the breeding and non-breeding PCH values.

Table 6. Proportion of birds flying above 20 m that was above 30 m during surveys of Alpha and Bravo in 2017.

Species	Project	Number flying above 20 m	Proportion above 30 m
Kittiwake	Alpha	71	0.296
	Bravo	87	0.161
	Alpha + Bravo	160	0.225
Gannet	Alpha	21	0.190
	Bravo	67	0.597
	Alpha + Bravo	94	0.479

Table 7. Proportion at collision height PCH (>30 m) estimates for Kittiwake and Gannet during their breeding and non-breeding seasons in each project area.

Species	Project area	Breeding	Non-breeding
Kittiwake	Alpha	6.30	5.19
	Bravo	3.80	2.88
	Alpha + Bravo	5.04	3.81
Gannet	Alpha	1.77	2.52
	Bravo	7.78	11.12
	Alpha + Bravo	5.37	6.97

2.1.15 For Kittiwake, the site-specific PCH values (Table 7) were generally similar to that derived from the maximum likelihood flight height distribution used in Option 2 of the Band model (5.5%). During the non-breeding season, Kittiwake appeared to be less likely to fly above 30 m and the PCH was lower in Bravo relative to Alpha. In contrast, Gannet appeared to be much more likely to fly above 30 m in Bravo relative to Alpha (Table 7), possibly reflecting a greater concentration of low-flying transiting birds passing through Alpha on the way to foraging sites to the northeast. As a result of the influence of birds in Bravo, the PCH for the combined project areas were greater than that derived from the maximum likelihood distribution used in Option 2 of the model (4.2%).

2.1.16 Combinations of these parameters were used to derive the most appropriate mortality estimates for all birds, regardless of age, during the breeding and non-breeding seasons respectively. Results are presented for the three species using the periods defined by SNH and also adopting a precautionary approach to breeding seasons for Gannet and Kittiwake that include the whole of March and April respectively.

2.2 Collision risk modelling to inform the cumulative assessment

2.2.1 The Inch Cape and Neart na Gaoithe projects were reassessed using the current assessment criteria (i.e. ARs and SNH defined breeding seasons). Mean monthly density estimates of all birds in flight (Table 1 and Table 8), in combination with the relevant worst-case wind farm parameters for each site (Table 9), were entered in the appropriate Band model. Data were supplied via SNH/Marine Scotland or were available in the Appendix 9.3 of the Neart na Gaoithe Offshore Windfarm - Revised Design Environmental Impact Assessment (EIA) Report (http://www.gov.scot/Topics/marine/Licensing/marine/scoping/NnGRev2017/apllicationvolume4appendices/appendix93crm).

2.2.2 The other parameters used in Marine Scotland's 2014 Appropriate Assessment and the bird parameters detailed in Table 4 remained unchanged. For comparative purposes, Option 2 alone was used for Gannet and Kittiwake with an AR of 98.9 ±0.2% (2SD) and Option 2 was used for Herring Gull as the worst case scenario and assuming an AR of 99.5 ±0.1% (2SD).

2.2.3 CRM for the current proposed STW sites was undertaken in the same manner but using the revised design envelopes taken from the relevant Scoping documents and from the Ornithology section of the Neart na Gaoithe Offshore Windfarm - Revised Design EIA Report (http://nngoffshorewind.com/files/EIA/Vol1/Chapter-9-Ornithology-Mar-2018.pdf).

Table 8. Densities (ind. km^{-2}) of all flying birds at Inch Cape and Neart na Gaoithe used for the cumulative assessments.

Project	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inch Cape	Kittiwake	0.200	0.048	0.570	0.612	0.839	1.998[1]	3.682	0.487	2.495	1.591	0.628	0.348
	Gannet	0.151	0.556	0.579	2.175	4.328	3.777	3.629	5.134	1.512	1.036	0.193	0.000
	Herring Gull	0.100	0.048	0.000	0.000	0.024	0.122	0.000	0.024	0.000	0.025	0.048	0.147
Neart na Gaoithe	Kittiwake	0.147	0.044	0.189	0.214	0.616	0.234	0.943	0.171	0.653	0.803	0.764	3.364
	Gannet	0.084	1.328	2.358	1.240	4.412	3.419	5.120	4.175	4.742	2.272	0.287	0.031
	Herring Gull	0.231	0.065	0.118	0.043	0.085	0.086	0.042	0.000	0.000	0.000	0.096	0.159

Table 9. Collision risk model parameters used for Inch Cape and Neart na Gaoithe for cumulative assessment.

Project	Lat	No. WTGs	No. of blades	Pitch (degrees)	Rotor radius (m)	Hub height to MSL (m)	Air gap at MSL (m)	Max blade width (m)
Inch Cape (2014)	56.4	110	3	10	86	111.0	25.0	6
Inch Cape (proposed 72 x 167 m WTGs)	56.4	72	3	10	83.5	116.1	32.6	6
Inch Cape (proposed 40 x 250 m WTGs)	56.4	40	3	10	125	152.6	27.6	7.8
Neart na Gaoithe (2014)	56.27	75	3	15	77	101.9	24.9	5
Neart na Gaoithe (proposed)	56.27	54	3	-0.7 to 3.41	83.5	115.5	32.0	5

2.2.4 Two proposed design scenarios were considered for Inch Cape. The first assessed the design option of 72[2] turbines with a rotor diameter of 167 m, maximum blade width of 6 m and an air gap to MSL of 32.6 m (see http://www.gov.scot/Resource/0051/00517517.pdf). The second was based on the installation of 40 WTGs with a rotor diameter of 250 m, maximum blade width of 7.8 m and an air gap to MSL of 27.6 m. For Neart na Gaoithe, the design scenario was for 54 WTGs with a rotor diameter of 167 m and an air gap of 32 m to MSL. Rotation speeds and proportions of operational time for Inch Cape (Table 10) were also taken from the CRM appendix for the Neart na Gaoithe EIA for the revised design for continuity (see http://www.gov.scot/Topics/marine/Licensing/marine/scoping/NnGRev2017/apllicationvolume4appendices/appendix93inchcape).

2.2.5 Estimated monthly rotor speeds for each project scenario are shown in Table 10 (and see Table 3 for proposed Seagreen projects). As with the modelling described above, mean rotor speeds were used for the breeding and non-breeding seasons and these

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[1] Densities were apparently derived from the values presented in the original Inch Cape ES, with the exception of June, where the mean value would have been 6.6 ind. km^{-2}. It remains unclear why this value had been altered so radically for the 2014 CRM assessments.
[2] Neart na Gaoithe discuss an assessment for 70 WTGs (167 m diameter), but their annex contains modelling scenarios for 72 WTGs as per the scoping.

are shown in Table 11. The submission for the proposed Neart na Gaoithe project included variable monthly pitch estimates, which here are averaged for the relevant breeding seasons (Table 11). Monthly estimates of operational time for each scenario are shown in Table 12.

Table 10. Estimates of rotor speeds, expressed as revolutions per minute (rpm), by month used for Inch Cape and Neart na Gaoithe projects.

Project	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inch Cape (2014)	9.3	8.6	8.5	6.9	6.1	5.6	5.1	5.6	7.0	8.1	8.9	9.1
Inch Cape (proposed 72 x 167 m WTGs)	6.7	6.3	6.4	5.5	5.0	4.7	4.4	4.7	5.5	6.2	6.5	6.6
Inch Cape (proposed 40 x 250 m WTGs)	10.3	9.7	9.7	8.4	7.7	7.2	6.7	7.2	8.5	9.4	10.0	10.1
Neart na Gaoithe (2014)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Neart na Gaoithe (proposed)	9.1	8.6	8.5	8.0	7.9	7.3	7.3	7.4	8.1	8.7	8.8	8.7

Table 11. Mean estimates of rotor speeds and pitch for Inch Cape and Neart na Gaoithe project scenarios in the breeding and non-breeding season for each species.

Species	Project	Rotor speed (rpm)		Pitch (degrees)	
		Breeding	Non-breeding	Breeding	Non-breeding
Kittiwake					
	Inch Cape (2014)	5.86	8.29	10	10
	Inch Cape (proposed 72 x 167 m WTGs)	7.42	9.49	10	10
	Inch Cape (proposed 40 x 250 m WTGs)	4.87	6.23	10	10
	Neart na Gaoithe (2104)	8.00	8.00	15	15
	Neart na Gaoithe (proposed)	7.61	8.55	-0.10	1.92
Gannet					
	Inch Cape (2014)	6.39	8.73	10	10
	Inch Cape (proposed 72 x 167 m WTGs)	7.89	9.85	10	10
	Inch Cape (proposed 40 x 250 m WTGs)	5.18	6.46	10	10
	Neart na Gaoithe (2104)	8.00	8.00	15	15
	Neart na Gaoithe (proposed)	7.80	8.72	0.29	2.36
Herring Gull					
	Inch Cape (2014)	5.86	8.48	10	10
	Inch Cape (proposed 72 x 167 m WTGs)	7.42	9.65	10	10
	Inch Cape (proposed 40 x 250 m WTGs)	4.87	6.33	10	10
	Neart na Gaoithe (2104)	8.00	8.00	15	15
	Neart na Gaoithe (proposed)	7.61	8.62	-0.10	2.12

Table 12. Estimates of operational times used in the CRM for Inch Cape and Neart na Gaoithe projects.

Project	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inch Cape (2014)	92%	92%	92%	91%	90%	90%	89%	89%	91%	92%	93%	92%
Inch Cape (proposed)	89%	85%	86%	77%	74%	71%	69%	72%	78%	86%	87%	88%
Neart na Gaoithe (2014)	89%	86%	87%	85%	86%	85%	84%	82%	86%	87%	89%	86%
Neart na Gaoithe (proposed)	92%	89%	90%	88%	85%	82%	81%	82%	87%	90%	91%	90%

3. RESULTS

3.1.1 The following sections present annual collision estimates for the proposed Seagreen projects, including the comparative model results using modified parameters. This is followed by the updated estimates for the Inch Cape and Neart na Gaoithe projects, which are combined with estimates for the redesigned projects to inform the cumulative assessment. The results presented are based on all flying birds, regardless of age and have not been adjusted due to methodological differences.

3.2 Collision mortality estimates for the proposed Seagreen Phase 1 projects

3.2.1 Table 13 provides an overview of the annual collision mortality estimates for each of the proposed Seagreen projects. Seagreen Alpha + Bravo produced the highest estimates of combined collision mortalities for Kittiwake (431 ind.) relative to Alpha (295 ind.) and Bravo (208 ind.) according to Option 2. Project Bravo delivered the lowest estimates for Kittiwake (Table 13). Option 1 delivered higher combined estimates for Alpha (303 ind.) relative to Option 2, but was lower for Bravo and Alpha + Bravo, reflecting variation in PCH relative to the standard flight height distributions used in Option 2.

3.2.2 The combined estimates for Gannet were also greatest for Project Alpha + Bravo according to both Option 2 (397 ind.) and Option 1 (518 ind.) of the model (Table 13). Project Alpha delivered the lowest values using Option 1 (115 ind.) and Bravo (199 ind.) produced the lowest number of collisions according to Option 2 (Table 13). This again reflects the impact of the variation in PCH values across the two projects relative to the standard distribution used in Option 2.

3.2.3 Option 3 delivered consistently lower combined estimates for Herring Gull relative to Option 1 (Table 13). Option 2 produced a maximum combined estimate of 22 collisions for Alpha + Bravo, with 16 for Project Alpha and 10 for Project Bravo (Table 13).

3.2.4 The use of the precautionary breeding season (i.e. inclusion of the whole of April) resulted in between a 6.6 and 8.1% increase in the mortality estimates for Kittiwake depending on the option and project. For Gannet, the inclusion of the whole of March resulted in an increase of between 2.8 and 3.3% in the estimates.

Table 13. **Annual collision risk estimates (±2SD ARs) for Kittiwake, Gannet and Herring Gull during respective SNH prescribed breeding, non-breeding and combined seasons for each of the projects. Estimates are provided according to the Band model Option applied. Results are also presented based on precautionary breeding seasons for Kittiwake (April - August inclusive) and Gannet (March - September inclusive).**

Period	Species	Project	SNH breeding seasons			Precautionary breeding seasons	
			Option 1	Option 2	Option 3	Option 1	Option 2
Breeding	Kittiwake	Alpha	145 (26)	127 (23)		156 (28)	136 (25)
		Bravo	57 (10)	83 (15)		62 (11)	89 (16)
		Alpha + Bravo	165 (30)	180 (33)		177 (32)	194 (35)
	Gannet	Alpha	102 (19)	244 (44)		105 (19)	251 (46)
		Bravo	319 (58)	174 (32)		330 (60)	180 (33)
		Alpha + Bravo	451 (82)	356 (65)		466 (85)	368 (67)
	Herring Gull	Alpha		4 (1)	3 (1)		
		Bravo		4 (1)	2 (0)		
		Alpha + Bravo		7 (1)	4 (1)		
Non-breeding	Kittiwake	Alpha	158 (29)	168 (30)			
		Bravo	65 (12)	124 (23)			
		Alpha + Bravo	173 (31)	250 (46)			
	Gannet	Alpha	13 (2)	22 (4)			
		Bravo	67 (12)	25 (5)			
		Alpha + Bravo	67 (12)	41 (7)			
	Herring Gull	Alpha		11 (2)	8 (2)		
		Bravo		7 (1)	5 (1)		
		Alpha + Bravo		16 (3)	11 (2)		
Combined	Kittiwake	Alpha	303 (55)	295 (54)			
		Bravo	122 (22)	208 (38)			
		Alpha + Bravo	338 (61)	431 (78)			
	Gannet	Alpha	115 (21)	266 (48)			
		Bravo	386 (70)	199 (36)			
		Alpha + Bravo	518 (94)	397 (72)			
	Herring Gull	Alpha		16 (3)	10 (7)		
		Bravo		10 (2)	7 (1)		
		Alpha + Bravo		22 (4)	15 (3)		

3.2.5 The comparative modelling exercise (Table 14) illustrated the decrease in flight speed estimates used in the model for Kittiwake could equate to a ~19% reduction in collision estimates. In contrast, the reduction for Gannet was less dramatic with the result being around a 6% decrease in collision estimates. Reducing the rotation speeds to those that are more reflective of a 220 m diameter WTG resulted in around an 8.5% decrease in estimates for Kittiwake and 10.5% decrease for Gannet (Table 14). A reduction in maximum blade width to 5.4 m would reduce collision estimates for Kittiwake by more than 20% and by more than 16% for Gannet.

Table 14. Comparison of combined breeding and non-breeding season collision estimates from Option 2 (±2SD ARs) for Kittiwake and Gannet using the worst-case parameters, reduced flight speeds (derived during ORJIP), reduced rotor speeds (based on 220 m diameter blades) and reduced maximum blade width (5.4 m vs 7.5 m).

Species	Project	Worst-case parameters	Reduced flight speeds	Reduced rotor speeds	Reduced blade width
Kittiwake	Alpha	295 (54)	239 (43)	270 (49)	234 (42)
	Bravo	208 (38)	168 (31)	190 (35)	165 (30)
	Alpha + Bravo	431 (78)	349 (64)	395 (72)	342 (62)
Gannet	Alpha	266 (48)	250 (45)	238 (43)	223 (41)
	Bravo	199 (36)	187 (34)	178 (32)	167 (30)
	Alpha + Bravo	397 (72)	373 (68)	355 (65)	332 (60)

3.3 Collision mortality estimates to inform the cumulative assessment

3.3.1 Tables 15, 16 and 17 present collision estimates for Kittiwake, Gannet and Herring Gull, respectively, for Seagreen and existing and proposed STW projects during the SNH prescribed breeding seasons using Band model Option 2.

Table 15. Predicted number of annual collisions of Kittiwake, associated with each project scenario, during breeding, non-breeding and combined seasons derived from Band Option 2 with an AR of 98.9% ±0.2% (2SD).

Project	Breeding	Non-breeding	Total
Alpha	127 (23)	168 (30)	295 (54)
Bravo	83 (15)	124 (23)	208 (38)
Alpha + Bravo	180 (33)	250 (46)	431 (78)
STW sites			
Inch Cape (2014)	143 (26)	99 (18)	241 (44)
Inch Cape (proposed 72 x 167 m WTGs)	36 (7)	28 (5)	65 (12)
Inch Cape (proposed 40 x 250 m WTGs)	40 (7)	32 (6)	72 (13)
Neart na Gaoithe (2014)	23 (4)	47 (9)	70 (13)
Neart na Gaoithe (proposed)	8 (2)	18 (3)	27 (5)

3.3.2

Table 16. Predicted number of annual collisions of Gannet, associated with each project scenario, during breeding, non-breeding and combined seasons derived from Band Option 2 with an AR of 98.9% ±0.2% (2SD).

Project	Breeding	Non-breeding	Total
Alpha	244 (44)	22 (4)	266 (48)
Bravo	174 (32)	25 (5)	199 (36)
Alpha + Bravo	356 (65)	41 (7)	397 (72)
STW sites			
Inch Cape (2014)	384 (70)	29 (5)	412 (75)
Inch Cape (proposed 72 x 167 m WTGs)	96 (17)	8 (1)	104 (19)
Inch Cape (proposed 40 x 250 m WTGs)	108 (20)	9 (2)	117 (21)
Neart na Gaoithe (2014)	259 (47)	37 (7)	296 (54)
Neart na Gaoithe (proposed)	91 (16)	14 (3)	105 (19)

3.3.3

Table 17. Predicted number of annual collisions of Herring Gull, associated with each project scenario, during breeding, non-breeding and combined seasons derived from Band Option 2 with an AR of 99.5% ±0.1% (2SD).

Project	Breeding	Non-breeding	Total
Alpha	4 (1)	11 (2)	16 (3)
Bravo	4 (1)	7 (1)	10 (2)
Alpha + Bravo	7 (1)	16 (3)	22 (4)
STW sites			
Inch Cape (2014)	4 (1)	6 (1)	11 (2)
Inch Cape (proposed 72 x 167 m WTGs)	1 (0)	3 (1)	4 (1)
Inch Cape (proposed 40 x 250 m WTGs)	1 (0)	2 (0)	4 (1)
Neart na Gaoithe (2014)	4 (1)	7 (1)	11 (2)
Neart na Gaoithe (proposed)	2 (0)	4 (1)	5 (1)

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