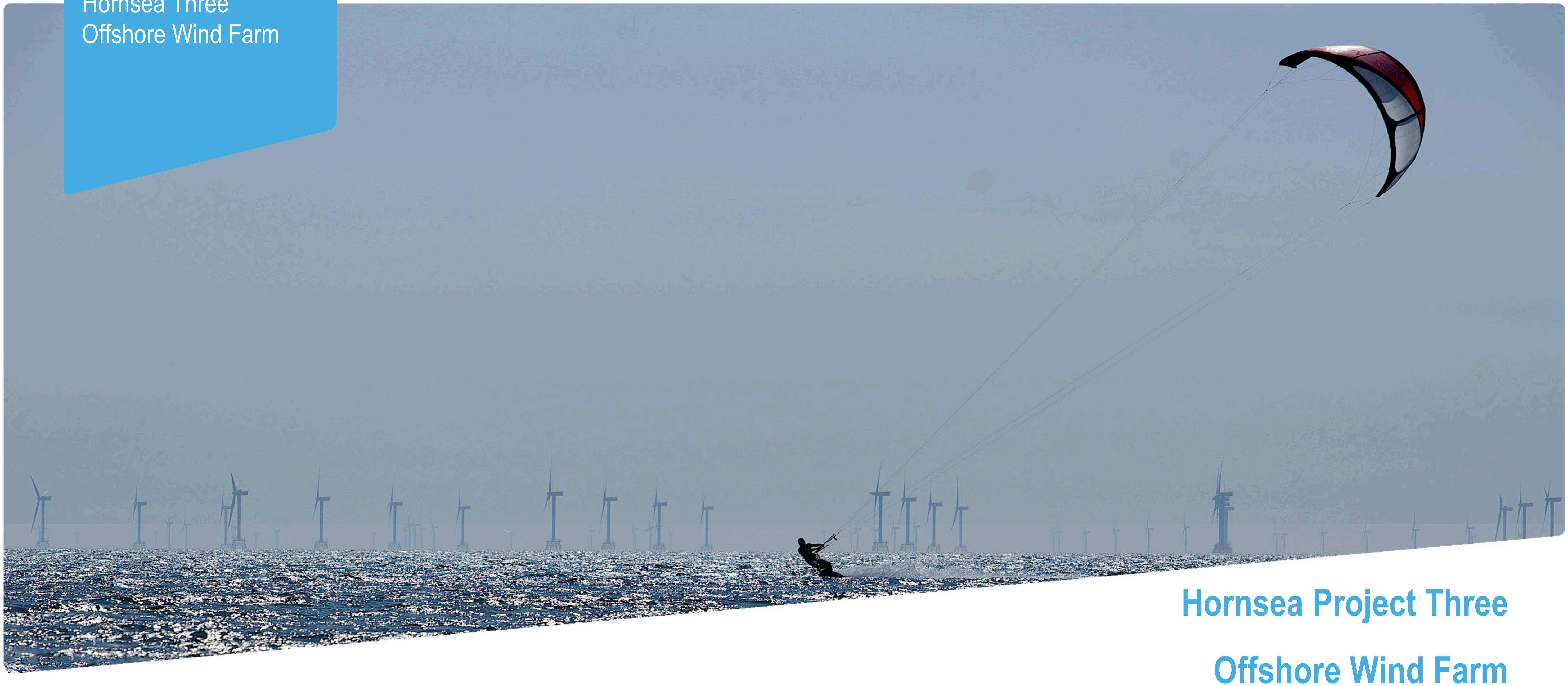
Hornsea Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Environmental Statement:
Volume 5, Annex 5.3 - Collision Risk Modelling

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Hornsea 3
Offshore Wind Farm

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Environmental Impact Assessment

Environmental Statement

Volume 5

Annex 5.3 Collision Risk Modelling Report

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1. Collision Risk Modelling

1.1 Introduction

1.1.1.1 This Annex presents the collision risk modelling processes undertaken for Hornsea Three to inform Volume 2, Chapter 5: Offshore Ornithology, incorporating, where relevant site-specific data collected between April 2016 and November 2017. This includes collision risk modelling for the following groups of species:

- Regularly occurring seabird species at Hornsea Three - e.g. gannet and kittiwake;
- Migratory seabird species – e.g. skuas, terns and little gull; and
- Migratory waterbirds – e.g. ducks and waders.

1.1.1.2 The main focus of this Annex is regularly occurring seabird species while Appendices B and C present the collision risk modelling process for migratory seabirds and for migratory waterbirds respectively.

1.2 Background

1.2.1 Overview

1.2.1.1 Birds can collide with turbine rotor blades, which is almost certain to result in direct mortality. Most studies have found evidence of only low levels of bird mortality associated with operational onshore wind farms, as birds are able to take avoiding action (Drewitt and Langston, 2006), although evidence from offshore wind farms is limited. The actual risk of collision depends on a number of factors including the location of a wind farm, the bird species using the area, weather and visibility conditions, and the size and design of the wind farm, including the number and size of turbines and the use, or otherwise, of lighting (e.g., Kerlinger and Curry, 2002).

1.2.1.2 The effect of collision rates on a population is influenced by various characteristics, notably its size, density, recruitment rate (additions to the population through reproduction and immigration) and mortality rate (the natural rate of losses due to death and emigration). In general, the effect of an individual lost from the population will be greater for species that occur at low density, are relatively long-lived and reproduce at a low rate with most seabird species falling into this category. Conversely, the effect will often be reduced for shorter-lived species with higher reproductive rates found at high densities, including some smaller gull species. Species that habitually fly at night or during low light conditions at dawn and dusk may also be at increased risk from collisions, however, both eider and scoter have been shown to detect and avoid offshore turbines at night in both the Netherlands (Winkelman, 1995) and at offshore towers at Tuno Knob in Denmark (Tulp *et al*., 1999).

1.2.1.3 Wade *et al.* (2016), assigned cumulative vulnerability scores for a range of seabird species in relation to collision impacts although did not categorise these for use in impact assessment. Table 1.1 provides an interpretation of these vulnerability scores; these are used alongside the size of the population occurring at Hornsea Three (see Annex 5.1 Baseline Characterisation Report and Section 1.3.1 below) in order to identify those Valued Ornithological Receptors (VORs) (identified in Annex 5.1: Baseline Characterisation Report) for which collision risk modelling was required.

Table 1.1: Vulnerability of VORs to collision with offshore wind turbines (based on Wade *et al.* 2016).

Species	Vulnerability	Uncertainty level (Wade *et al.*, 2016)
Fulmar	Very Low	Low
Gannet	High	Very low
Arctic skua	High	Moderate
Great skua	High	Moderate
Puffin	Very Low	Moderate
Razorbill	Very Low	Low
Guillemot	Very Low	Low
Common tern	Moderate	Very low
Arctic tern	Moderate	Moderate
Kittiwake	High	Very low
Little gull[1]	Low	Not included in Wade *et al.* (2016)
Lesser black-backed gull	Very High	Very low
Great black-backed gull	Very High	Low

1.2.1.4 In general, the effects of increased mortality on populations due to collisions with turbines are considered to be long-term (i.e., throughout the operational wind farm's lifespan) and it is assumed that in the model, collision rate does not decrease in response to losses in the population. In reality, effects may change over time, as birds, particularly those resident near the wind farm, may become habituated to the presence of turbines, or external factors such as changes in fishing activities, may alter the attractiveness of the wind farm area to birds, thereby changing activity levels within it.

[1] Garthe and Hüppop (2004)

1.2.2 Collision risk modelling

1.2.2.1 The most frequently used collision risk model in the UK is commonly referred to as 'the Band model'. This model was originally devised in 1995 and has since been subject to a number of iterations, most recently to facilitate application in the offshore environment (Band, 2011) and to allow for the use of flight height distribution data and to include a methodology for considering birds on migration (Band, 2012).

1.2.2.2 Masden (2015) presents an update to Band (2012) which further develops the application of the Band model using a simulation modelling approach to incorporate variability and uncertainty. The update provides for an improved understanding of uncertainty by pseudo-randomly sampling parameter values from distributions for each parameter, deriving average collision risk estimates with associated measures of variability. However, recent advice from Natural England has identified that further amendment of the Masden (2015) update of the collision risk model is required before they advise its use. . As a result, Masden (2015) has not been used to calculate collision risk estimates for Hornsea Three.

1.2.2.3 Figure 1.1 provides an overview of the information required for Band (2012) and the key outputs from the modelling process. The process to calculate the collision risk for a given species is a six stage process described as follows:

- Stage A: assemble data on the number of flights which, in the absence of birds being displaced or taking other avoiding action, or being attracted to the wind farm, are potentially at risk from wind farm turbines;
- Stage B: use that flight activity data to estimate the potential number of bird transits through rotors of the wind farm;
- Stage C: calculate the probability of collision during a single bird transit;
- Stage D: multiply these to yield the potential collision mortality rate for the bird species under consideration, allowing for the proportion of time the turbines are not operational, assuming current bird use of the site and that no avoiding action is taken;
- Stage E: allow for the proportion of birds likely to avoid the wind farm or its turbines, either because they have been displaced from the site or because they take evasive action; and allow for any attraction by birds to the wind farm; and
- Stage F: express the uncertainty surrounding such a collision risk estimate.

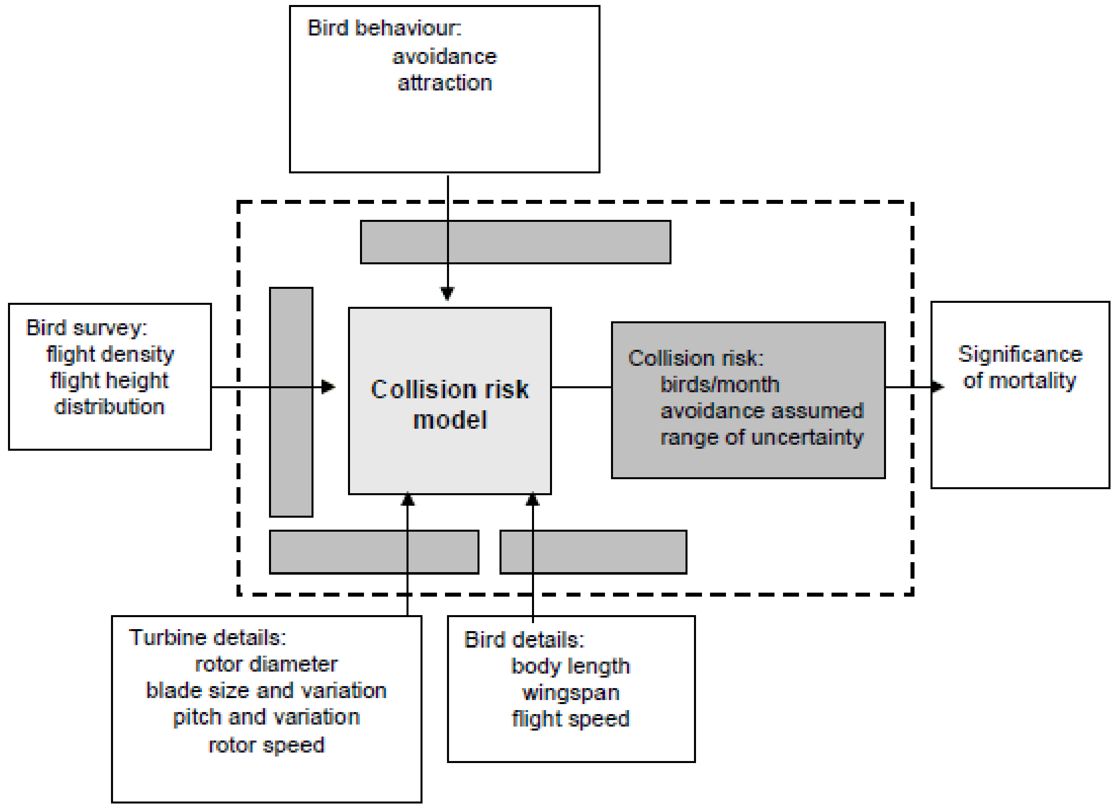

Figure 1.1: Band (2012) collision risk model overview.

1.2.2.4 The Band (2012) model incorporates two approaches to calculating the risk of collision referred to as the 'Basic' and 'Extended' versions of the model. A key difference between these versions is the extent to which they account for the flight height patterns of seabirds (Band, 2012). The distribution of seabird flights across the sea is generally skewed towards lower altitudes. As stated by Band (2012) there are three consequences of a skewed flight height distribution:

- *"the proportion of birds flying at risk height decreases as the height of the rotor is increased;*
- *more birds miss the rotor, where flights lie close to the bottom of the circle presented by the rotor; and*
- *the collision risk, for birds passing through the lower parts of a rotor, is less than the average collision risk for the whole rotor."*

1.2.2.5 The Basic model assumes a uniform distribution of flights across the rotor with a consistent risk of collision across the whole rotor swept area. The Extended model of Band (2012) takes into account the distribution of birds in addition to the differential risk across the rotor swept area.

Consideration of uncertainty

1.2.2.6 The Band (2012) guidance states that *"the output* [from collision risk modelling] *should convey the uncertainty in the collision risk estimate by indicating, in addition to a 'best estimate', a range of confidence around that estimate"*. The guidance further states that "*the aim should be to express the range of uncertainty at around the 95% confidence level*". The range of uncertainty should reflect uncertainty and/or variability associated with flight activity data, limitations of the collision risk model and turbine parameters that may not yet be finalised.

1.3 Methodology

1.3.1 Species for consideration

1.3.1.1 The process to identify Valued Ornithological Receptors (VORs) that may be affected by impacts associated by Hornsea Three is documented in the Baseline Characterisation Report (Annex 5.1: Baseline Characterisation Report). Those VORs that are potentially affected by collision risk are those that are:

- Known to be vulnerable to collision risk (based on Wade *et al.,* 2016; Bradbury *et al.,* 2014) (Table 1.1); and
- Where the population of the species observed at the development site plus a 4 km buffer is considered to be of importance, when compared against a relevant population scale thresholds (regional, national or international).

1.3.1.2 Table 1.2 identifies those VORs for which collision risk modelling is required based on the above criteria. The following species were selected for collision risk modelling:

- Gannet (high vulnerability, regionally important population);
- Kittiwake (high vulnerability, nationally important population);
- Lesser black-backed gull (very high vulnerability, regionally important population); and
- Great black-backed gull (very high vulnerability, nationally important population,).

1.3.1.3 In addition to the four species above a further five species were identified for collision risk modelling (Arctic skua, great skua, common tern, Arctic tern and little gull). These species were recorded in only low numbers at Hornsea Three however, traditional survey methods are considered unlikely to accurately capture the migratory movements of these species. Therefore a migratory collision risk approach has been used to quantify the potential collision risk impact on these species. This is included in Appendix B.

Table 1.2: Identification of VORs for which collision risk modelling is required

VOR	Vulnerability to collision risk impacts	Importance of population at Hornsea Three	Collision risk modelling required (Yes/No)
Fulmar	Very Low	Regional	No – very low vulnerability to collision risk
Gannet	High	Regional	Yes – high vulnerability, species recorded in regionally important numbers at Hornsea Three
Arctic skua	High	Local	Yes – high vulnerability, migratory species
Great skua	High	Local	Yes – high vulnerability, migratory species
Puffin	Very Low	Regional	No – very low vulnerability to collision risk
Razorbill	Very Low	Regional	No – very low vulnerability to collision risk
Guillemot	Very Low	Regional	No – very low vulnerability to collision risk
Common tern	Moderate	Local	Yes – migratory species
Arctic tern	Moderate	Local	Yes – migratory species
Kittiwake	High	National	Yes – high vulnerability, species recorded in nationally important numbers at Hornsea Three
Little gull	Low	Local	Yes – migratory species
Lesser black-backed gull	Very High	Regional	Yes – very high vulnerability, species recorded in regionally important numbers at Hornsea Three
Great black-backed gull	Very High	National	Yes – very high vulnerability, species recorded in nationally important numbers at Hornsea Three

1.3.2 Species parameters

Bird biometric and behavioural data

1.3.2.1 Table 1.3 presents the species-specific parameters for those species identified for collision risk modelling.

1.3.2.2 The avoidance rates presented in Table 1.3 are taken from Cook *et al*. (2014) which presents avoidance rates for all four species incorporated into this Annex. The report recommended avoidance rates for use with the Basic model for all four species and for the Extended model for lesser black-backed gull and great black-backed gull. However, Cook *et al.* (2014) were unable to recommend an avoidance rate for use in the Extended model for gannet and kittiwake and as such, a default 98% avoidance rate is applied in the modelling conducted in this Annex consistent with that recommended by the review of avoidance rates conducted in SMartWind and Forewind (2014). Ongoing research is currently investigating the avoidance behaviour of seabirds at offshore wind farms with any information that becomes available during the consenting process for Hornsea Three to be incorporated into the generic empirical evidence base for avoidance rates, if considered appropriate.

1.3.2.3 In a joint response, UK SNCBs supported the recommended avoidance rates of Cook *et al*. (2014) with the exception of those calculated for use with the Basic model for kittiwake (JNCC *et al.,* 2014). The SNCBs did not agree with the application of avoidance rates calculated for the 'small gull' category to kittiwake and recommended that the avoidance rate calculated for the 'all gull' category should be applied instead. Modelling in this Annex is therefore conducted using the avoidance rates presented in Table 1.3 taking into account the recommendations in both Cook *et al*. (2014) and JNCC *et al*. (2014).

1.3.2.4 The Band (2012) CRM requires the incorporation of a nocturnal activity parameter which describes the amount of flight activity at night in relation to the amount of flight activity in the day. In the absence of available empirical data, Band (2012) suggests that the subjectively-defined nocturnal activity factors presented in Garthe and Hüppop (2004) and King *et al.* (2009) be used to populate the CRM and so translating the rankings presented (1-5) into activity factors of 0, 25, 50, 75 and 100%. There now exists a body of empirical evidence from which nocturnal activity factors for gannet and kittiwake can be defined (see for example MacArthur Green, 2015).

1.3.2.5 A number of studies have deployed loggers on seabirds with the data collected providing empirical evidence as to the actual level of nocturnal flight activity by a number of bird species (Hamer *et al*., 1993; Daunt *et al*., 2002; Kotzerka *et al*., 2010; Orben *et al*., 2015; Garthe *et al*., 1999; Hamer *et al.,* 2000; Hamer *et al*., 2007; Garthe *et al*., 2012). These studies indicate that the nocturnal activity of gannet and kittiwake is lower than estimated by Garthe and Hüppop (2004) and King *et al*. (2009). A full review of the available literature in relation to nocturnal activity factors for the four species for which collision risk modelling is required is provided in Appendix D.

1.3.2.6 The nocturnal activity factors to be used in the collision risk modelling process for Hornsea Three are presented in Table 1.3. For gannet and kittiwake the substantial amount of evidence outlined in Appendix D indicates that the nocturnal activity factors previously used for these species will over-estimate collision risk. Therefore, for these species, nocturnal activity factors derived from empirical evidence have been used in CRM. The nocturnal activity factors presented for gannet and kittiwake in Table 1.3 have previously been used to qualitatively support the assessments presented for the East Anglia Three offshore wind farm and are those recommended by SNH and Marine Scotland for use in CRM for projects in Scottish waters.

Table 1.3: Seabird parameters used for collision risk modelling.

Parameter	Source	Gannet	Kittiwake	Lesser black-backed gull	Great black-backed gull
Bird length (m)	Robinson (2017)	0.94	0.39	0.58	0.71
Wingspan (m)	Robinson (2017)	1.72	1.08	1.42	1.58
Flight speed (m/s)	Pennycuick (1987) or Alerstam (2007)	14.9	13.1	13.1	13.7
Nocturnal activity factor [2]	Empirically derived/King *et al.* (2009)	1	2	3	3
Flight type	N/A[3]	Flapping	Flapping	Flapping	Flapping
Proportion of flights upwind	N/A[4]	50	50	50	50
Avoidance rate (Basic model) (%)[5]	Cook *et al.* (2014) JNCC *et al.* (2014)	98.9 (±0.2)	98.9 (±0.2) 99.2 (±0.2)	99.5 (±0.1)	99.5 (±0.1)
Avoidance rate (Extended model) (%)	Cook *et al.* (2014)	98.0	98.0	98.9 (±0.2)	98.9 (±0.2)

[2] A 1-5 scale is used for nocturnal activity with 1 representing limited nocturnal activity and 5 large amounts of nocturnal activity
[3] Based on expert opinion - the input parameters for flight type are either 'flapping' or 'gliding' with flapping representing the worst case scenario
[4] Assumed that there is a 50:50 split in flights upwind and downwind
[5] A range of avoidance rates are presented in the following sections, with those in Table 1.3 the rates reported in Cook *et al.* (2014)

Density data

1.3.2.7 Project-specific data for Hornsea Three has been collected by twenty digital aerial surveys carried out between April 2016 and November 2017 encompassing the wind farm array area plus a 4 km buffer. From these data, and to inform collision risk assessment, monthly densities of birds in flight (including upper and lower 95% confidence limits) in the Hornsea Three array area have been derived.

1.3.2.8 These density values have not been adjusted for population age structure or apportioning to SPAs. This element of analysis is conducted where relevant as part of assessments presented in Volume 2, Chapter 5: Offshore Ornithology and the Hornsea Three Report to Inform Appropriate Assessment (RIAA).

1.3.2.9 Further information on the aerial surveys undertaken for Hornsea Three and the methodologies used to derive population estimates is provided in the Annex 5.1: Offshore Ornithology Baseline Characterisation Report.

1.3.2.10 Natural England recommend that two years of baseline survey data be collected in order to capture the inherent variability in seabird populations within assessments presented in an EIA/HRA. The Hornsea Three aerial surveys have collected two years of data for the six month period (April to September) and this is considered to adequately capture the variability in seabird populations for assessment purposes in this period.

1.3.2.11 One year of baseline data is currently available for December to March. To further understand the inherent variability in seabird populations at Hornsea Three (including the period where only one year of data is available) a detailed analysis investigating the variability in seabird populations at Hornsea Three has been conducted. This uses both the site-specific aerial survey data and boat-based survey data collected as part of the application process for previous projects in the former Hornsea Zone (see document titled 'A method for assessing priority of seabird density data for use in EIA at Hornsea 3. Addendum 1.'). The results of this analysis have been used to identify appropriate densities for use in CRM for Hornsea Three. The full approach applied is presented in the document titled 'A method for assessing priority of seabird density data for use in EIA at Hornsea 3. Addendum 1.' alongside the resulting monthly densities to be used for CRM.

1.3.3 Hornsea Three design and turbine parameters

1.3.3.1 The turbine scenario to be used at Hornsea Three has been refined since the Preliminary Environmental Information Report in order to reduce the collision risk impacts on birds. The worst case scenario for collision risk in this modelling process is now taken to be the development scenario comprising 300 turbines with parameters as presented in Table 1.4 (see the maximum adverse scenario table in Volume 2, Chapter 5: Offshore Ornithology). The parameters for this turbine scenario required by Band (2012) are presented in Table 1.4. The large array correction feature of Band (2012) was not applied at this stage as this does not have a meaningful effect on collision risk estimates (although if applied it would be expected to very slightly decrease collision estimates).

1.3.3.2 A minimum lower tip height clearance of 34.97 m LAT will be used at Hornsea Three. This equates to an "air gap" between mean sea level (MSL) and lower tip height of 33.17m. This has been incorporated into the turbine design at Hornsea Three in order to mitigate collision risk impacts on seabirds. The flight height distribution of birds flying across the sea is known to be skewed to lower heights (Johnston *et al.*, 2014). It then follows that by increasing the lower rotor height at an offshore wind farm considerably fewer birds will occur within the rotor swept area and therefore collision risk will be lower.

Table 1.4: Wind farm and turbine parameters used for collision risk modelling.

Parameter	Value
Wind farm	
Latitude (degrees)	53.87
Number of turbines	300
Tidal offset (m)	1.8
Turbine	
Average rotation speed (rpm)	8.1
Rotor radius (m)	97.5
Hub height (m)	128.87 (HAT)
Max blade width (m)	6
Average pitch (°)	4.3

1.3.3.3 Band (2012) also requires information relating to the monthly proportion of time turbines will be operational taking into account maintenance activities and wind availability. Table 1.5 presents this information with this provided by Ørsted for the worst case turbine scenario.

Table 1.5: Monthly proportion of time turbines at Hornsea Three will be operational.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Proportion of time operational (%)	92.50	92.61	92.14	90.96	90.71	89.36	89.18	89.86	91.29	92.57	92.59	92.61

1.3.4 Band model options

1.3.4.1 The Band (2012) model incorporates two approaches to calculating the risk of collision referred to as the 'Basic' and 'Extended' versions of the model. A key difference between these versions is the extent to which they account for the flight height patterns of seabirds (Band, 2012). The distribution of seabird flights across the sea is generally skewed towards lower altitudes. As stated by Band (2012) there are three consequences of a skewed flight height distribution:

- *"the proportion of birds flying at risk height decreases as the height of the rotor is increased;*
- *more birds miss the rotor, where flights lie close to the bottom of the circle presented by the rotor; and*
- *the collision risk, for birds passing through the lower parts of a rotor, is less than the average collision risk for the whole rotor."*

1.3.4.2 The Basic model assumes a uniform distribution of flights across the rotor with a consistent risk of collision across the whole rotor swept area. The Extended model of Band (2012) takes into account the distribution of birds in addition to the differential risk across the rotor swept area. It should be noted that the use of the basic model is precautionary as it does not take into account the variability in risk of collision that occurs across a rotor swept area, with the risk of collision decreasing as the distance from the hub of the turbine increases. If this were to be taken into account (as when using Option 3) it is likely that collision risk estimates would be lower as the vertical distribution of birds flying across water is skewed towards lower heights (i.e. those associated with a lower risk of collision within a rotor swept area).

1.3.4.3 Both the Basic and Extended models of Band (2012) allow for the use of two 'Options' termed Options 1-4. Options 1 and 2 use the Basic model with Options 3 and 4 utilising the Extended model. The difference between the two Options under each model is linked to the use of flight height data. Options 2 and 3 use generic data from Johnston et al. (2014) whereas Options 1 and 4 use site-specific data derived from site-specific surveys. It is standard practice to present collision risk estimates calculated using all Options in Band (2012) and this has been followed throughout this Annex and associated assessments.

1.3.4.4 The flight height data collected as part of site-specific digital aerial surveys at Hornsea Three has been thoroughly reviewed and is concluded to be of limited use in collision risk modelling. For the majority of species the number of records falls below a 100 record threshold which has been recommended as being required by Natural England in order to calculate a representative proportion of birds at potential collision height (PCH) value (Natural England, 2013). For the two species for which a representative PCH value is calculable (gannet and kittiwake), the resulting value falls considerably outside of the confidence limits associated with generic flight height information (Johnston *et al*., 2014) with no valid ecological reason as to why this should occur.

1.3.4.5 Further to this, there are a significant number of records that are assigned a negative flight height while the majority of records have associated wide confidence intervals. Of the 3,553 records of birds in flight a height value could be estimated for just over 39% (1,393 birds). Of these birds, a negative flight height was estimated for over 29%. For those birds for which a positive flight height was estimated (987 records) the lower confidence limit for 38% was also negative. This therefore leaves only 538 records that are unaffected by negative values.

1.3.4.6 There exists a considerable amount of flight height data that were collected during boat-based surveys conducted to support the application process for the Hornsea Project One and Hornsea Project Two offshore wind farms. Surveys were conducted between March 2010 and February 2013 covering the former Hornsea Zone (which includes Hornsea Three) and were based on standard survey methodologies (Camphuysen *et al.,* 2004). A full description of the surveys conducted is presented in SMartWind (2015a) and SMartWind (2013). These data have been interrogated in order to identify those records that occur within Hornsea Three plus a 4 km buffer.

1.3.4.7 The boat-based surveys categorised flying birds into five metre height bands meaning that, for example, birds assigned to the 10 metre flight height band were flying between 7.5 and 12.5 m. The lower rotor tip height at Hornsea Three is 33.17 (MSL), therefore the 35 metre flight height band (32.5 – 37.5 m) has been used to calculate the proportion of birds at PCH. Although likely to include a proportion of birds that are actually outside of the rotor swept area (i.e. those between 32.5 and 33.17 m), the use of a complete five metre band is considered precautionary. In order to provide a measure of confidence to the flight height data to be used for Option 1 the next flight height band below 32.5 m (27.5 to 32.5 m) has also been included in the PCH value. The inclusion of these band as an 'upper confidence' measure aligns with the approach to analysis requested by Natural England during the examination at Hornsea Project Two (see SMart Wind, 2015b). The PCH values calculated for each species are presented in Table 1.6.

Table 1.6: Proportion of birds at PCH calculated from boat-based survey data collected between March 2010 and February 2013 within Hornsea Three plus a 4 km buffer

Species	No. of birds recorded in flight	Proportion of birds at PCH ('upper confidence' PCH) (%)
Gannet	142	1.41 (4.23)
Kittiwake	510	0.78 (1.76)
Lesser black-backed gull	123	9.76 (22.76)
Great black-backed gull	177	7.34 (19.21)

1.3.4.8 In addition to Option 1, collision risk estimates have also been calculated using Options 2 and 3 of the Band (2012) model which make use of aggregated generic flight height data contained in Johnston *et al.* (2014).

1.3.4.9 It is highlighted that the use of the basic version of the model (Options 1 and 2 in this case) is precautionary as it does not take into account the variability in risk of collision that occurs across a rotor swept area, with the risk of collision decreasing as the distance from the hub of the turbine increases. If this were to be taken into account (as when using Option 3) it is likely that collision risk estimates would be of a lower magnitude as the vertical distribution of birds flying across water is skewed towards lower heights (i.e. those associated with a lower risk of collision within a rotor swept area).

1.3.5 Expressing uncertainty

1.3.5.1 In order to express the uncertainty associated with the collision risk estimates presented in this Annex, modelling has been conducted incorporating confidence metrics associated with species densities and flight height distributions. The upper and lower 95% confidence limits associated with density values are used within collision risk modelling to provide a range of collision risk estimates describing the variability around density estimates. In addition this process has also been undertaken for flight height distribution with the upper and lower 95% confidence intervals associated with the flight height distributions presented in Johnston *et al.* (2014) used in collision risk modelling for each species. The results obtained are presented on an annual basis in Section 1.4 and on a monthly basis in Appendix A.

1.4 Results

1.4.1 Collision risk estimates

Gannet

1.4.1.1 The annual collision risk estimates (Options 1, 2 and 3) calculated for gannet using Band (2012) are shown in Table 1.7.

Table 1.7: Annual collision risk estimates for gannet calculated using Options 1, 2 and 3 of the Band (2012) collision risk model using mean estimate and upper and lower 95% confidence interval density values.

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
	Lower CL	*Mean estimate*	*Upper CL*
Option 1			
98.7	11	20	29
98.9	10	17	24
99.1	8	14	20
Option 2			
98.7	25	44	63
98.9	21	37	54
99.1	17	31	44
Option 3			
98	9	15	22

Table 1.8: Annual collision risk estimates for gannet calculated using Options 1, 2 and 3 of the Band (2012) collision risk model using maximum likelihood and upper and lower 95% confidence interval flight height distributions.

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
	Lower CL	*Maximum likelihood*	*Upper CL*
Option 1			
98.7		20	60
98.9		17	51
99.1		14	42
Option 2			
98.7	14	44	98
98.9	11	37	83
99.1	9	31	68
Option 3			
98	4	15	43

Kittiwake

1.4.1.2 The annual collision risk estimates (Options 1, 2 and 3) calculated for kittiwake using Band (2012) are shown in Table 1.9.

Table 1.9: Annual collision risk estimates for kittiwake calculated using Options 1, 2 and 3 of the Band (2012) collision risk model using mean estimate and upper and lower 95% confidence interval density values.

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
	Lower CL	*Mean estimate*	*Upper CL*
Option 1			
98.7	34	54	75
98.9	29	45	64
99.1	23	37	52
99.2	21	33	46
99.5	13	21	29
Option 2			
98.7	177	281	395
98.9	150	238	334
99.1	123	195	273
99.2	109	173	243
99.5	68	108	152
Option 3			
98	52	83	116

Table 1.10: Annual collision risk estimates for kittiwake calculated using Options 1, 2 and 3 of the Band (2012) collision risk model using maximum likelihood and upper and lower 95% confidence interval flight height distributions.

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
	Lower CL	*Maximum likelihood*	*Upper CL*
Option 1			
98.7		54	120
98.9		45	102
99.1		37	83
99.2		33	74
99.5		21	46
Option 2			
98.7	184	281	368
98.9	156	238	312
99.1	127	195	255
99.2	113	173	227
99.5	71	108	142
Option 3			
98	49	83	118

Lesser black-backed gull

1.4.1.3 The annual collision risk estimates (Options 1, 2 and 3) calculated for lesser black-backed gull using Band (2012) are shown in Table 1.11.

Table 1.11: Annual collision risk estimates for lesser black-backed gull calculated using Options 1, 2 and 3 of the Band (2012) collision risk model using mean estimate and upper and lower 95% confidence interval density values.

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
	Lower CL	*Mean estimate*	*Upper CL*
Option 1			
99.4	5	17	29
99.5	4	14	24
99.6	3	11	19
Option 2			
99.4	6	21	36
99.5	5	17	30
99.6	4	14	24
Option 3			
98.7	4	14	23
98.9	3	12	20
99.1	3	9	16

Table 1.12: Annual collision risk estimates for lesser black-backed gull calculated using Options 1, 2 and 3 of the Band (2012) collision risk model using maximum likelihood and upper and lower 95% confidence interval flight height distributions.

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
	Lower CL	*Maximum likelihood*	*Upper CL*
Option 1			
99.4		17	40
99.5		14	33
99.6		11	26
Option 2			
99.4	12	21	44
99.5	10	17	37
99.6	8	14	29
Option 3			
98.7	6	14	40
98.9	5	12	34
99.1	4	9	28

Great black-backed gull

1.4.1.4 The annual collision risk estimates (Options 1, 2 and 3) calculated for great black-backed gull using Band (2012) are shown in Table 1.13.

Table 1.13: Annual collision risk estimates for great black-backed gull calculated using Options 1, 2 and 3 of the Band (2012) collision risk model using mean estimate and upper and lower 95% confidence interval density values.

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
	Lower CL	*Mean estimate*	*Upper CL*
Option 1			
99.4	12	38	65
99.5	10	32	54
99.6	8	25	44
Option 2			
99.4	24	79	136
99.5	20	66	113
99.6	16	53	91
Option 3			
98.7	19	62	106
98.9	16	52	90

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
99.1	13	43	73

Table 1.14: Annual collision risk estimates for great black-backed gull calculated using Options 1, 2 and 3 of the Band (2012) collision risk model using maximum likelihood and upper and lower 95% confidence interval flight height distributions.

Avoidance rate (%)	Collision risk estimates (no. of collisions/annum)		
	Lower CL	***Maximum likelihood***	***Upper CL***
Option 1			
99.4		38	100
99.5		32	83
99.6		25	66
Option 2			
99.4	62	79	137
99.5	52	66	114
99.6	42	53	91
Option 3			
98.7	43	62	149
98.9	37	52	126
99.1	30	43	103

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Appendix A Additional collision risk modelling outputs

A.1.1 Gannet

Table A.1: Monthly collision risk estimates for gannet calculated using Option 1 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
98.7	0.11	1.05	0.83	1.05	0.22	0.73	3.39	4.23	1.64	3.84	0.82	2.19
98.9	0.10	0.89	0.70	0.89	0.19	0.62	2.86	3.58	1.39	3.25	0.70	1.86
99.1	0.08	0.73	0.57	0.73	0.15	0.51	2.34	2.93	1.14	2.66	0.57	1.52
Density = UCL												
98.7	0.29	2.06	1.43	1.49	0.40	1.19	4.54	6.00	2.25	4.85	1.15	3.21
98.9	0.25	1.74	1.21	1.26	0.34	1.01	3.84	5.08	1.90	4.10	0.98	2.71
99.1	0.20	1.43	0.99	1.03	0.28	0.82	3.14	4.15	1.56	3.36	0.80	2.22
Density = LCL												
98.7	0.00	0.00	0.29	0.60	0.04	0.28	2.23	2.46	1.03	2.83	0.49	1.18
98.9	0.00	0.00	0.24	0.51	0.03	0.23	1.89	2.08	0.87	2.40	0.42	1.00
99.1	0.00	0.00	0.20	0.42	0.03	0.19	1.54	1.70	0.71	1.96	0.34	0.82

Table A.2: Monthly collision risk estimates for gannet calculated using Option 1 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PCH = Mean estimate												
98.7	0.11	1.05	0.83	1.05	0.22	0.73	3.39	4.23	1.64	3.84	0.82	2.19
98.9	0.10	0.89	0.70	0.89	0.19	0.62	2.86	3.58	1.39	3.25	0.70	1.86
99.1	0.08	0.73	0.57	0.73	0.15	0.51	2.34	2.93	1.14	2.66	0.57	1.52
PCH = Upper confidence metric												
98.7	0.34	3.14	2.48	3.15	0.66	2.20	10.16	12.69	4.92	11.53	2.47	6.58
98.9	0.29	2.66	2.10	2.66	0.56	1.86	8.59	10.74	4.16	9.75	2.09	5.57
99.1	0.23	2.18	1.72	2.18	0.46	1.52	7.03	8.78	3.41	7.98	1.71	4.56

Table A.3: Monthly collision risk estimates for gannet calculated using Option 2 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
98.7	0.25	2.30	1.81	2.30	0.48	1.61	7.43	9.28	3.60	8.43	1.81	4.81
98.9	0.21	1.94	1.53	1.95	0.41	1.36	6.28	7.85	3.04	7.13	1.53	4.07
99.1	0.17	1.59	1.26	1.59	0.33	1.11	5.14	6.42	2.49	5.83	1.25	3.33
Density = UCL												
98.7	0.64	4.52	3.15	3.28	0.88	2.61	9.96	13.16	4.93	10.64	2.53	7.03
98.9	0.54	3.82	2.66	2.77	0.74	2.21	8.43	11.14	4.17	9.00	2.14	5.95
99.1	0.45	3.13	2.18	2.27	0.61	1.81	6.90	9.11	3.41	7.36	1.75	4.87
Density = LCL												
98.7	0.00	0.00	0.63	1.32	0.08	0.61	4.89	5.40	2.27	6.22	1.08	2.60
98.9	0.00	0.00	0.53	1.12	0.07	0.51	4.14	4.57	1.92	5.26	0.92	2.20
99.1	0.00	0.00	0.44	0.92	0.06	0.42	3.38	3.74	1.57	4.30	0.75	1.80

Table A.4: Monthly collision risk estimates for gannet calculated using Option 2 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flight height distribution = Maximum Likelihood												
98.7	0.25	2.30	1.81	2.30	0.48	1.61	7.43	9.28	3.60	8.43	1.81	4.81

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
98.9	0.21	1.94	1.53	1.95	0.41	1.36	6.28	7.85	3.04	7.13	1.53	4.07
99.1	0.17	1.59	1.26	1.59	0.33	1.11	5.14	6.42	2.49	5.83	1.25	3.33
Flight height distribution = UCL												
98.7	0.55	5.09	4.02	5.10	1.07	3.57	16.46	20.56	7.97	18.68	4.01	10.67
98.9	0.46	4.31	3.40	4.31	0.90	3.02	13.93	17.40	6.75	15.80	3.39	9.03
99.1	0.38	3.52	2.78	3.53	0.74	2.47	11.39	14.24	5.52	12.93	2.77	7.39
Flight height distribution = LCL												
98.7	0.08	0.70	0.56	0.70	0.15	0.49	2.27	2.84	1.10	2.58	0.55	1.47
98.9	0.06	0.60	0.47	0.60	0.12	0.42	1.92	2.40	0.93	2.18	0.47	1.25
99.1	0.05	0.49	0.38	0.49	0.10	0.34	1.57	1.97	0.76	1.79	0.38	1.02

Table A.5: Monthly collision risk estimates for gannet calculated using Option 3 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
98	0.09	0.81	0.64	0.81	0.17	0.57	2.61	3.26	1.26	2.96	0.63	1.69
Density = UCL												
98	0.23	1.59	1.11	1.15	0.31	0.92	3.50	4.62	1.73	3.74	0.89	2.47
Density = LCL												
98	0.00	0.00	0.22	0.46	0.03	0.21	1.72	1.90	0.80	2.18	0.38	0.91

Table A.6: Monthly collision risk estimates for gannet calculated using Option 3 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flight height distribution = Maximum Likelihood												
98	0.09	0.81	0.64	0.81	0.17	0.57	2.61	3.26	1.26	2.96	0.63	1.69
Flight height distribution = UCL												
98	0.24	2.22	1.75	2.22	0.46	1.55	7.16	8.95	3.47	8.13	1.74	4.64
Flight height distribution = LCL												
98	0.02	0.19	0.15	0.19	0.04	0.14	0.63	0.79	0.30	0.71	0.15	0.41

A.1.2 Kittiwake

Table A.7: Monthly collision risk estimates for kittiwake calculated using Option 1 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
98.7	1.84	0.73	6.54	7.61	6.66	1.95	11.12	3.29	5.71	1.42	2.02	4.62
98.9	1.56	0.61	5.54	6.44	5.64	1.65	9.41	2.78	4.84	1.20	1.71	3.91
99.1	1.28	0.50	4.53	5.27	4.61	1.35	7.70	2.27	3.96	0.98	1.40	3.20
99.2	1.13	0.45	4.03	4.68	4.10	1.20	6.84	2.02	3.52	0.88	1.24	2.84
99.5	0.71	0.28	2.52	2.93	2.56	0.75	4.28	1.26	2.20	0.55	0.78	1.78
Density = UCL												
98.7	2.72	1.46	11.18	10.30	8.91	2.60	15.54	4.11	8.07	1.80	2.40	5.96
98.9	2.30	1.23	9.46	8.72	7.54	2.20	13.15	3.48	6.83	1.52	2.03	5.05
99.1	1.88	1.01	7.74	7.13	6.17	1.80	10.76	2.85	5.59	1.24	1.66	4.13
99.2	1.67	0.90	6.88	6.34	5.48	1.60	9.56	2.53	4.97	1.11	1.48	3.67
99.5	1.04	0.56	4.30	3.96	3.43	1.00	5.98	1.58	3.11	0.69	0.92	2.29
Density = LCL												
98.7	1.08	0.23	3.35	4.91	4.41	1.29	6.71	2.46	3.35	1.05	1.64	3.28
98.9	0.91	0.19	2.83	4.16	3.74	1.09	5.68	2.08	2.84	0.89	1.39	2.77
99.1	0.74	0.16	2.32	3.40	3.06	0.89	4.64	1.70	2.32	0.73	1.13	2.27
99.2	0.66	0.14	2.06	3.02	2.72	0.79	4.13	1.51	2.06	0.65	1.01	2.02

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
99.5	0.41	0.09	1.29	1.89	1.70	0.50	2.58	0.95	1.29	0.40	0.63	1.26

Table A.8: Monthly collision risk estimates for kittiwake calculated using Option 1 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PCH = Mean estimate												
98.7	1.84	0.73	6.54	7.61	6.66	1.95	11.12	3.29	5.71	1.42	2.02	4.62
98.9	1.56	0.61	5.54	6.44	5.64	1.65	9.41	2.78	4.84	1.20	1.71	3.91
99.1	1.28	0.50	4.53	5.27	4.61	1.35	7.70	2.27	3.96	0.98	1.40	3.20
99.2	1.13	0.45	4.03	4.68	4.10	1.20	6.84	2.02	3.52	0.88	1.24	2.84
99.5	0.71	0.28	2.52	2.93	2.56	0.75	4.28	1.26	2.20	0.55	0.78	1.78
PCH = Upper confidence metric												
98.7	4.15	1.63	14.72	17.11	14.99	4.38	25.03	7.39	12.86	3.20	4.55	10.39
98.9	3.51	1.38	12.46	14.48	12.68	3.71	21.18	6.25	10.88	2.71	3.85	8.80
99.1	2.87	1.13	10.19	11.85	10.38	3.03	17.33	5.12	8.90	2.22	3.15	7.20
99.2	2.55	1.00	9.06	10.53	9.23	2.70	15.40	4.55	7.91	1.97	2.80	6.40
99.5	1.59	0.63	5.66	6.58	5.77	1.68	9.63	2.84	4.94	1.23	1.75	4.00

Table A.9: Monthly collision risk estimates for kittiwake calculated using Option 2 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
98.7	9.69	3.81	34.40	39.98	35.02	10.23	58.47	17.27	30.04	7.48	10.62	24.29
98.9	8.20	3.23	29.10	33.83	29.63	8.66	49.47	14.61	25.42	6.33	8.99	20.55
99.1	6.71	2.64	23.81	27.68	24.25	7.09	40.48	11.96	20.79	5.18	7.35	16.81
99.2	5.96	2.35	21.17	24.61	21.55	6.30	35.98	10.63	18.48	4.60	6.54	14.94

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
99.5	3.73	1.47	13.23	15.38	13.47	3.94	22.49	6.64	11.55	2.88	4.09	9.34
Density = UCL												
98.7	14.28	7.65	58.76	54.15	46.84	13.69	81.67	21.62	42.45	9.44	12.63	31.35
98.9	12.08	6.48	49.72	45.82	39.64	11.59	69.10	18.29	35.92	7.99	10.69	26.52
99.1	9.89	5.30	40.68	37.49	32.43	9.48	56.54	14.97	29.39	6.54	8.74	21.70
99.2	8.79	4.71	36.16	33.32	28.83	8.43	50.26	13.30	26.12	5.81	7.77	19.29
99.5	5.49	2.94	22.60	20.83	18.02	5.27	31.41	8.31	16.33	3.63	4.86	12.06
Density = LCL												
98.7	5.65	1.19	17.60	25.82	23.20	6.78	35.27	12.92	17.63	5.51	8.62	17.22
98.9	4.78	1.01	14.89	21.85	19.63	5.74	29.84	10.93	14.91	4.66	7.29	14.57
99.1	3.91	0.83	12.19	17.88	16.06	4.69	24.42	8.95	12.20	3.81	5.96	11.92
99.2	3.48	0.73	10.83	15.89	14.28	4.17	21.70	7.95	10.85	3.39	5.30	10.60
99.5	2.17	0.46	6.77	9.93	8.92	2.61	13.56	4.97	6.78	2.12	3.31	6.62

Table A.10: Monthly collision risk estimates for kittiwake calculated using Option 2 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flight height distribution = Maximum Likelihood												
98.7	9.69	3.81	34.40	39.98	35.02	10.23	58.47	17.27	30.04	7.48	10.62	24.29
98.9	8.20	3.23	29.10	33.83	29.63	8.66	49.47	14.61	25.42	6.33	8.99	20.55
99.1	6.71	2.64	23.81	27.68	24.25	7.09	40.48	11.96	20.79	5.18	7.35	16.81
99.2	5.96	2.35	21.17	24.61	21.55	6.30	35.98	10.63	18.48	4.60	6.54	14.94
99.5	3.73	1.47	13.23	15.38	13.47	3.94	22.49	6.64	11.55	2.88	4.09	9.34
Flight height distribution = UCL												
98.7	12.68	4.99	45.03	52.34	45.85	13.40	76.54	22.61	39.32	9.79	13.91	31.79
98.9	10.73	4.22	38.10	44.29	38.80	11.34	64.76	19.13	33.27	8.28	11.77	26.90
99.1	8.78	3.46	31.17	36.24	31.74	9.28	52.99	15.65	27.22	6.78	9.63	22.01

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
99.2	7.80	3.07	27.71	32.21	28.21	8.25	47.10	13.91	24.20	6.02	8.56	19.56
99.5	4.88	1.92	17.32	20.13	17.63	5.15	29.44	8.70	15.12	3.76	5.35	12.23
Flight height distribution = LCL												
98.7	6.34	2.50	22.51	26.17	22.92	6.70	38.27	11.30	19.66	4.89	6.95	15.90
98.9	5.37	2.11	19.05	22.15	19.40	5.67	32.38	9.56	16.64	4.14	5.88	13.45
99.1	4.39	1.73	15.59	18.12	15.87	4.64	26.49	7.83	13.61	3.39	4.81	11.00
99.2	3.90	1.54	13.85	16.11	14.11	4.12	23.55	6.96	12.10	3.01	4.28	9.78
99.5	2.44	0.96	8.66	10.07	8.82	2.58	14.72	4.35	7.56	1.88	2.67	6.11

Table A.11: Monthly collision risk estimates for kittiwake calculated using Option 3 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
98	2.85	1.12	10.13	11.77	10.31	3.01	17.22	5.09	8.85	2.20	3.13	7.15
Density = UCL												
98	4.21	2.25	17.30	15.95	13.79	4.03	24.05	6.37	12.50	2.78	3.72	9.23
Density = LCL												
98	1.66	0.35	5.18	7.60	6.83	2.00	10.39	3.81	5.19	1.62	2.54	5.07

Table A.12: Monthly collision risk estimates for kittiwake calculated using Option 3 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flight height distribution = Maximum Likelihood												
98	2.85	1.12	10.13	11.77	10.31	3.01	17.22	5.09	8.85	2.20	3.13	7.15
Flight height distribution = UCL												
98	4.05	1.59	14.37	16.71	14.63	4.28	24.43	7.22	12.55	3.12	4.44	10.15
Flight height distribution = LCL												
98	1.68	0.66	5.95	6.91	6.06	1.77	10.11	2.99	5.19	1.29	1.84	4.20

A.1.3 Lesser black-backed gull

Table A.13: Monthly collision risk estimates for lesser black-backed gull calculated using Option 1 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
99.4	0.00	0.00	0.00	0.79	0.34	8.65	5.62	1.63	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	0.66	0.28	7.21	4.68	1.36	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	0.52	0.22	5.77	3.75	1.09	0.00	0.00	0.00	0.00
Density = UCL												
99.4	0.00	0.00	0.00	1.49	0.76	13.70	9.87	3.30	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	1.24	0.63	11.42	8.23	2.75	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	0.99	0.51	9.14	6.58	2.20	0.00	0.00	0.00	0.00
Density = LCL												
99.4	0.00	0.00	0.00	0.08	0.00	3.60	1.36	0.00	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	0.07	0.00	3.00	1.14	0.00	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	0.06	0.00	2.40	0.91	0.00	0.00	0.00	0.00	0.00

Table A.14: Monthly collision risk estimates for lesser black-backed gull calculated using Option 1 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PCH = Mean estimate												
99.4	0.00	0.00	0.00	0.79	0.34	8.65	5.62	1.63	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	0.66	0.28	7.21	4.68	1.36	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	0.52	0.22	5.77	3.75	1.09	0.00	0.00	0.00	0.00
PCH = Upper confidence metric												
99.4	0.00	0.00	0.00	1.83	0.78	20.19	13.11	3.81	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	1.53	0.65	16.83	10.93	3.18	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	1.22	0.52	13.46	8.74	2.54	0.00	0.00	0.00	0.00

Table A.15: Monthly collision risk estimates for lesser black-backed gull calculated using Option 2 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
99.4	0.00	0.00	0.00	0.96	0.41	10.56	6.85	1.99	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	0.80	0.34	8.80	5.71	1.66	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	0.64	0.27	7.04	4.57	1.33	0.00	0.00	0.00	0.00
Density = UCL												
99.4	0.00	0.00	0.00	1.82	0.93	16.72	12.04	4.03	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	1.51	0.77	13.93	10.04	3.36	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	1.21	0.62	11.14	8.03	2.68	0.00	0.00	0.00	0.00
Density = LCL												
99.4	0.00	0.00	0.00	0.10	0.00	4.39	1.66	0.00	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	0.08	0.00	3.66	1.39	0.00	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	0.07	0.00	2.93	1.11	0.00	0.00	0.00	0.00	0.00

Table A.16: Monthly collision risk estimates for lesser black-backed gull calculated using Option 2 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flight height distribution = Maximum Likelihood												
99.4	0.00	0.00	0.00	0.96	0.41	10.56	6.85	1.99	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	0.80	0.34	8.80	5.71	1.66	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	0.64	0.27	7.04	4.57	1.33	0.00	0.00	0.00	0.00
Flight height distribution = UCL												
99.4	0.00	0.00	0.00	2.03	0.87	22.34	14.50	4.22	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	1.69	0.72	18.61	12.09	3.51	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	1.35	0.58	14.89	9.67	2.81	0.00	0.00	0.00	0.00
Flight height distribution = LCL												
99.4	0.00	0.00	0.00	0.55	0.23	6.01	3.90	1.13	0.00	0.00	0.00	0.00
99.5	0.00	0.00	0.00	0.45	0.19	5.00	3.25	0.94	0.00	0.00	0.00	0.00
99.6	0.00	0.00	0.00	0.36	0.16	4.00	2.60	0.76	0.00	0.00	0.00	0.00

Table A.17: Monthly collision risk estimates for lesser black-backed gull calculated using Option 3 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
98.7	0.00	0.00	0.00	0.63	0.27	6.95	4.51	1.31	0.00	0.00	0.00	0.00
98.9	0.00	0.00	0.00	0.53	0.23	5.88	3.82	1.11	0.00	0.00	0.00	0.00
99.1	0.00	0.00	0.00	0.44	0.19	4.81	3.12	0.91	0.00	0.00	0.00	0.00
Density = UCL												
98.7	0.00	0.00	0.00	1.20	0.61	11.01	7.93	2.65	0.00	0.00	0.00	0.00
98.9	0.00	0.00	0.00	1.01	0.52	9.31	6.71	2.24	0.00	0.00	0.00	0.00
99.1	0.00	0.00	0.00	0.83	0.42	7.62	5.49	1.84	0.00	0.00	0.00	0.00

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = LCL												
98.7	0.00	0.00	0.00	0.07	0.00	2.89	1.10	0.00	0.00	0.00	0.00	0.00
98.9	0.00	0.00	0.00	0.06	0.00	2.45	0.93	0.00	0.00	0.00	0.00	0.00
99.1	0.00	0.00	0.00	0.05	0.00	2.00	0.76	0.00	0.00	0.00	0.00	0.00

Table A.18: Monthly collision risk estimates for lesser black-backed gull calculated using Option 3 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flight height distribution = Maximum Likelihood												
98.7	0.00	0.00	0.00	0.63	0.27	6.95	4.51	1.31	0.00	0.00	0.00	0.00
98.9	0.00	0.00	0.00	0.53	0.23	5.88	3.82	1.11	0.00	0.00	0.00	0.00
99.1	0.00	0.00	0.00	0.44	0.19	4.81	3.12	0.91	0.00	0.00	0.00	0.00
Flight height distribution = UCL												
98.7	0.00	0.00	0.00	1.87	0.80	20.53	13.33	3.88	0.00	0.00	0.00	0.00
98.9	0.00	0.00	0.00	1.58	0.67	17.37	11.28	3.28	0.00	0.00	0.00	0.00
99.1	0.00	0.00	0.00	1.29	0.55	14.21	9.23	2.68	0.00	0.00	0.00	0.00
Flight height distribution = LCL												
98.7	0.00	0.00	0.00	0.30	0.13	3.25	2.11	0.61	0.00	0.00	0.00	0.00
98.9	0.00	0.00	0.00	0.25	0.11	2.75	1.79	0.52	0.00	0.00	0.00	0.00
99.1	0.00	0.00	0.00	0.20	0.09	2.25	1.46	0.42	0.00	0.00	0.00	0.00

A.1.4 Great black-backed gull

Table A.19: Monthly collision risk estimates for great black-backed gull calculated using Option 1 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
99.4	3.72	0.98	1.06	0.26	0.00	0.68	8.40	0.82	2.90	2.45	4.17	12.65
99.5	3.10	0.82	0.89	0.21	0.00	0.57	7.00	0.68	2.42	2.04	3.47	10.54
99.6	2.48	0.66	0.71	0.17	0.00	0.45	5.60	0.55	1.94	1.63	2.78	8.43
Density = UCL												
99.4	7.24	2.14	2.33	0.58	0.00	1.21	16.75	1.37	5.52	3.73	5.42	18.99
99.5	6.03	1.78	1.94	0.48	0.00	1.01	13.96	1.14	4.60	3.11	4.51	15.83
99.6	4.83	1.43	1.56	0.39	0.00	0.81	11.17	0.91	3.68	2.49	3.61	12.66
Density = LCL												
99.4	0.80	0.00	0.00	0.00	0.00	0.15	0.05	0.27	0.00	0.00	2.91	7.53
99.5	0.67	0.00	0.00	0.00	0.00	0.12	0.04	0.23	0.00	0.00	2.43	6.28
99.6	0.54	0.00	0.00	0.00	0.00	0.10	0.03	0.18	0.00	0.00	1.94	5.02

Table A.20: Monthly collision risk estimates for great black-backed gull calculated using Option 1 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PCH = Mean estimate												
99.4	3.72	0.98	1.06	0.26	0.00	0.68	8.40	0.82	2.90	2.45	4.17	12.65
99.5	3.10	0.82	0.89	0.21	0.00	0.57	7.00	0.68	2.42	2.04	3.47	10.54
99.6	2.48	0.66	0.71	0.17	0.00	0.45	5.60	0.55	1.94	1.63	2.78	8.43
PCH = Upper confidence metric												
99.4	9.73	2.57	2.78	0.67	0.00	1.78	21.97	2.14	7.59	6.41	10.89	33.07

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
99.5	8.11	2.14	2.32	0.56	0.00	1.49	18.31	1.79	6.33	5.34	9.08	27.56
99.6	6.49	1.71	1.85	0.45	0.00	1.19	14.65	1.43	5.06	4.27	7.26	22.05

Table A.21: Monthly collision risk estimates for great black-backed gull calculated using Option 2 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
99.4	7.74	2.04	2.21	0.54	0.00	1.42	17.47	1.70	6.04	5.09	8.66	26.30
99.5	6.45	1.70	1.84	0.45	0.00	1.18	14.55	1.42	5.03	4.25	7.22	21.91
99.6	5.16	1.36	1.47	0.36	0.00	0.95	11.64	1.14	4.02	3.40	5.77	17.53
Density = UCL												
99.4	15.05	4.45	4.85	1.21	0.00	2.52	34.83	2.84	11.48	7.77	11.26	39.49
99.5	12.54	3.71	4.04	1.01	0.00	2.10	29.03	2.37	9.57	6.47	9.38	32.91
99.6	10.03	2.97	3.23	0.81	0.00	1.68	23.22	1.89	7.66	5.18	7.51	26.33
Density = LCL												
99.4	1.67	0.00	0.00	0.00	0.00	0.31	0.10	0.57	0.00	0.00	6.06	15.67
99.5	1.39	0.00	0.00	0.00	0.00	0.26	0.08	0.47	0.00	0.00	5.05	13.06
99.6	1.11	0.00	0.00	0.00	0.00	0.21	0.06	0.38	0.00	0.00	4.04	10.44

Table A.22: Monthly collision risk estimates for great black-backed gull calculated using Option 2 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flight height distribution = Maximum Likelihood												
99.4	7.74	2.04	2.21	0.54	0.00	1.42	17.47	1.70	6.04	5.09	8.66	26.30
99.5	6.45	1.70	1.84	0.45	0.00	1.18	14.55	1.42	5.03	4.25	7.22	21.91
99.6	5.16	1.36	1.47	0.36	0.00	0.95	11.64	1.14	4.02	3.40	5.77	17.53
Flight height distribution = UCL												
99.4	13.36	3.53	3.81	0.93	0.00	2.45	30.16	2.94	10.42	8.80	14.95	45.41
99.5	11.14	2.94	3.18	0.77	0.00	2.04	25.13	2.45	8.69	7.33	12.46	37.84
99.6	8.91	2.35	2.54	0.62	0.00	1.63	20.11	1.96	6.95	5.86	9.97	30.27
Flight height distribution = LCL												
99.4	6.09	1.61	1.74	0.42	0.00	1.12	13.75	1.34	4.75	4.01	6.82	20.70
99.5	5.08	1.34	1.45	0.35	0.00	0.93	11.46	1.12	3.96	3.34	5.68	17.25
99.6	4.06	1.07	1.16	0.28	0.00	0.74	9.17	0.89	3.17	2.67	4.54	13.80

Table A.23: Monthly collision risk estimates for great black-backed gull calculated using Option 3 of Band (2012) using confidence intervals associated with density.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Density = Mean estimate												
98.7	6.05	1.60	1.73	0.42	0.00	1.11	13.65	1.33	4.72	3.98	6.77	20.55
98.9	5.12	1.35	1.46	0.35	0.00	0.94	11.55	1.13	3.99	3.37	5.73	17.39
99.1	4.19	1.11	1.19	0.29	0.00	0.77	9.45	0.92	3.27	2.76	4.69	14.23
Density = UCL												
98.7	11.76	3.48	3.79	0.94	0.00	1.97	27.22	2.22	8.97	6.07	8.80	30.86
98.9	9.95	2.94	3.21	0.80	0.00	1.67	23.03	1.88	7.59	5.13	7.45	26.11
99.1	8.14	2.41	2.62	0.65	0.00	1.37	18.84	1.54	6.21	4.20	6.09	21.36
Density = LCL												
98.7	1.31	0.00	0.00	0.00	0.00	0.24	0.08	0.44	0.00	0.00	4.74	12.24
98.9	1.11	0.00	0.00	0.00	0.00	0.21	0.06	0.37	0.00	0.00	4.01	10.36
99.1	0.90	0.00	0.00	0.00	0.00	0.17	0.05	0.31	0.00	0.00	3.28	8.48

Table A.24: Monthly collision risk estimates for great black-backed gull calculated using Option 3 of Band (2012) using confidence intervals associated with flight height distribution.

Avoidance rate (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flight height distribution = Maximum Likelihood												
98.7	6.05	1.60	1.73	0.42	0.00	1.11	13.65	1.33	4.72	3.98	6.77	20.55
98.9	5.12	1.35	1.46	0.35	0.00	0.94	11.55	1.13	3.99	3.37	5.73	17.39
99.1	4.19	1.11	1.19	0.29	0.00	0.77	9.45	0.92	3.27	2.76	4.69	14.23
Flight height distribution = UCL												
98.7	14.57	3.85	4.16	1.01	0.00	2.67	32.89	3.21	11.37	9.59	16.31	49.52
98.9	12.33	3.26	3.52	0.85	0.00	2.26	27.83	2.71	9.62	8.12	13.80	41.90
99.1	10.09	2.67	2.88	0.70	0.00	1.85	22.77	2.22	7.87	6.64	11.29	34.28
Flight height distribution = LCL												
98.7	4.22	1.12	1.20	0.29	0.00	0.77	9.53	0.93	3.29	2.78	4.72	14.35
98.9	3.57	0.94	1.02	0.25	0.00	0.65	8.06	0.79	2.79	2.35	4.00	12.14
99.1	2.92	0.77	0.83	0.20	0.00	0.54	6.60	0.64	2.28	1.92	3.27	9.93

Appendix B Migratory seabirds

B.1 Introduction

B.1.1.1 This Annex presents the results of collision risk modelling undertaken for migratory seabirds in relation to Hornsea Three which will be used to inform assessments conducted in Volume 2, Chapter 5: Offshore Ornithology. The results will also be used to inform HRA Screening for migratory seabirds however, additional steps are required in order to conduct this process with these included in the RIAA Annex 2: Additional Screening Exercise.

B.1.1.2 This Annex is structured to include the following sections:

- Migratory seabird species considered with reference to their known migratory behaviour and the Biologically Defined Minimum Population Scale (BDMPS) populations applied;
- Collision risk analysis methodology including the calculation of potentially interacting populations and modelling parameters; and
- Collision risk modelling results; assessment for Hornsea Three alone and cumulatively with other plans and projects.

B.2 Species for consideration

B.2.1.1 A number of information sources, including migratory routes, migratory behaviour and regional SPA populations have been used in order to identify migratory seabird species to be included in this modelling process. Based on this information five species have been identified the migratory routes from which may interact with Hornsea Three:

- Arctic skua;
- Great skua;
- Little gull;
- Common tern; and
- Arctic tern.

B.2.1.2 This suite of species is identical to those species incorporated into migratory collision risk modelling at the Hornsea Project Two and Hornsea Project One offshore wind farms (SMart Wind, 2013; SMartWind, 2015a; SMartWind, 2015b). It is not considered necessary to include any additional species as there are no other species that will migrate through Hornsea Three in numbers that may result in a significant effect. The following sections outline the migratory behaviour and Biologically Defined Minimum Population Scales (BDMPS) used for each of the five species which were used in the identification of species for inclusion in the modelling presented in this Annex with additional information provided in Annex 5.1: Baseline Characterisation Report.

B.2.2 Arctic skua

B.2.2.1 Arctic skuas breed in small numbers in northern Scotland and more widely in the Arctic and sub-Arctic. The species is a transequatorial migrant moving to wintering areas off Australia, South Africa and southern South America (Wernham *et al*., 2002). Arctic skuas generally migrate through coastal waters, often associating with aggregations of terns and small gulls in areas such as estuaries from which they are able to obtain food by kleptoparasitism (Taylor, 1979). Birds that migrate through UK waters are UK breeding birds, mainly from Shetland and Orkney, and birds that breed in northern Europe (Furness, 1987).

B.2.2.2 Autumn migration of Arctic skua starts in August (Wernham *et al*., 2002; Forrester *et al*., 2007; Pennington *et al*., 2004). Peak autumn migration through UK waters occurs in August-September (Wernham *et al*., 2002) with peak migration in English waters occurring in September (Brown and Grice, 2005). In spring, birds begin to reach UK waters from early April with peak in migratory movements in April to May (Wernham *et al*., 2002).

B.2.2.3 Furness (2015) presents UK North Sea and Channel BDMPS populations for Arctic skua in both the post-breeding and pre-breeding seasons. In the post-breeding season the BDMPS is 6,427 birds composed mainly of birds from Scottish colonies with a smaller proportion from Arctic and northern European populations. In the pre-breeding season the BDMPS is 1,227 birds again composed mainly of birds from Scottish colonies and much smaller proportions from Arctic and northern European colonies.

B.2.3 Great skua

B.2.3.1 The majority of the global population of great skua breeds in Scotland with the remainder breeding in Iceland. Great skua is principally a passage migrant through English waters moving between breeding colonies in Scotland and wintering grounds in southern Europe (Wernham *et al*., 2002).

B.2.3.2 Autumn migration of great skua starts in August with peak autumn migration through UK waters occurring between August and October (Wernham *et al*., 2002; Brown and Grice, 2005). In spring, migration begins in March and peaks from late March into April (Wernham *et al*., 2002; Pennington *et al*., 2004; Forrester *et al*., 2007). During spring migration, a much smaller proportion of great skuas migrate through the North Sea.

B.2.3.3 Furness (2015) presents UK North Sea and Channel BDMPS populations for great skua in both the post-breeding and pre-breeding seasons. In the post-breeding season the North Sea and Channel waters BDMPS population is 19,556 birds composed mainly of birds from Scottish colonies with a smaller proportion from northern European populations. In the pre-breeding season the North Sea and Channel waters population is 8,485 birds again composed mainly of birds from Scottish colonies and smaller proportions from northern European colonies.

B.2.4 Little gull

B.2.4.1 Little gull is primarily a passage migrant to the UK occurring during both autumn and spring migration. Birds from breeding colonies in north-western Russia migrate through the Baltic into the North Sea with birds then moving on to wintering areas in the western Mediterranean (Wernham *et al*., 2002).

B.2.4.2 Birds begin to arrive in the North Sea in late July and early August off the coast of eastern Scotland. These birds precede a second wave of birds which reaches England and Wales (Wernham *et al*., 2002). Movements of birds out of the North Sea occur in October with the majority of the flyway population of little gull (40-100%) leaving the North Sea through the English Channel (Wernham *et al*., 2002; Stienen *et al*., 2007).

B.2.4.3 Spring migratory movements of little gull back to breeding areas occurs from April into early May with birds moving up the west coast of the UK and through the English Channel into the southern North Sea (Wernham *et al*., 2002).

B.2.4.4 The population of birds that migrate via the North Sea in autumn and spring has not been quantified (e.g. in Furness, 2015) and therefore for the purposes of this analysis the flyway population of little gull (75,000 individuals) is applied to the analysis as defined for the English Channel by Stienen *et al*. (2007).

B.2.5 Common tern

B.2.5.1 Common tern is a migrant breeder and passage visitor to the UK and throughout Europe that winters on the western and southern African coast, with a small proportion wintering as far north as Portugal (Wernham *et al*., 2002).

B.2.5.2 Post-fledging dispersal of common tern starts as early as July and continues into October (Wernham *et al*., 2002). Peak autumn migratory movements of common tern through UK waters occurs in August-September (Wernham *et al*., 2002) with peak movements through northern England occurring in August with the movement of many birds likely to occur overland (Ward, 2000). Many common terns return to breeding areas by April with peak pre-breeding movements occurring in English waters during this month (Brown and Grice, 2005). The frequency of inland sightings during spring suggests that a large proportion of spring movements also occur overland.

B.2.5.3 Furness (2015) presents UK North Sea and Channel BDMPS populations for common tern for migratory seasons with the same number of birds considered to migrate through this area during both autumn and spring. This population is estimated to consist of 144,911 birds originating mainly from UK North Sea colonies but also from northern European colonies and a smaller proportion from colonies on the west coast of the UK.

B.2.6 Arctic tern

B.2.6.1 Arctic tern is a migrant breeder and passage visitor to the UK which undertakes extensive migratory movements to waters off the west and south African coast, continuing on as far south as Australia. The species has a circumpolar breeding distribution with the populations in the UK and Ireland on the southern limit of this distribution (Wernham *et al*., 2002).

B.2.6.2 Autumn migratory movements of Arctic tern through UK waters start in early July, with the majority of movements completed by October (Pennington *et al*., 2004; Forrester *et al*., 2007). The majority of these movements are thought to occur offshore (Wernham *et al*., 2002). Peak autumn migratory movements through Shetland and Scotland occurs in July (Pennington *et al*., 2004; Forrester *et al*., 2007), with peak movements in southern England occurring in September (Brown and Grice, 2005). The first spring migrants arrive in UK waters in March (Wernham *et al*., 2002) with peak spring migratory movements occurring through UK waters in May (Brown and Grice, 2005; Pennington *et al*., 2004; Forrester *et al*., 2007).

B.2.6.3 Furness (2015) presents UK North Sea and Channel BDMPS populations for Arctic tern for migration seasons. The same number of birds is considered to migrate through the UK North Sea and Channel during both the post-breeding and pre-breeding seasons. This population is estimated to consist of 163,930 birds originating mainly from UK North Sea colonies but also from northern European colonies.

B.3 Methodology

B.3.1 Overview

B.3.1.1 Unlike the modelling approach used for collision risk modelling for regularly occurring seabird species at Hornsea Three, density data collected during site-specific surveys is deemed to be unsuitable to estimate the impact of collision for migratory seabird species. This is due to the snapshot nature of site-specific surveys and consequential limitations in recording sporadic movements of migratory species. Therefore the collision risk modelling approach used for migratory seabirds incorporates species-specific information relating to population estimates and migratory behaviour. A generic 'migratory front' is then defined which is then used to calculate the number of birds that have the potential to interact with Hornsea Three during spring and autumn migration.

B.3.1.2 In order to identify the interacting population for use in collision risk modelling the following stages are applied:

1. Define relevant seasonal BDMPS populations for each species considered;
2. Define a migratory front that incorporates the longest width of Hornsea Three across which migration will occur;
3. Calculate the proportion of the migratory front represented by Hornsea Three; and

4. Calculate interacting populations for each species in each migratory season.

B.3.1.3 The interacting populations are then incorporated into collision risk modelling to provide a collision risk estimate for each species.

B.3.1.4 Collision risk modelling has been undertaken using the Band (2012) Collision Risk Model (CRM) which, allows for consideration of birds on migration. As the modelling approach used for migratory seabird species uses population estimates, the update to the Band (2012) CRM presented by Masden (2015) cannot be used as this requires density information.

B.3.2 Calculation of interacting populations

B.3.2.1 In order to calculate the number of birds that may interact with Hornsea Three, a BDMPS must first be defined for each species which represents the population from which birds may exhibit connectivity with Hornsea Three. In most cases this population represents those birds that migrate through the North Sea and English Channel between breeding and wintering areas.

B.3.2.2 The proportion of this population that may interact with Hornsea Three is calculated based on the proportion of the migratory front represented by Hornsea Three. The migratory front represents a hypothetical line across which the whole BDMPS population will cross, incorporating the greatest width of Hornsea Three. It is assumed that birds are equally distributed across this front, however it should be noted that the migratory movements of some species may be biased towards inshore or offshore waters (Stienen *et al*., 2007).

B.3.2.3 The migratory front to be used to estimate the population of migratory seabirds passing through the Hornsea Three is assumed to extend from the UK coast to the edge of UK waters (Figure B.1). The populations of migratory seabird species considered to have potential to interact with Hornsea Three are calculated using the following formula:

*Interacting population = Width of development area / width of migration route * species population*

B.3.2.4 The length of this migratory front is 202.1 km with Hornsea Three representing 32.4 km. Hornsea Three therefore represents 16.0% of the total migratory front with this proportion applied to the BDMPS populations in Table B.1

Table B.1: Migratory seabird BDMPS populations and the proportion of these populations predicted to have potential to interact with Hornsea Three.

Species	Season	BDMPS population (Furness, 2015)	Migrant estimate of BDMPS population
Arctic skua	Autumn	6,427	1,031
	Spring	1,227	197
Great skua	Autumn	19,556	3,136
	Spring	8,485	1,361
Little gull	Autumn/Spring	75,000	12,026
Common tern	Autumn/Spring	144,911	23,236
Arctic tern	Autumn/Spring	163,930	26,286

B.3.3 Peak migratory movements

B.3.3.1 To populate a collision risk model, single months are selected to represent autumn movements and spring movements respectively. In the Band (2012) CRM these months are populated with the populations in Table B.1, while the months selected are presented in Table B.2 (as informed by the information detailed in Section B.2).

Table B.2: Months populated with potentially interacting populations for collision risk modelling.

Species	Post-breeding peak migratory month	Pre-breeding peak migratory month
Arctic skua	September	April
Great skua	September	April
Little gull	September	April
Common tern	August	April
Arctic tern	August	May

B.3.4 Collision risk modelling

B.3.4.1 To quantify collision risk, collision risk modelling has been undertaken using the Band (2012) CRM. Band (2012) uses information derived from population estimation, bird behaviour, biological parameters and project specific turbine information to calculate monthly collision risk values (see Section 1.2).

B.3.4.2 The wind farm and turbine parameters used for migratory seabird collision risk modelling are consistent with those used for regularly occurring seabirds (see Table 1.4).

B.3.4.3 The species-specific parameters used in the Band (2012) collision risk model for migratory seabirds are presented in Table B.3.

Table B.3: Species input parameters used in collision risk modelling.

Parameter	Source	Arctic skua	Great skua	Little gull	Common tern	Arctic tern
Bird length (m)	Robinson (2017)	0.44	0.56	0.26	0.33	0.34
Wingspan (m)	Robinson (2017)	1.18	1.36	0.78	0.88	0.8
Flight speed (m/s)	Pennycuick (1987) or Alerstam (2007)	13.8	14.9	11.5	10.9[6]	10.9
Nocturnal activity[7]	King *et al*., (2009)	1	1	2	1	1
Flight type (flapping/gliding)	N/A	Flapping	Flapping	Flapping	Flapping	Flapping

B.3.4.4 Site-specific aerial survey data is unsuitable to calculate PCH values for any species at Hornsea Three. In addition, boat-based survey data from the former Hornsea Zone does not provide an adequate number of records (i.e. more than 100) to allow for the calculation of a PCH value. Therefore generic flight height data from Johnston *et al*. (2014) has been used to inform Options 2 and 3 of the Band (2012) CRM.

B.3.5 Avoidance rates

B.3.5.1 No species-specific avoidance rates are available for the migratory seabird species considered (e.g. in Cook *et al*., 2014) and therefore results are presented at a variety of rates. However, Cook *et al.* (2014) did derive avoidance rates for use with the Basic Band model for small gull spp. and gull spp., two groups which include data relating to the avoidance behaviour of little gull. Avoidance rates of 99.2% and 98.9% were derived for the small gull spp. and gull spp. respectively. As such, avoidance rates of 98%, 98.9%, 99.2% and 99.5% will be used in the collision risk modelling for little gull, with a 99.2% avoidance rate considered to be the most relevant for assessment purposes. Therefore this avoidance rate is considered the most applicable to little gull for Option 2 only.

[6] No flight speed is available for common tern and therefore the flight speed for Arctic tern is used as a surrogate
[7] A 1-5 scale is used for nocturnal activity with 1 representing limited nocturnal activity and 5 large amounts of nocturnal activity

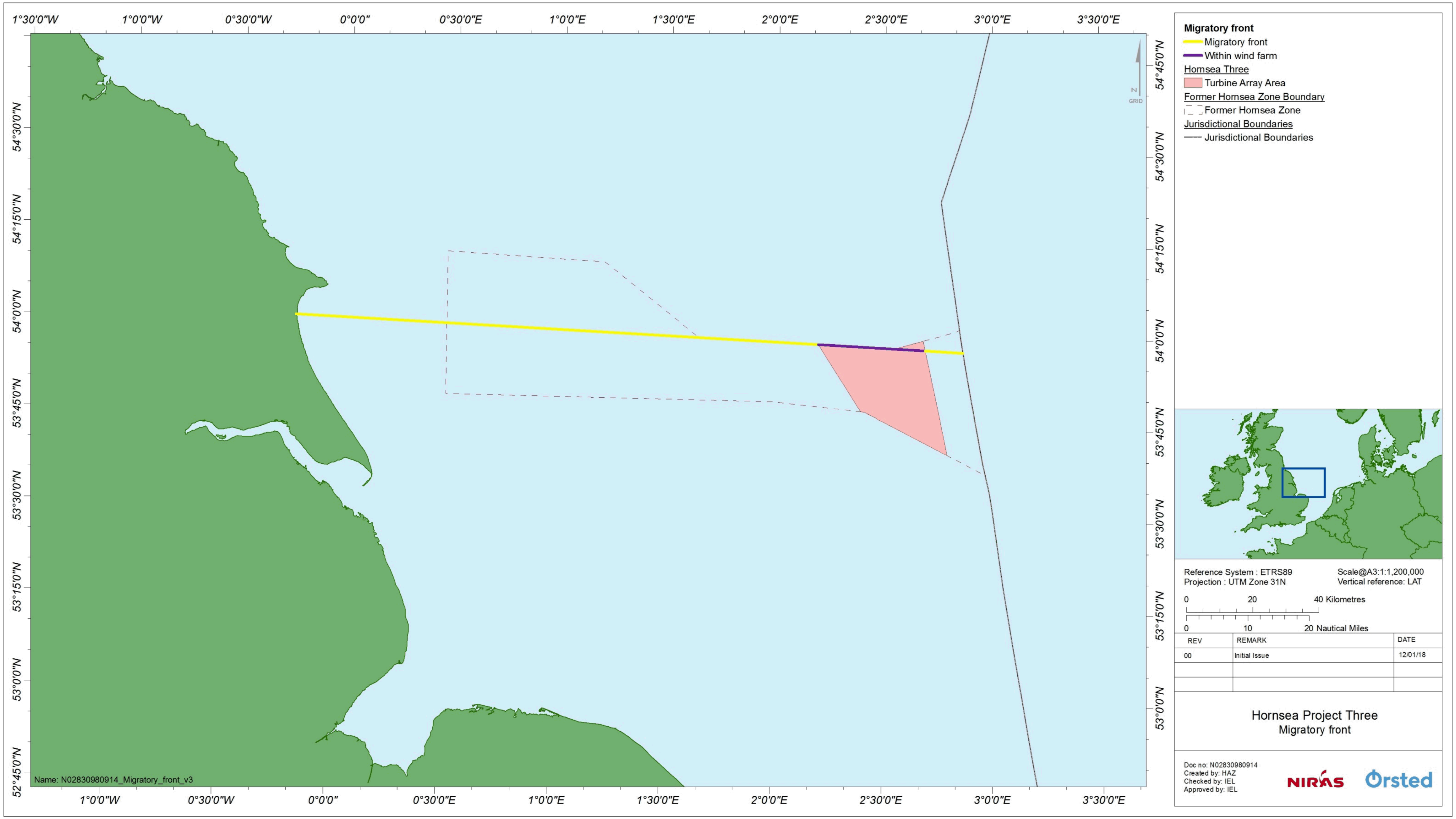

Figure B.1: Migratory front used to calculate populations of migratory seabirds interacting with Hornsea Three.

B.4 Results

B.4.1.1 Collision risk estimates calculated using Options 2 and 3 of the Band (2012) CRM are presented in Table B.4 and Table B.5 respectively.

Table B.4: Band (2012) Option 2 migratory seabird collision risk (collisions/annum).[8]

Species	Avoidance rate (%)				
	95	*98*	*99*	*99.2*	*99.5*
Arctic skua	0.01	**0.00**	0.00		0.00
Great skua	0.19	**0.08**	0.04		0.02
Little gull	3.09	1.24	0.62	**0.49**	0.31
Common tern	1.95	**0.78**	0.39		0.20
Arctic tern	0.76	**0.31**	0.15		0.08

Table B.5: Band (2012) Option 3 migratory seabird collision risk (collisions/annum).

Species	Avoidance rate (%)				
	95	*98*	*99*	*99.2*	*99.5*
Arctic skua	0.00	**0.00**	0.00		0.00
Great skua	0.03	**0.01**	0.01		0.00
Little gull	0.53	**0.21**	0.11	0.08	0.05
Common tern	0.29	**0.12**	0.06		0.03
Arctic tern	0.09	**0.04**	0.02		0.01

[8] Grey cells indicate not relevant to the species.

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Appendix C Migratory waterbirds

C.1 Introduction

C.1.1.1 Migratory birds move across offshore areas in large numbers predominantly over short temporal periods. These movements are poorly recorded by traditional boat-based or aerial surveys used to define the baseline environment for Environmental Impact Assessments of offshore wind farms. As such, this report uses a migratory collision risk modelling approach, as described by Wright *et al.* (2012) that is used to inform the assessment of collision risk at Hornsea Three for migratory waterbirds.

C.2 Species for consideration

C.2.1.1 For the purposes of collision risk modelling, a list of 12 species were selected. with this consistent with the suite of species incorporated into similar modelling undertaken for other offshore wind farms in the vicinity of Hornsea Three (i.e. Hornsea Project One and Hornsea Project Two). This list represents those species recorded during boat-based surveys at Hornsea Project One in addition to migrant species that may potentially cross the former Hornsea Zone with species ultimately selected through consultation with Natural England and JNCC based on a relatively high proportion of birds occurring within the SPAs close to the former Hornsea Zone. The following species were therefore incorporated into modelling:

- Bewick's swan (*Cygnus columbianus bewickii);*
- Taiga bean goose (*Anser fabalis fabalis*);
- Dark-bellied brent goose (*Branta bernicla bernicla*);
- Shelduck (*Tadorna tadorna*);
- Wigeon (*Anas penelope*);
- Golden plover *(Pluvialis apricaria*);
- Grey plover (*Pluvialis squatarola*);
- Lapwing (*Vanellus vanellus*);
- Knot (*Calidris canutus*);
- Dunlin (*Calidris alpina*);
- Black-tailed godwit (*Limosa limosa*); and
- Bar-tailed godwit (*Limosa lapponica*).

C.2.1.2 The species parameters used to populate the collision risk models for each species are shown in Table C.1 Bird length and wingspan have been sourced from Robinson (2017) with flight speed sourced from Alerstam *et al.* (2007) or Pennycuick *et al.* (2013). The flight type was set at 'flapping' for all species with the nocturnal activity factor, sourced from King *et al.* (2009), was set at 5 for all species.

C.2.1.3 As stated in Band (2012), the proportion of birds on migration at rotor height is likely to be different from the proportion of birds at PCH when not on migration for a number of species. Wright *et al.* (2012) makes recommendations for the values to use for the proportion of birds at rotor height. For swans, geese, ducks and waders Wright *et al*. (2012) recommends PCH values of 50%, 30%, 25 % and 15 %, respectively.

C.2.1.4 Parameters for the wind farm, including turbine parameters are consistent with those presented in Table 1.4.

Table C.1: Species parameters used for collision risk modelling.

Species	Bird length (m)	Wingspan (m)	Flight speed (m/s)	Nocturnal activity[9]	Flight type	PCH (%)
Bewick's swan	1.21	1.96	18.5	5	flapping	50
Taiga bean goose	0.75	1.58	17.3	5	flapping	30
Dark-bellied brent goose	0.58	1.15	17.7	5	flapping	30
Shelduck	0.62	1.12	15.4	5	flapping	15
Wigeon	0.48	0.8	20.6	5	flapping	15
Golden plover	0.28	0.72	17.9	5	flapping	25
Grey plover	0.28	0.77	17.9	5	flapping	25
Lapwing	0.3	0.84	12.8	5	flapping	25
Knot	0.24	0.59	20.1	5	flapping	25
Dunlin	0.18	0.4	15.3	5	flapping	25
Black-tailed godwit	0.42	0.76	14.4	5	flapping	25
Bar-tailed godwit	0.38	0.75	14.4	5	flapping	25

[9] A 1-5 scale is used for nocturnal activity with 1 representing limited nocturnal activity and 5 large amounts of nocturnal activity

C.3 Methodology

C.3.1 Overview

C.3.1.1 This modelling process uses guidance from the British Trust for Ornithology (BTO) (Wright and Austin, 2012), relating to the SOSS Migration Assessment Tool (MAT), which details a method in which the migration passages of migratory species can be calculated. This guidance (Wright and Austin, 2012) states that, as a general rule, the use of the MAT is not relevant for pelagic seabirds, such as gannet, or land-based seabirds that follow the coastline during migration. However, this approach was used, where appropriate, in the collision risk modelling process for other species.

C.3.2 Migration passages

C.3.2.1 The MAT utilizes 251,599 lines of connectivity which were constructed as line of sight sea crossings for migrants travelling across UK waters. These lines were then assigned on a species-specific basis based on the migration routes presented in Wright *et al.* (2012).

C.3.2.2 Provided with the guidance is a GIS shapefile which is used to determine those lines of connectivity which interact with a wind farm site. A dataset which details those lines which interact with the wind farm site can then be extracted from GIS and imported into the MAT. For Hornsea Three this dataset contained 15,217 lines of connectivity.

C.3.2.3 The next stage in the process is to decide which sea crossings are pertinent to the wind farm being assessed. The following sea crossings were selected for Hornsea Three based on the descriptions given in Wright and Austin (2012):

- Central Europe North Sea coast to England North Sea coast;
- Central Europe North Sea coast to Norway;
- Central Europe North Sea coast to Orkney;
- Central Europe North Sea coast to Scottish mainland North Sea coast;
- Central Europe North Sea coast to Shetland;
- Denmark to England North Sea coast;
- England North Sea coast to Orkney;
- England North Sea coast to Scottish mainland North Sea coast;
- England North Sea coast to Shetland; and
- Norway to England North Sea coast.

C.3.2.4 The final stage of the MAT requires two parameters relating to the population estimated to interact with Hornsea Three. The first parameter is the population size of the considered species that occurs in UK waters. These values were obtained from Wright *et al.* (2012). The second parameter is a population correction factor which estimates the percentage of the GB population that interacts with the Hornsea Three array area. The population of each species predicted to interact with the footprint of the wind farm was estimated using the maps presented in Wright *et al.* (2012). All of these data are presented in Table C.2. Two months during each generic migration period (spring and autumn) were populated (April and September) with the number of movements across the Hornsea Three footprint.

Table C.2: The population size, population corrections factors and movements across the Hornsea Three footprint for species included for collision risk modelling.

Species	Population size	Population correction factor	Number crossing Hornsea Three footprint
Bewick's swan	7,000	100	2,709
Taiga bean goose	730	50	79
Dark-bellied brent goose	91,000	80	30,852
Shelduck	61,000	40	4,442
Wigeon	440,000	40	31,186
Golden plover	400,000	40	38,072
Grey plover	43,000	40	3,098
Lapwing	620,000	40	44,662
Knot	32,000	40	2,283
Dunlin	350,000	50	45,370
Black-tailed godwit	43,000	40	4,167
Bar-tailed godwit	38,000	40	2,916

C.3.3 Collision risk modelling

C.3.3.1 The width of the migration corridor, required for the migratory stage of the CRM, was calculated using ArcGIS. The migration corridor was taken as the longest width of Hornsea Three across which a species migratory route would cross. For birds migrating north to south, a migration corridor of 32.4 km was used with a migration corridor of 36 km used for birds migrating east to west (Figure C.1). The proportion of flights upwind for migratory species was assumed to be 50% for all species.

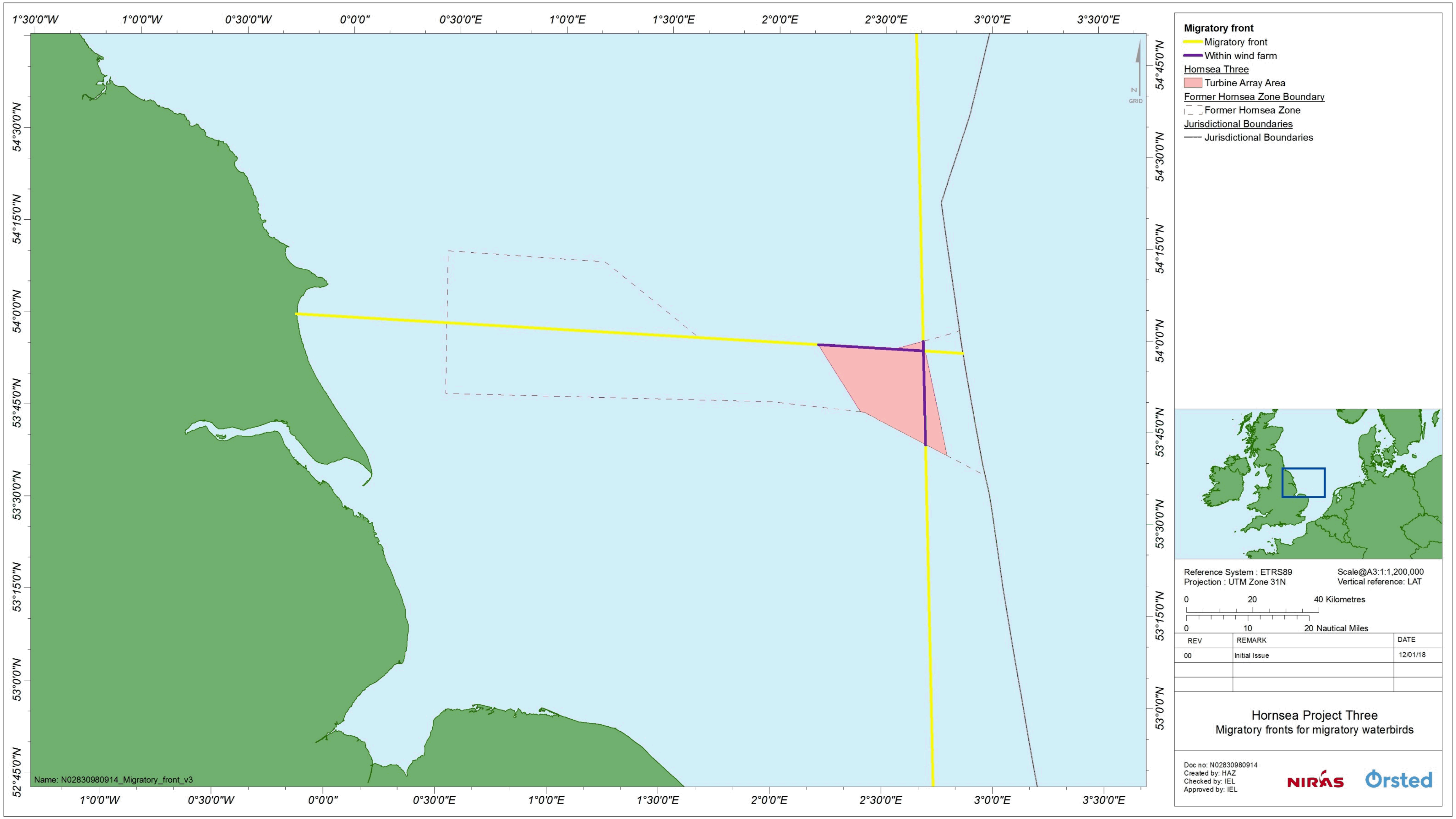

Figure C.1: Migratory fronts used for migratory waterbirds interacting with Hornsea Three.

C.3.3.2 The Band (2012) CRM includes two models (basic and extended) which both incorporate two 'Options'. Generic flight height distributions, used for Options 2 and 3 of Band (2012) are unavailable for the species considered in this Appendix and therefore it is not possible to use these model options. Therefore Option 1 is used incorporating the PCH values from Wright *et al.* (2012). Collision risk estimates are calculated using a default avoidance rate of 98%, as recommended by SNH guidance (SNH, 2010), applied for all species.

C.4 Results

C.4.1.1 Table C.3 presents collision risk estimates for all waterfowl species included in the modelling process.

Table C.3: Seasonal and annual collision risk estimates for migratory waterbirds at a 98% avoidance rate.

Species	Spring	Autumn	Total
Bewick's swan	2.12	2.12	4.24
Taiga bean goose	0.03	0.03	0.06
Dark-bellied brent goose	11.42	11.46	22.89
Shelduck	0.86	0.86	1.72
Wigeon	5.28	5.30	10.58
Golden plover	11.27	11.31	22.58
Grey plover	0.83	0.83	1.66
Lapwing	12.66	12.71	25.37
Knot	0.65	0.65	1.30
Dunlin	11.39	11.43	22.82
Black-tailed godwit	1.36	1.36	2.72
Bar-tailed godwit	0.84	0.84	1.68

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Appendix D Nocturnal activity factors – sensitivity analysis

D.1 Introduction

D.1.1.1 The Band (2012) CRM requires the incorporation of a nocturnal activity parameter which describes the amount of flight activity at night in relation to the amount of flight activity in the day. In the absence of available empirical data, Band (2012) suggests that the nocturnal activity factors presented in Garthe and Hüppop (2004) and King *et al*. (2009) be used to populate the CRM and so translating the rankings presented (1-5) into activity factors of 0, 25, 50, 75 and 100%. Although the nocturnal activity factors presented by Garthe and Hüppop (2004) were not intended to represent quantifiable rankings, collision risk modelling undertaken as part of the applications for multiple offshore wind farms has applied the Band (2012) recommendation.

D.1.1.2 The suitability of translating the rankings presented in Garthe and Hüppop (2004) to nocturnal activity factors for use in Band (2012) was recently reviewed as part of the application for the East Anglia Three offshore wind farm (MacArthur Green, 2015). This review concluded that the nocturnal activity factors derived from the rankings presented in Garthe and Hüppop (2004) for gannet and kittiwake suggest a minimum of a 7% reduction in all collision risk estimates. In addition, Scottish Natural Heritage and Marine Scotland, in their advice to projects in Scottish waters (Inch Cape, Neart na Gaoithe, Seagreen and Moray East), have advised the use of nocturnal activity factors consistent with those derived by MacArthur Green (2015) (i.e. 1 for gannet and 2 for kittiwake).

D.1.1.3 The purpose of this Appendix is to review the use of nocturnal activity factors that have previously been applied for collision risk modelling (Garthe and Hüppop (2004) for those species included in collision risk modelling for Hornsea Three and, if possible, to identify nocturnal activity factors that better reflect the behaviour of seabirds at night, building on the review conducted by MacArthur Green (2015). Consideration is also given to the effect of using nocturnal activity factors derived from empirical evidence at projects considered in-combination/cumulatively.

D.2 Background

D.2.1.1 Literature relating to the nocturnal activity of gannet, kittiwake, lesser black-backed gull and great black-backed gull has been reviewed with key studies summarised in Table D.1. Due to differences in the number of daylight and night-time hours throughout the year, the magnitude of reduction in collision risk estimates is dependent on the time of year when birds are present with a reduction in nocturnal activity having a larger effect during non-breeding season months when there are more night-time hours. This has been taken into account in the literature review undertaken in the following sections with attempts made to identify studies undertaken at different times of the annual cycle.

D.2.2 Gannet

D.2.2.1 The earliest study included in Table D.1, Garthe *et al.* (1999) involved the foraging trips of three birds from a colony in Shetland. The study was conducted in the breeding season (July) and recorded very limited flight activity at night, with none between 22:35 and 02:15. Comparable results were also obtained by Hamer *et al.* (2000, 2001, 2007), Lewis *et al.* (2002) and Garthe *et al.* (2003). Further evidence is provided by Warwick-Evans *et al.* (2015) which recorded the foraging behaviour of gannets breeding at Les Etacs, Alderney. Foraging behaviours exhibited by gannets include plunge-diving where a bird dives from height into the sea to capture prey with this behaviour generally used to determine when and where birds may be foraging. No plunge-diving was recorded by Warwick-Evans *et al.* (2015) throughout the night but did re-commence as early as 03:00. However, although the sun may not have risen at this time light is still available to aid visual foraging such as plunge-diving.

D.2.2.2 Information on the nocturnal flight activity of gannets outside of the breeding season was obtained by Garthe *et al.* (2012) which tracked birds during migration and winter. A total of 34 birds were tracked with negligible nocturnal flight activity recorded when compared to daylight flight activity levels.

D.2.2.3 In addition to the studies included in Table D.1, a number of studies have recorded very little foraging behaviour by gannets during hours of darkness (e.g. Garthe *et al.,* 2000; Lewis *et al.,* 2004; Hamer *et al.,* 2009) however, these studies do not present information relating to the total proportion of time birds spend in flight including foraging and commuting behaviour and as such it is not possible to determine a nocturnal activity factor suitable for use in CRM.

D.2.2.4 There is a significant amount of evidence (as discussed above) to suggest that the current nocturnal activity factor applied for gannet (2) will over-estimate collision risk. Therefore it is concluded that a nocturnal activity factor of 1 should be used for CRM.

Table D.1: Review of studies for which information on nocturnal activity is available for gannet, kittiwake and lesser black-backed gull

Species	Reference	Sample size	Season	Nocturnal activity	Daylight activity	Empirically derived nocturnal activity factor
Gannet	Garthe *et al.* (1999)	Several foraging trips by three birds	Breeding (chick-rearing)	No flight activity between 23:00 and 3:00	Approximately 35% in flight between sunrise and sunset	1
	Hamer *et al.* (2000); Hamer *et al.* (2001)	22 birds	Breeding (chick-rearing)	0%	Roughly 50%	1
	Lewis *et al.* (2002)	29 foraging trips of 20 birds	Breeding (chick-rearing)	No flight activity at night	-	1
	Garthe *et al.* (2003)	25 foraging trips of 16 birds	Breeding (chick-rearing)	0%	44% in flight	1
	Hamer *et al.* (2007)	53 birds (48 birds used for analyses)	Breeding (chick-rearing)	0% (presents conclusion from Hamer *et al.* (2000)	Approximately 50%	1
	Garthe *et al.* (2012)	34 birds	Migration	Very little (approximately less than 2%)	27-50% (North Sea)	1
	Garthe *et al.* (2012)	34 birds	Winter	Very little	Max = 35.2% (North Sea) Min = 9.6% (North Sea and Bay of Biscay)	1
Kittiwake	Daunt *et al.* (2002)	9 birds	Breeding (chick-rearing)	Approximately 7%, no foraging flight between 23:00 and 02:00 and no travelling flight between 00:00 and 01:00	Approximately 33% (maximum 60%, minimum 15%)	2
	Kotzerka *et al.* (2010); Kotzerka *et al.* (2011)	9 birds	Breeding (chick-rearing)	Birds mostly inactive – potential foraging trips by two birds	35%	1-2
	Gonzalez-Sallis *et al.* (2011)	6 birds	Post-breeding migration	Proportion of time spent not resting at night = 16.6%	36.3%	3
	Gonzalez-Sallis *et al.* (2011)	6 birds	Non-breeding (Labrador Sea)	Proportion of time spent not resting at night =8.0%	29.5%	2-3
	Gonzalez-Sallis *et al.* (2011)	3 birds	Non-breeding (NE Atlantic)	Proportion of time spent not resting at night = 5.9%	36.0%	2
	Gonzalez-Sallis *et al.* (2011)	3 birds	Pre-breeding migration	Proportion of time spent not resting at night = 11.1%	41.9%	2-3
	Orben *et al.* (2015)	34 birds	Non-breeding	<5%	40%[10]	2
Lesser black-backed gull	Klaassen *et al.* (2012)	14 birds	Non-breeding	Activity at night represented approximately 25% of daylight activity		2

[10] As reported by MacArthur Green (2015)

D.2.3 Kittiwake

D.2.3.1 Table D.1 presents information from a number of studies that have recorded nocturnal behaviour of kittiwakes. The absence of kittiwakes from their nest at night was considered by Hamer *et al.* (1993) to suggest that birds were roosting offshore and displaying no flight activity. Daunt *et al.* (2002) represents the most detailed study relating to the nocturnal behaviour of kittiwake. This study recorded very little flight activity (approximately 7%) between 23:00 and 03:00 by nine tagged birds breeding on the Isle of May, Scotland compared to an average 33% (range of 15-60%) of time spent in flight during the day. A similar conclusion was obtained by Kotzerka *et al.* (2010; 2011). Birds were mostly inactive at night however, three of the trips recorded by Kotzerka *et al.* (2010; 2011) were classified as overnight trips. These trips did not occur solely at night with GPS fixes showing that the two birds were resting on the sea surface at night.

D.2.3.2 Gonzalez-Sallis *et al.* (2011) provides information in relation to the nocturnal flight activity of kittiwake outside of the breeding season. Geolocators were fitted to birds from a breeding colony in north Norway (Hornøya) between May 2008 and May 2009. The study provides information on the proportion of time birds were recorded resting on the sea surface during different periods of the non-breeding season. In order to calculate the percentage values presented in Table D.1 it has been assumed that the inverse of the percentages presented by Gonzalez-Sallis *et al.* (2011) represent flight activity, however, this may over-estimate actual flight activity with swimming activity also likely to have occurred and not included in the percentage of time resting. Despite this over-estimate, the data collected throughout the post-breeding, non-breeding and pre-breeding periods indicate low levels of nocturnal flight activity by kittiwakes. However, this activity is associated with birds feeding on prey species that occur in deeper waters and therefore may not be directly applicable to the North Sea. Similar conclusions were also obtained by Orben *et al.* (2015), with flight behaviours during the non-breeding season representing less than 5% of nocturnal activity compared to 40% during daylight hours.

D.2.3.3 Collins *et al*. (2016) obtained data from 21 accelerometers fitted to kittiwakes on Puffin Island, Wales. Birds undertaking over-night foraging trips exhibited significantly less flight behaviour than birds undertaking foraging trips that were completed on the same day (72% time in flight compared to 31%). The percentages presented suggest that a nocturnal activity of 3 would therefore be appropriate for kittiwake however, overnight foraging trips do not necessarily occur only in night time hours and are likely to have commenced during daylight. Therefore the percentages presented are an overestimate of the flight activity that occurs at night only.

D.2.3.4 The studies presented in Table D.1 and discussed here indicate that the nocturnal activity factor derived from Garthe and Hüppop (2004) will over-estimate the collision risk for kittiwake. Therefore it is concluded that a nocturnal activity factor of 2 should be used for CRM.

D.2.4 Large gulls

D.2.4.1 Large gulls (lesser black-backed gull, herring gull and great black-backed gull) are known to be active at night having been observed scavenging at fishing boats (Garthe and Hüppop, 1996). Garthe and Hüppop noted that on average the number of ship-following herring and great black-backed gulls was 18% and 51% lower at night than during the day respectively. However, it would not be suitable to apply these percentages as nocturnal activity factors within collision risk modelling as the presence of an attracting influence (i.e. a fishing boat) does not represent the general conditions to be found at an offshore wind farm.

D.2.4.2 Klaasen *et al.* (2012) obtained tracking data during the non-breeding season for 14 lesser black-backed gulls from a breeding colony in the Netherlands. From the figures presented it can be inferred that the nocturnal activity of these birds was on average equivalent to approximately 25% of daylight activity across the entire non-breeding season.

D.2.4.3 Corman and Garthe (2014) recorded the flight heights of eight lesser black-backed gulls from a breeding colony in Germany. The number of GPS fixes during the day was higher than at night, however, the temporal extents of day and night are not equal and it is not known how long each bird remained in flight meaning a simple comparison is not possible. Tracking of lesser black-backed gulls has also been undertaken at two breeding colonies as part of a project conducted by the British Trust for Ornithology (BTO) (Thaxter *et al.,* 2015; Scragg *et al.,* 2016). These studies show that lesser black-backed gulls are active at night but it is not possible to identify the level of nocturnal activity in relation to daytime activity. However, Scragg *et al.* (2016) does show that birds were less wide-ranging at night, with spatial usage much lower. This potentially suggests lower nocturnal activity however, as with the results presented in Corman and Garthe (2014) it is not clear how active birds were (i.e. were they flying constantly or spending prolonged periods on the sea surface?).

D.2.4.4 Evidence relating to the nocturnal activity of large gulls is limited when compared to the amount of information for gannet and kittiwake. Only one study, relating to lesser black-backed gull, presents information that can be used to infer nocturnal activity levels and this suggests that the use of a nocturnal activity factor representing 25-50% of daylight activity is an over-estimate. There is however, not considered to be enough information available to support a change in the nocturnal activity factor used for CRM.

D.2.5 Conclusion

D.2.5.1 Table D.2 summarises the changes to the nocturnal activity factors for each species proposed in the sections above. Following the conclusions of this review the nocturnal activity factors proposed in Table D.2 have been incorporated into the collision risk modelling for Hornsea Three.

Table D.2: Proposed changes to nocturnal activity factors for gannet, kittiwake, lesser black-backed gull and great black-backed gull

Species	Nocturnal activity factor (based on Garthe and Hüppop, 2004)	Empirically derived nocturnal activity factor
Gannet	2	1
Kittiwake	3	2
Lesser black-backed gull	3	-
Great black-backed gull	3	-

D.3 Sensitivity of cumulative/in-combination projects to changes in nocturnal activity factors

Overview

D.3.1.1 In order to investigate the potential effect a change in nocturnal activity factor would have on in-combination and cumulative collision risk estimates a sensitivity analysis has been formulated. The approach uses four generic offshore wind farms that are located in the following geographic areas in the North Sea:

- East Anglia and English Channel (latitude = 51.64 degrees);
- Southern North Sea (latitude = 53.87 degrees);
- Firth of Forth (latitude = 56.18 degrees); and
- Moray Firth (latitude = 57.99 degrees).

D.3.1.2 These areas correspond with the main development areas for offshore wind farms in the North Sea.

Collision risk modelling parameters

D.3.1.3 In order to conduct collision risk modelling a number of assumptions are necessary to facilitate the calculation of collision risk estimates. Throughout all modelling the bird, wind farm and turbine parameters used were consistent with those used at Hornsea Three (Table 1.3, Table 1.4 and Table 1.5), with the exception of latitude which was changed to reflect the geographic area in which each generic wind farm was located and bird density which was assumed to be constant in all geographic areas in all months. It is not necessary to use project-specific parameters for this sensitivity analysis as the aim of this analysis is to demonstrate the change that would occur if the nocturnal activity factors presented in Table D.2 were used with the use of identical project parameters providing a consistent comparison across all geographic areas.

D.3.1.4 Two nocturnal activity scenarios have been used that correspond with the changes to the factors used for gannet and kittiwake (Table D.2). The 'gannet' scenario involves changing the nocturnal activity factor from 2 to 1 with the 'kittiwake' scenario changing the nocturnal activity factor from 3 to 2.

Results

D.3.1.5 Figure 1.2 and Figure 1.3 show the effect of changing the nocturnal activity factor on monthly collision estimates for gannet and kittiwake respectively in the four defined geographic regions. Table D.3 shows the minimum and maximum monthly changes that occur alongside the overall change in collision risk estimates for each of the four geographic areas.

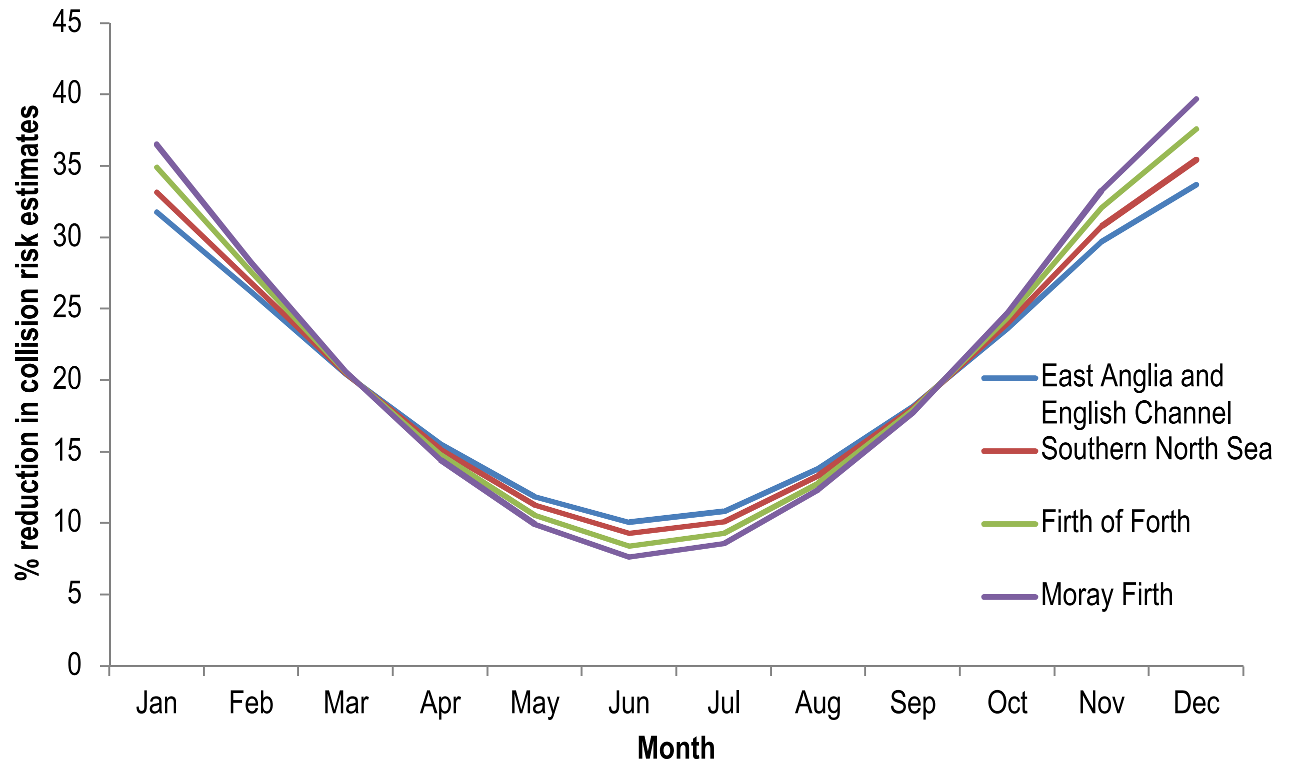
Table D.3: Reductions in collision risk modelling in four geographic areas as a result of changes to the nocturnal activity factor used in CRM

Geographic area	Minimum (%)	Maximum (%)	Overall (%)
Gannet scenario			
East Anglia and English Channel	10.1	33.7	19.4
Southern North Sea	9.3	35.4	19.3
Firth of Forth	8.4	37.6	19.3
Moray Firth	7.6	39.7	19.2
Kittiwake scenario			
East Anglia and English Channel	9.2	25.2	16.2
Southern North Sea	8.5	26.2	16.2
Firth of Forth	7.8	27.3	16.2
Moray Firth	7.1	28.4	16.1

D.3.1.6 Reductions in the number of collisions occur in all months using both scenarios. These reductions occur due to the reduction in the proportion of time during which birds are at risk of collision. For the gannet scenario, birds were originally assumed to exhibit a nocturnal flight activity equivalent to 25% of daylight flight activity compared to no nocturnal flight activity whereas for the kittiwake scenario, birds were originally assumed to exhibit a nocturnal flight activity equivalent to 50% of daylight flight activity compared to an updated nocturnal flight activity equivalent to 25% of daylight flight activity. Identical changes would occur using both scenarios regardless of the species modelled as changes to the nocturnal flight activity have no influence on species-specific parameters within the Band (2012) CRM.

D.3.1.7 The effect of changing the nocturnal activity from 2 to 1 has a larger effect on resulting collision risk estimates than when reducing the nocturnal activity factor from 3 to 2. This effect is more pronounced in winter months and is due to the monthly variation in the number of night-time hours when these are added to the number of daylight hours which remains constant in both scenarios.

D.3.1.8 The largest reductions in collision risk estimates using both scenarios occur in winter months across all latitudes with this linked to the relative durations of day and night. In winter months, the largest changes in both scenarios occur in the Moray Firth. This is due to there being more night-time hours at this latitude meaning a reduction in the nocturnal flight activity of a species in this season has a greater effect than at more southerly latitudes. In summer months the opposite is true with larger changes occurring in the English Channel due to there being more night-time hours.



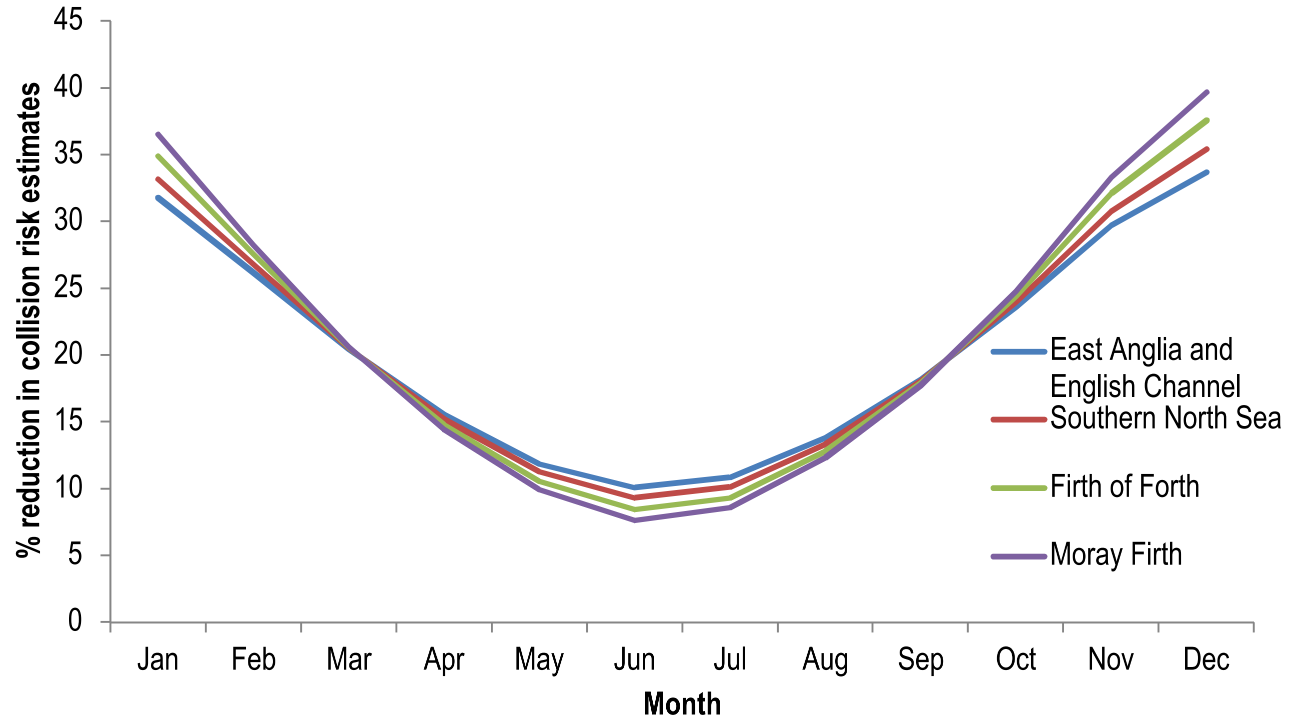


Figure 1.2: Reductions in collision risk estimates in each geographic region using the 'gannet' scenario – nocturnal activity factor changed from 2 (25%) to 1 (0%)

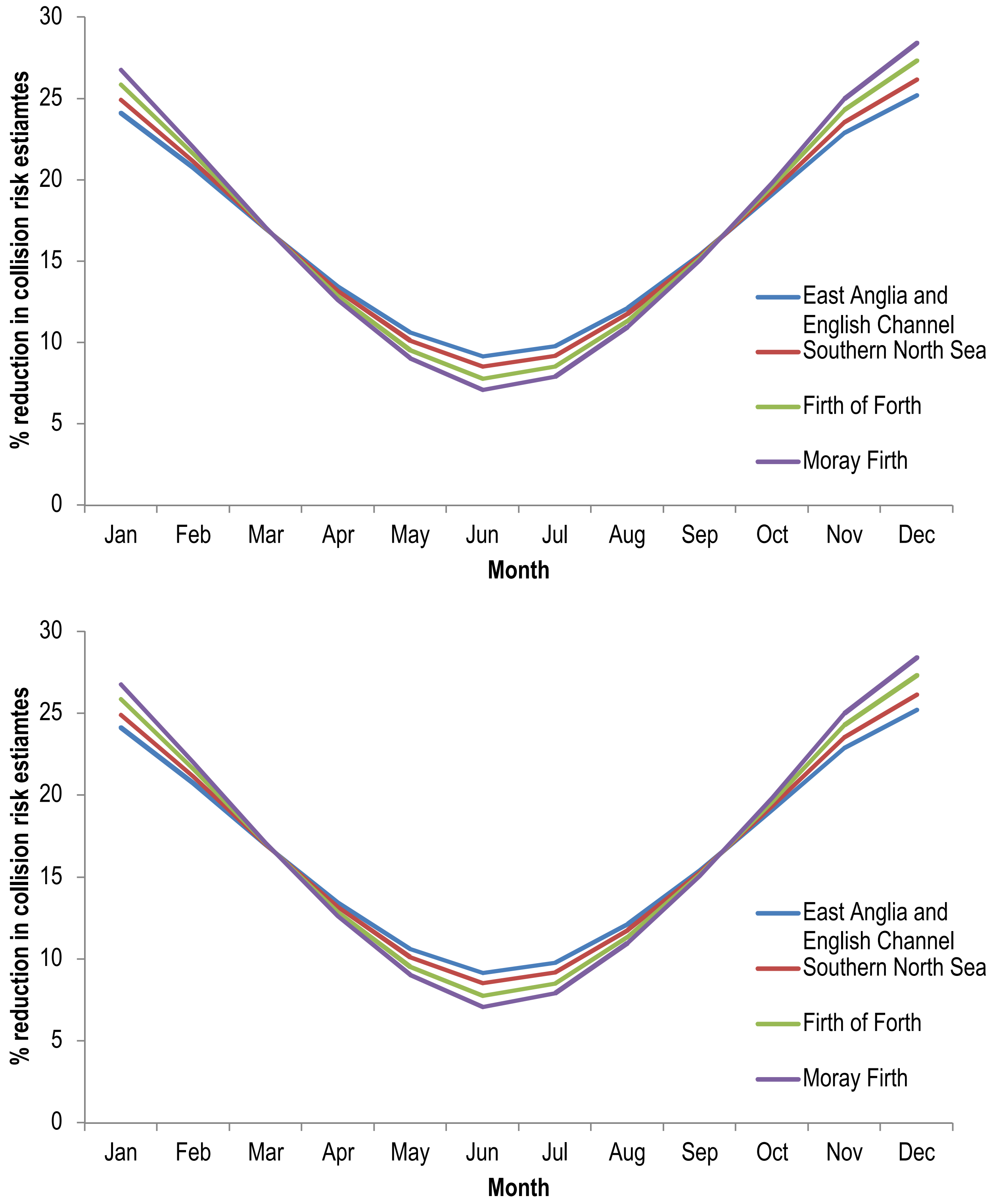


Figure 1.3: Reductions in collision risk estimates in each geographic region using the 'kittiwake' scenario – nocturnal activity factor changed from 3 (50%) to 2 (25%)

D.4 Implications for assessment

D.4.1 Nocturnal activity factors

D.4.1.1 The studies reviewed in this Appendix provide considerable evidence to support a change in the nocturnal activity factors used for gannet and kittiwake in collision risk modelling at Hornsea Three. By using these factors collision risk estimates for the two species decrease by approximately 20% and 15%, respectively. Up until now the nocturnal activity factors previously used for collision risk modelling were based on information presented in Garthe and Hüppop (2004). The nocturnal activity rankings presented by Garthe and Hüppop (2004) were not intended to be quantifiable and were not based on empirical data. Based on the information presented in the preceding sections the use of nocturnal activity factors derived from empirical evidence for gannet and kittiwake is therefore considered to provide increased confidence and reduce the uncertainty associated with the collision risk estimates obtained through CRM.

D.4.1.2 There is considered to be insufficient evidence to support a change in the nocturnal activity factors applied for lesser black-backed gull and great black-backed gull in CRM for Hornsea Three.

D.4.2 In-combination/cumulative collision risk impacts

D.4.2.1 It is proposed that the changes to the nocturnal activity factors presented in Table D.2 and applied in collision risk modelling for Hornsea Three also be applied to the collision risk estimates used for projects considered in-combination/cumulatively.

D.4.2.2 In order to apply the changes in nocturnal activity factors presented in Table D.2, it is necessary to have monthly collision risk estimates for projects considered in-combination/cumulatively. For many projects collision risk estimates at this temporal resolution are unavailable and therefore a precautionary approach has been adopted. Each project included in the in-combination and cumulative assessments for Hornsea Three has been assigned to one of the four geographic regions used in Section D.3 (Table D.4). As monthly collision risk estimates are not available for all projects the lowest monthly reduction has been applied for all projects in each of the four geographic regions (Table D.4). This information will be discussed in Chapter 5: Offshore Ornithology on a qualitative basis.

Table D.4: Reductions to apply to collision risk estimates for projects in each geographic region

Geographic region	Projects within region	% reduction in collision risk estimates
East Anglia and English Channel	East Anglia One East Anglia Three Galloper Greater Gabbard Kentish Flats Extension London Array Thanet	Gannet = 10.1% Kittiwake = 9.2%
Southern North Sea	Dogger Bank Creyke Beck A & B Dogger Bank Teesside A & B Dudgeon Hornsea Project One Hornsea Project Two Humber Gateway Lincs Race Bank Sheringham Shoal Teesside Triton Knoll Westermost Rough	Gannet = 9.3% Kittiwake = 8.5%
Firth of Forth	Aberdeen (EOWDC) Inch Cape Kincardine Methil Neart na Gaoithe Seagreen Alpha Seagreen Bravo	Gannet = 8.4% Kittiwake = 7.8%
Moray Firth	Beatrice Hywind Moray East	Gannet = 7.6% Kittiwake = 7.1%

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