Hornsea Project Four

Ornithological Assessment Sensitivity Report

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Prepared APEM Ltd, May 2022
Checked Faye Mc Ginn, Orsted, May 2022
Accepted Hannah Towner-Roethe, Orsted, May 2022
Approved Julian Carolan, Orsted, May 2022

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01	06/05/2022	Matthew Boa, APEM Ltd	Sean Sweeney, APEM Ltd	Julian Carolan, Orsted

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Glossary

Term	Definition
Bio-season	Bird behaviour and abundance is recognised to differ across a calendar year, with particular months recognised as being part of different seasons. The biologically defined minimum population scales (BDMPS) bio-seasons used in this report are based on those in Furness (2015), hereafter referred to as bio-seasons.
Confidence intervals	Range of values that with a specified certainty contains the true mean of the population that a sample was taken from. For example, 95% confidence intervals states a range of values with a 95% certainty those values contain the population mean.
Design-based Abundance Estimates	An estimated total abundance of identified targets (in the case of this report gannets) within a given area ("design- based" because the approach relies on the survey design providing representative sampling and assuming transects can be considered independent samples from a uniform distribution) based on the raw observations recorded within a survey.
Displacement	The potential for birds and other animals to avoid an area due to the presence of the wind turbines or from vessel activity.
Macro Avoidance	Avoidance response prior to entry of the OWF array area.
Meso Avoidance	Avoidance response within the OWF array area.
Micro Avoidance	avoidance response within 10 m of the rotor swept zone of individual wind turbine generators.
MRSea	Statistical package to model spatial count data and predict spatial abundances; developed by the Centre for Research into Ecological and Environmental Modelling (CREEM) specifically for dealing with data collected for offshore wind farm projects.

Acronyms

Term	Definition
BDMPS	Biologically Defined Minimum Population Scale
BEIS	Business, Energy and Industrial Strategy
BTO	British trust for Ornithology
CFPS	Counterfactual of Final Population Size
CPGR	Counterfactual of Population Growth Rate
CRM	Collision Risk Modelling
DCO	Development Consent Order
EIA	Environmental Impact Assessment
EP	Evidence Plan
ExA	Examining Authority
FAME	Future of the Atlantic Marine Environment project
HRA	Habitats Regulations Assessment
JNCC	Joint Nature Conservation Committee
ORJIP	Offshore Renewables Joint Industry Programme
OWF	Offshore Wind Farm
RSPB	Royal Society for the Protection of Birds
sCRM	Stochastic Collision Risk Modelling
SD	Standard Deviation
SofS	Secretary of State
WTG	Wind Turbine Generator

1 Introduction

1.1.1.1 In the Applicant's comments on Relevant Representations submitted at Deadline 1 (**REP1-038**) and in summary of Natural England's Relevant Representation (**RR-029**), the Applicant committed to submit an Assessment Sensitivity Report presenting the Applicant and SNCB position on ornithology assessment parameters.

1.1.1.2 The objective of this report is to provide the Examining Authority (ExA) and Secretary of State (SoS) for Business, Energy and Industrial Strategy (BEIS) the relevant information pertaining to the Applicant and SNCB position in relation to all assessment parameters for ornithology.

1.2 Background

1.2.1.1 A continued theme in relation to the assessment of potential impacts on seabirds from offshore wind farm (OWF) projects is the issue of balancing the inclusion of precaution in assessments and addressing of uncertainty, whilst trying to present a realistic and scientifically robust assessment incorporating the most up to date and accurate evidence-led approaches. Due to the sheer complexity of offshore ornithology assessments, which include multiple different input parameters, variability and uncertainty are inherent within the assessments and treatment of such needs to be carefully considered to minimise under and over precaution, particularly when considering cumulative and in-combination assessments.

1.2.1.2 The treatment of such uncertainty and variability within assessments often leads to differing of preferred assessment approaches between Applicants and Statutory Nature Conservation Bodies (SNCBs), with SNCBs requesting a precautionary approach be taken for each respective parameter within the assessment. The issue with this approach, however, is the accumulation of precaution for each individual component of the assessment process can lead to a wholly unrealistic and significantly over inflated impact value for project level assessments and result in overly precautionary conclusions being drawn. This is then further exacerbated when project alone assessments are added together within cumulative or in-combination assessments with other consented and planned projects.

1.2.1.3 The primary aim of this report is to identify the multiple components of different offshore ornithology impact assessments where sources of uncertainty and / or variability exist and the scale to which these affect the overall assessment. This is being undertaken to provide the ExA and SoS with confidence that the Applicant's approach to offshore ornithology impact assessments can be considered suitably precautionary and presents a realistic scenario. It is also hoped that this process demonstrating the inherent issues with cumulative and in-combination assessments for OWFs that currently inflate potential impact values as a consequence of precaution being added in at multiple stages and duplicated across different projects that are amassed.

1.2.1.4 This report will also provide an update to the assessments presented within **Volume A2 Chapter 5 Offshore and Intertidal Ornithology** (**APP-017**) and **2.2: Report to Inform**

Appropriate Assessment (APP-167 & APP-178), due to the emergence of further new evidence or guidance since Hornsea Four's DCO Submission.

1.2.1.5 This report is in two parts:

- **Part1:** Literature review summarising where the Applicant has identified uncertainty and / or variability in assessment parameters, including contextualising all uncertainty identified.
- **Part2:** Presentation of how the uncertainty and / or variability in each of the assessment parameters effects the overall impact assessment process and the Applicant's recommendation of how best for this to be treated to ensure a suitably precautionary assessment.

2 Part 1: Identification of sources of uncertainty/ variability and updates to Assessments

2.1 BDMPS Breeding Bio-season Population Estimates

2.1.1.1 The Applicant consulted with Natural England on the most appropriate method for calculation of the breeding Biologically Defined Minimum Population Scale (BDMPS) bio-seasons for all species scoped in for assessment ((agreement OFF-ORN-2.1– as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (B1.1.1: Evidence Plan (APP-130)). Details of the approach taken is presented in Section 5.7 of Volume A2 Chapter 5 Offshore and Intertidal Ornithology (APP-017). During the final consultation meeting (EP#15) prior to the Hornsea Four DCO Application, Natural England proposed a different calculation method for BDMPS breeding bio-seasons. This revised method is reiterated in Natural England's Relevant Representations (RR-029; RR-029-APDX:B-3). The Applicant sought clarification regarding this matter, to which Natural England provided a clarification note on 22ND March 2022 (included within Appendix A) ahead of their originally proposed Deadline 2 submission.

2.1.1.2 The Applicant welcomes the note and explanation as to how Natural England derived breeding season population estimates for use in estimating the annual impacts at the BDMPS scale. Utilising these revised breeding season BDMPS values to assess the annual total impacts from Hornsea Four alone and cumulatively with other plans and projects would lead to a reduced overall effect for guillemot and puffin, which would mean the current effect levels are precautionary.

2.1.1.3 In both cases, the breeding BDMPS bio-season value calculated following Natural England's method is higher than that which the Applicant used. For guillemot, Natural England generated a population of 2,045,078, whilst the Applicant used 936,876. For puffin, Natural England generated a population of 868,689, whilst the Applicant used 260,726.

2.1.1.4 The Applicant does note, however, that when considering annual impacts, birds from both the UK and overseas should be accounted for. In order to fulfil this the Applicant suggests that, as well as the revised breeding population from UK colonies that reside within the species-specific BDMPS area, additional bird populations from outside the UK should also be accounted for in order to reflect the spread of potential impacts across the entire population of birds residing within the BDMPS area across the different bio-seasons. The Applicant has provided in Table 1 a revised annual impact value using Natural England's new breeding

BDMPS value plus the additional overseas populations expected based on the value presented in Appendix A of Furness (2015) for the overseas total for each species. For some species the non-breeding BDMPS population in Furness (2015) might be higher than the revised annual population calculated in **Table 1**. In these instances, the Applicant would recommend keeping the annual assessments against the largest non-breeding BDMPS population total over the revised annual total.

2.1.1.5 Breeding season BDMPS values following the Applicant's DCO Application method, Natural England's method and a revised annual impact value using Natural England's breeding BDMPS method incorporating overseas individuals is presented in **Table 1**.

Table 1: Calculated breeding season and annual BDMPS values for species assessed for Hornsea Four.

Species	Applicant's DCO Application breeding BDMPS population*	Natural England's breeding BDMPS method population**	Revised annual BDMPS population
Gannet	139,302	400,326	445,503***
Kittiwake	439,902	839,456	1,237,264
Great black-backed gull	55,114	25,826	88,562***
Guillemot	936,876	2,045,078	2,139,238
Razorbill	282,582	158,031	574,910***
Puffin	260,726	868,689	938,585

Table Note: * Values derived from **Table 5.14** of **Volume A2 Chapter 5 Offshore and Intertidal Ornithology** (**APP-017**). ** Values derived following the method detailed in **Appendix A**. *** Value calculated lower than non-breeding BDMPS population in Furness (2015) for the species.

2.2 Collision Risk Modelling

2.2.1.1 There is potential risk to birds from offshore wind farms through collision with wind turbines and associated infrastructure. As detailed in **A5.5.3 ES Volume A5 Annex 5.3 Offshore Ornithology Collision Risk Modelling** (**APP-076**), the Applicant, Natural England and the Royal Society for the Protection of Birds (RSPB) agreed on the use of the Marine Scotland developed stochastic Collision Risk Model (sCRM) (Donovan, 2018) in order to assess the risk of collision from Hornsea Four to seabirds ((agreement **OFF-ORN-2.7, 2.16 & 2.38**– as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)). The rationale for model selection is detailed in **A5.5.3 ES Volume A5 Annex 5.3 Offshore Ornithology Collision Risk Modelling** (**APP-076**).

2.2.1.2 Five species were selected and agreed between the Applicant, Natural England and the RSPB to be modelled for collision risk ((agreement **OFF-ORN-2.11**– as set out in Evidence

Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)), which were:

- Gannet, *Morus bassanus*;
- Kittiwake, *Rissa tridactyla*;
- Herring gull, *Larus argentatus*;
- Lesser black-backed gull, *Larus fuscus* (at the request of Natural England); and
- Great black-backed gull, *Larus marinus*.

2.2.1.3 Within the model the input parameters where potential variability exist are presented below and described in detail within the following sections:

- Avoidance rates;
- Species biometrics;
- Flight speeds;
- Nocturnal activity factors;
- Seabird density; and
- Flight height data.

2.2.2 Avoidance Rates

2.2.2.1 For the assessment of collision risk to seabirds presented within the Hornsea Four **Volume A2 Chapter 5 Offshore and Intertidal Ornithology** (**APP-017**), the Applicant used the avoidance rates presented in a joint response from the UK SNCBs to the Marine Scotland Science avoidance rate review (JNCC et al, 2014) as advocated by and agreed with Natural England for all species assessed, the response being to the source data on avoidance rates by Cook et al. (2014). Since this guidance was published, a more recent paper on seabird avoidance rates was published by Bowgen & Cook (2018), which provides higher avoidance rates for gannet and kittiwake than previously published. Those provided by this latter paper accounted for strong evidence of macro avoidance of OWFs in gannet behaviour from multiple studies. It also suggested the use of a new species-specific avoidance rate for kittiwake using monitoring data from an active OWF over the grouped generic value previously suggested for kittiwake in the joint SNCBs response note (JNCC et al, 2014). The Applicant initially proposed the use of the latest avoidance rates from Bowgen & Cook (2018) for use in assessment of collision risk for Hornsea Four following on from the use of it within other OWF collision risk assessments, however Natural England disagreed with this approach, stating their advice hadn't changed from the joint SNCBs response note (JNCC, 2014).

2.2.2.2 A further recent study since the joint SNCBs response note (JNCC et al, 2014) was drafted on the calculation of avoidance rates has also been produced by Offshore Renewables Joint Industry Programme (ORJIP) (Skov et al. 2018), which aimed to calculate an empirical avoidance rate based on recorded macro (avoidance response prior to entry of the OWF array area out to a 3 km buffer), meso (avoidance response within the OWF array area) and micro avoidance (avoidance response within 10 m of the rotor swept zone of individual wind turbine generators (WTGs)) recorded. The incorporation of these additional avoidance responses resulted in significantly higher avoidance rates than previously advocated in the joint SNCBs response note (JNCC et al, 2014) (**Table 2**).

2.2.2.3 The RSPB primarily agreed with the avoidance rates advocated in the joint SNCBs (JNCC et al, 2014) response note, with the exception of the recommended avoidance rate for gannet. As detailed in the RSPB's Relevant Representations (**RR-029**; **RR-033-K**) the RSPB stated the following:

2.2.2.4 "Whilst the RSPB agrees with almost all of the SNCB's avoidance rates (JNCC et al, 2014), we differ with regard to gannet. We are content that 98.9% is suitable for non-breeding birds, but do not agree that this figure should be applied to the breeding season due to the lack of available evidence relating to breeding birds. GPS tracking of gannets breeding on the Bass Rock between 2010 and 2021 has shown variation in the two-dimensional foraging behaviour of birds across the breeding season (prior to chick-rearing, and during chick-rearing), between sexes, and between years (Cleasby et al. 2015a, Lane et al. 2020, Lane and Hamer 2021). Three-dimensional tracking of gannets during chick-rearing has revealed that flight height and flight speed both vary according to behaviour, sex and wind conditions (Cleasby et al. 2015b, Lane et al. 2019, Lane et al. 2020,) and similar patterns have been recorded in other seabirds (Masden et al. 2021). As the misspecification of these parameters contributes to the model error component of avoidance rate (Johnston et al., 2021) such variability should result in differential avoidance rates."

2.2.2.5 The Applicant acknowledges the RSPB's comment and as detailed in the Applicant's **G2.9 gannet displacement and mortality evidence review** (**REP2-045**) the Applicant concluded that a difference in behaviour was observed for gannet between the breeding and non-breeding seasons, in terms of macro avoidance and displacement rates. This change in behaviour, however, does not equate to a need to reduce the avoidance rate of gannet in the breeding season. The current joint SNCB's response note (JNCC et al, 2014) advocated avoidance rate of 0.989 is already an inherently precautionary value as stated within the note itself as follows:

2.2.2.6 "We note that the northern gannet avoidance rate represents, in reality, an 'all gull' avoidance rate, due to the absence of species-specific within windfarm avoidance data. We agree it is inappropriate to combine a within wind farm avoidance rate for this species based on the rates established for gulls with the gannet-specific macro-avoidance rate of 0.64, as this would result in a non-evidence based total avoidance rate higher than for any of the other groups considered. However, we agree that, without a within windfarm avoidance component for gannets, and acknowledging their more marked tendency to exhibit macro-avoidance behaviour; it is reasonable to ascribe to gannets the lowest of the total avoidance rates determined for any of the other groups (i.e. the 'all gull'category). In the absence of gannet-specific data for all elements of avoidance, this is also appropriately precautionary."

2.2.2.7 Similarly, within the more recent Bowgen & Cook (2018) and Skov et al. (2018) papers, the evidence of strong macro-avoidance for gannet was the rationale for a suitable minimum avoidance rate of 0.995 to use for this species in relation to Band Option 2 within the Band (2012) Collision Risk Model (CRM).

2.2.2.8 The Applicant was advised after the final drafts of the Hornsea Four DCO Application were completed (in late August 2021) that Natural England had commissioned a new research paper on avoidance rates from the British trust for Ornithology (BTO). As part of their research the BTO undertook an analysis that combined avoidance rates from various sites as presented in Cook et al. (2014) with those derived from the ORJIP study (Bowgen & Cook 2018) and any additional sites, where the appropriate data were available, in order to provide avoidance rates based on data across a range of sites where possible. This paper was circulated to the Applicant as a report entitled *Additional analysis to inform SNCB recommendations regarding collision risk modelling - BTO Research Report No.739* (Cook, 2021).

2.2.2.9 The Applicant was advised that Natural England and the other SNCBs were then to work on producing a joint advice note on CRM, including avoidance rates. It was suggested likely that the rates recommended in the 2021 BTO review would be adopted in their formal joint SNCBs advice note, and in advance of that note, they recommend that the avoidance rates in Table A2 of the BTO report (Cook, 2021) were to be used in impact assessments.

2.2.2.10 The Applicant reviewed these data, but as they were provided after all the collision risk assessments had been completed for the Hornsea Four DCO Application did not apply them. Following this, in October 2021, Natural England alerted the Applicant that the data used to inform the report and the R code used to formulate the updated avoidance rates had errors in them. In particular, concerns had been raised surrounding the inclusion of one of the post-construction studies within the report and the coding within the modelling of all the data.

2.2.2.11 Following these concerns Natural England and the other SNCBs withdrew their advice on the use of the Cook (2021) avoidance rates commenting that '*Having carefully considered the issues raised we have concluded that they present reasonable grounds for the exclusion of that study from the findings of the report. Accordingly, Natural England has concluded that it is not appropriate to use the recommended rates in the BTO report. Therefore our advice is that CRM modelling should use the avoidance rates previously advised by SNCBs i.e. those presented in the 2014 SNCB advice note (JNCC et al, 2014) based on Cook et al (2014)*'. Natural England also stated that they were working hard to identify a course of action to ensure that any future joint SNCBs recommendations regarding avoidance rates are robust and can be adopted with confidence by stakeholders.

2.2.2.12 The Applicant is aware that a revision to the Cook (2021) paper is pending in 2022 (date unconfirmed) and a further update to the current joint SNCBs response note (JNCC et al, 2014) will follow, but is unaware of when these revised papers will be made publicly available.

2.2.2.13 Therefore, the Applicant continues to use the range of avoidance rates available, for which a summary of the possible variability in avoidance rates and source references are presented in **Table 2**. The difference in terms of impact values these rates have on the overall assessment will be presented in Part 2 of this report, which will be submitted into the Hornsea Four examination at Deadline 5.

Table 2: Summary of the potential variability in avoidance rates for use in collision risk modelling.

Species	Value	Reference
Gannet (BO2)	0.989 ± 0.002	JNCC (2014)
	0.995	Bowgen & Cook (2018)
	0.999 ± 0.003	Skov et al. (2018)
Kittiwake (BO2)	0.989 ± 0.002	JNCC (2014)
	0.990	Bowgen & Cook (2018)
	0.998 ± 0.006	Skov et al. (2018)
Kittiwake (BO3)	0.980	Bowgen & Cook (2018)
Herring gull (BO2)	0.995 ± 0.001	JNCC (2014)
	0.995	Bowgen & Cook (2018)
	0.999 ± 0.005	Skov et al. (2018)
Herring gull (BO3)	0.990 ± 0.002	JNCC (2014)
	0.993	Bowgen & Cook (2018)
Lesser black-backed gull (BO2)	0.995 ± 0.001	JNCC (2014)
	0.995	Bowgen & Cook (2018)
	0.998 ± 0.006	Skov et al. (2018)
Lesser black-backed gull (BO3)	0.989 ± 0.002	JNCC (2014)
	0.993	Bowgen & Cook (2018)
Great black-backed gull (BO2)	0.995 ± 0.001	JNCC (2014)
	0.995	Bowgen & Cook (2018)
	0.996 ± 0.011	Skov et al. (2018)
Great black-backed gull (BO3)	0.989 ± 0.002	JNCC (2014)
	0.993	Bowgen & Cook (2018)

2.2.3 Species Biometrics

2.2.3.1 Within the sCRM (Donovan, 2018) pre-formulated species biometrics (body length and wingspan) values are included with Standard Deviations (SDs) around the central estimates, which are based on those presented in Robinson (2005). The use of these SDs to model variation around seabird biometrics was discussed during the Evidence Plan (EP) process. It was agreed with Natural England and the RSPB that due to the uncertainty around the calculation of the SDs within the sCRM the central estimate value was to be used for all assessment without any variability (agreement **OFF-ORN-2.32**– as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)). Although individual birds of the same species size may differ considerably, comparatively to the single value used, due to the significant amount of data used to derive the single figure the value can be considered suitably representative of a species with high confidence and therefore, no variation is required to be modelled for species biometrics in Part 2 of this report.

2.2.4 Flight Speeds

2.2.4.1 It is highly likely that the speed at which a bird flies is highly dependent on both wind speed and the type of flight behaviour exhibited, for example a seabird's flight speed when commuting or during migratory flights are likely to differ from when a species is actively foraging. Within both the Band (2012) CRM and Marine Scotland sCRM (Donovan, 2018) an increase in flight speed leads to an increase in collision risk. Within the guidance document for the Band (2012) CRM, one area of uncertainty identified related to species biometrics, including flight speed due to the parameters not being a single fixed value. The author (Bill Band) stated within the guidance (Band, 2012) that uncertainty relating to species biometrics and flight speed could affect the predicted impact by up to ±20%. The guidance provided one recommendation suggesting running the model with variable flight behaviours (migratory vs foraging flights) depending on the likely behaviour exhibited within the OWF at different times of the year.

2.2.4.2 The flight speeds advocated by Natural England and agreed for use by the Applicant within the Hornsea Four collision risk modelling ((agreement **OFF-ORN-2.19 & 2.33**– as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)) are derived from Pennycuick (1997) and Alerstam et al. (2007), which recorded observed flight speeds of species on commuting and migratory flights with no association to an OWF. A more recent study on bird flight speeds within an operational OWF has been undertaken (Skov et al. 2018), which calculated average flight speeds of birds within the OWF using rangefinders fitted to WTGs. The results of this study recorded slower flight speeds than currently advocated for collision risk modelling.

2.2.4.3 Kittiwake specific flight speeds are presented in Coulson (2011) and Masden (2015). Coulson (2011) recorded kittiwakes travelling at an average flight speed whilst commuting in relatively calm conditions and light winds of 43 km/h (11.94 m/s) without any influence of tail-wind assistance, reducing down to 25 km/h (6.94 m/s) in strong headwinds. Coulson (2011) also conducted a literature review of kittiwake flight speeds, which resulted in a wide range of flight speeds with peak values cited around 40-45 km/h (11.11 – 12.5 m/s), similar to that of his own research. Although a maximum record of 85-90 km/h (23.61 – 25.00 m/s) was found, Coulson dismissed this value as being unrealistic and down to an error value. No information within Coulson (2011) is provided on whether the flight speeds recorded were during migratory or commuting flights. Within the Masden (2015) avian collision risk model report a number of example assessments for kittiwakes are presented. These examples used data from the RSPB's Future of the Atlantic Marine Environment (FAME) research, collected from GPS tagged birds. Using these tagging data an overall average kittiwake flight speed was calculated as 7.26 ± 1.5 m/s. it should be noted that the RSPB FAME tagging data was collected during the breeding season and therefore does not account for any migratory flights.

2.2.4.4 A summary of the varying recorded flight speeds for different seabird species and the source references for each are presented in **Table 3**. The difference in terms of impact values these rates have on the overall assessment will be presented in Part 2 of this report.

Table 3: Summary of the potential variability in seabird flight speed values.

Species	Value (m/s)	Reference
Gannet	14.90	Pennycuick (1997) and Alerstam et al. (2007)
	13.33 ± 4.24	Skov et al. (2018)
Kittiwake	13.10	Pennycuick (1997) and Alerstam et al. (2007)
	8.71 ± 3.16	Skov et al. (2018)
	11.94 (6.94 – 25.00*)	Coulson (2011)
	7.26 ± 1.50	Masden (2015)
Herring gull	12.80	Pennycuick (1997) and Alerstam et al. (2007)
	9.68 ± 3.47	Skov et al. (2018)
Lesser black-backed gull	13.10	Pennycuick (1997) and Alerstam et al. (2007)
	10.13 ± 3.93	Skov et al. (2018)
Great black-backed gull	13.70	Pennycuick (1997) and Alerstam et al. (2007)
	9.78 ± 3.65	Skov et al. (2018)
Large gulls combined	9.80 ± 3.63	Skov et al. (2018)

Table Note: *Coulson (2011) concluded that the value cited of 85 - 90 km/h (23.61 – 25.00 m/s) seemed unrealistic.

2.2.5 Nocturnal Activity Factor

2.2.5.1 Although the five seabird species scoped in for assessment of collision risk for Hornsea Four can be considered as being primarily diurnally active there may be some instances where these species might be active pre-dawn and post-dusk. Collision risk models account for this nocturnal activity through the inclusion of a nocturnal activity factor, which can be specified within the sCRM based on the species estimated activity levels during these periods of the day. The nocturnal activity factors currently advocated by Natural England are included within the Applicant's collision risk modelling ((agreement **OFF-ORN-2.20** & **2.34**– as set out in Evidence Plan Logs, which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)) are derived from the scoring index for nocturnal activity presented in Garthe and Hüppop (2004) based on literature review and personal observations. These index values were then converted into a nocturnal activity factor as follows; 1 = 0%, 2 = 25%, 3 = 50%, 4 = 75%, 5 = 100%. More recent studies of nocturnal activity (MacArthur Green, APEM & Royal HaskoningDHV 2015; Masden 2015; Skov et al. 2018) have found significantly lower nocturnal activity than those presented in Garthe and Hüppop (2004), especially during the breeding season. A review of evidence in support of nocturnal activities rates for seabirds was undertaken for the East Anglia Three OWF (APEM & Royal HaskoningDHV 2015). This reviewed nocturnal activity based on the deployment of tracking loggers in both the breeding and non-breeding season, which provided evidence that activity levels recorded were significantly lower than currently advocated (Table 4). Within the accompanying guidance document for the Masden (2015) CRM, the nocturnal activity factor was derived from the RSPB FAME based on GPS tagging of kittiwakes, which provided a nocturnal activity factor of 0.033 (3%) ± 0.0045. The ORJIP collision avoidance study (Skov et al. 2018) also collected night and daytime video during the non-breeding season in the winter months (where nocturnal activity was anticipated to be higher) to compare day and night activity rates. Due to the difficulty in identifying to species level in the night-time video a general seabird activity factor of <3% was calculated.

2.2.5.2 A summary of the varying species nocturnal activity rates for different species and the source reference for each are presented in **Table 4**. The difference in terms of impact values these rates have on the overall assessment will be presented in Part 2 of this report.

Table 4: Summary of the potential variability in nocturnal activity values.

Species	Value (%)	Reference
Gannet	25	Garthe and Hüppop (2004)
	0 for breeding birds and 2 for non-breeding birds	MacArthur Green, APEM & Royal HaskoningDHV (2015)
Kittiwake	50	Garthe and Hüppop (2004)
	0 for breeding birds and 12 for non-breeding birds	MacArthur Green, APEM & Royal HaskoningDHV (2015)
	3	Masden (2015)
Herring gull	50	Garthe and Hüppop (2004)
	25 for breeding birds and 25* for non-breeding birds	MacArthur Green, APEM & Royal HaskoningDHV (2015)
Lesser black-backed gull	50	Garthe and Hüppop (2004)
	25 for breeding birds and 25* for non-breeding birds	MacArthur Green, APEM & Royal HaskoningDHV (2015)
Great black-backed gull	50	Garthe and Hüppop (2004)
	25 for breeding birds and 25* for non-breeding birds	MacArthur Green, APEM & Royal HaskoningDHV (2015)
Seabird	<3%	Skov et al. (2018)

Table Note: * Precautionary value based on lack of empirical evidence providing a more appropriate value.

2.2.6 Seabird Density

2.2.6.1 As detailed within **A5.5.3 ES Volume A5 Annex 5.3 Offshore Ornithology Collision Risk Modelling** (**APP-076**) a mean density estimate of flying seabirds was calculated based on two years of 24 months of site-specific surveys in order to assess for potential collision risk from Hornsea Four. The Applicant also presented SD values alongside the mean, which were calculated in order to model potential variability in the modelled density estimates as intended within the sCRM (Donovan, 2018).

2.2.6.2 The difference in terms of impact values the variability using the SD around the mean seabird density has on the overall assessment will be presented in Part 2 of this report.

2.2.7 Flight Height Data

2.2.7.1 The Applicant's position, which is reflected in the approach taken by other experts undertaking collision risk modelling for OWFs, is that the use of 95% CIs around generic flight heights are unsuitable for assessment. This is due to the Johnston et al. (2014) datasets being comprised from an extensive number of studies, therefore providing confidence that the maximum likelihood values for each species are a reflective value of a species average flight behaviour. Conversely due to the numerous studies included, if assessments use the 95% CIs these values are likely to be affected by outlying uncharacteristic flight behaviours (many in relation to studies from OWFs that are either onshore or in nearshore environments that are very different in nature to Hornsea Four.

2.2.7.2 Within the Johnston et al. (2014) paper the flight heights are shown to be positively skewed, demonstrating flight height distributions were strongly weighted near the sea surface, but less so for large gull species.

2.2.7.3 The model fit (r2) for flight height distribution is very strong (over 80%) for species including gannet and kittiwake, therefore including outlying flight heights without context may reflect outliers. Such outliers are likely to represent non-typical behaviours or responses to other activities such as survey vessels collecting the data. Therefore, the use of the best model fit data most accurately represent bird behaviour at sea and therefore the range of risk that may be used to estimate collision risk.

2.2.7.4 Therefore, the Applicant considers that inclusion of 95% flight height Confidence Intervals within the assessment adds further uncertainty and unreliability into the results reducing confidence in the overall CRM outputs for assessment purposes.

2.3 Displacement Analysis

2.3.1.1 The presence of WTGs has the potential to directly disturb and displace seabirds that would normally reside within and around the area of sea where Hornsea Four is proposed to be developed. This in effect represents indirect habitat loss, which would potentially reduce the area available to those seabirds to forage, loaf and / or moult that currently occur within and around Hornsea Four and may be susceptible to displacement from such a development. Displacement may contribute to individual birds experiencing fitness consequences, which at an extreme level could lead to the mortality of individuals.

2.3.1.2 Seabird species vary in their response to the presence of operational infrastructure associated with OWFs, such as WTGs and shipping activity related to maintenance activities. The potential seabird species affected by displacement impacts from the Hornsea Four array area were consulted and agreed upon through the EP Process ((agreement **OFF-**

ORN-2.10– as set out in Evidence Plan Logs, which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)) as the following:

- Gannet;
- Guillemot, *Uria aalge*;
- Razorbill, *Alca torda*; and
- Puffin, *Fratercula arctica*.

2.3.1.3 The SNCB's 'matrix approach' was agreed as the most appropriate method of analysing displacement for the four species scoped in for assessment following the updated Joint SNCB (2022) guidance note. Applicable displacement and mortality rates were consulted on with Natural England and the RSPB through the EP process, in which the Applicant presented a rate of up to 50% displacement and up to 1% mortality rate for auks (guillemot, razorbill and puffin) and 60-80% displacement and up to 1% mortality for gannet. Both of the Applicant's ranges for displacement were supported by initial reviews of data sets. Natural England disagreed with these displacement and mortality rates, recommending a wider range of 30-70% displacement and 1-10% mortality for auks and 60-80% displacement and 1-10% mortality for gannets, citing a lack of empirical evidence relating to displacement and mortality rates for both. However, Natural England did recommend that narrowing of those ranges could be possible through the provision of suitable evidence from further literature reviews based on empirical datasets (agreement **OFF-ORN-2.49**, **2.50** & **2.51**– as set out in Evidence Plan Logs, which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)). This advice is in line with the Joint SNCB (2022) guidance on displacement, which states:

2.3.1.4 "For those species lacking in empirical data on likely displacement levels resulting from OWF construction, there is potential utility in using the scores in order to maintain consistency of approach across different developments (where appropriate). For example, for auk species the SNCBs would typically advise a displacement level of 30-70% (Guillemot and Razorbill have a 'Disturbance Susceptibility' score of 3)."

2.3.1.5 In response to this advice provided by Natural England the Applicant undertook an extensive review of empirical datasets from 21 post-consent monitoring studies for auks and 25 post-consent monitoring studies for gannet with the detailed results presented in **G1.47 Auk Displacement and Mortality Evidence Review** (**REP1-069**) and **G2.9 Gannet Displacement and Mortality Evidence Review** (**REP2-045**).

2.3.1.6 For auks, Displacement effects varied from strong attraction to strong avoidance, however, OWFs could be separated into two groups: 1) OWFs with inferred avoidance or displacement rates higher than 50%, 2) OWFs with no significant displacement effect or suggested weak avoidance of <25% displacement. Further interrogation of these datasets suggesting displacement rates of over 50% were associated with low count data, which included high zero counts within the data set (i.e. where datasets included very low or no auks from pre-construction and / or post-construction surveys), which due to the statistical analysis method used to analyse the datasets at the time were unable to manage such zero-inflated data sets producing misleading displacement rates. The results of this study found that the current range of 30-70% advocated in the joint SNCB's (2022) guidance for auks had been compiled without due regard to the quality of the study or confidence in the derived displacement rates, furthermore it did not account for studies that have shown no significant displacement effect, attraction or likely habituation over time. The conclusion of the Applicant's own empirical study recommends that a revised displacement rate of 0-50% would be a realistic range to be applied for the assessment of Hornsea Four.

2.3.1.7 For gannet, the empirical study identified seasonal differences in the rate of displacement with a significantly lower displacement rate in the breeding season compared to the non-breeding season across the data. Displacement rates for the breeding season in general ranged from 40-60%, with the lower assigned rate being precautionary. For the non-breeding season, the displacement rate ranged from 60-75%, which excludes low confidence studies and OWF with higher rates that have certain design metrics.

2.3.1.8 Since the drafting of both reports a further post-consent monitoring study has been published for the OWFs in the Belgian North Sea (Degraer et al., 2021). This area of development is composed of a row of nine closely adjacent OWFs and together with five OWFs in the Dutch Borssele zone of the North Sea form a contiguous complex of OWFs with various WTG designs and layouts. Construction in this area commenced in 2008 at the Thorntonbank Phase I site, with all three phases being operational by 2012 with a second OWF, Bigh Bank, operational in 2010. Post-construction surveys have been conducted between these two sites from 2010 to 2018 and displacement assessments based on five years and six years data for Bligh Bank and Thorntobank, respectively. Displacement rates reported at these OWFs were 98% and 82% for gannet at Thorntonbank and Bligh Bank, respectively and 60% and 75% for guillemot at Thorntonbank and Bligh Bank, respectively. However, the area as a whole has seen continued development with only very short periods without construction activities until the final OWF became operational at the end 2020. Therefore, displacement rates reported for these OWFs may not truly reflect an operational phase if birds are subjected to disturbance effects from construction activities in the area.

2.3.1.9 Evidence to support this is suggested from the post-construction monitoring reports in year five and six which presented evidence of habituation of gannets at Bligh Bank and Thorntonbank, respectively, showing displacement effects decreasing from up to 3 km to >0.5 km from the array area (Vanermen et al., 2019). This behavioural change coincided with a period of 10 months during which survey data was collected at a time when no ongoing construction activities were occurring in the wider area. With the completion of the remaining OWFs in this complex at the end of 2020 the phase of development can now be accurately considered an operational phase. During 2021 a new monitoring strategy commenced aiming to assess the complete operational Belgian OWF zone by means of ship-based surveys five times a year. Results from the first survey conducted in February 2021 show considerable change in behaviour of auks and gannets to the OWFs (Degraer et al., 2021). Overall, densities inside the OWF zone were about twice as high compared to densities outside (4.59 versus 2.36 birds/km² respectively) for razorbill. Common guillemot occurred more homogenously spread across the study area, with comparable densities inside and outside the OWF zone (1.2 and 1.0 birds/km² respectively). Gannet densities were higher outside the OWF zone but were the highest densities to be recorded inside an array area (0.29 and 0.80 birds/km², respectively). Therefore, emerging data from one of the most intensely studied OWF areas suggests there is evidence of habituation of both gannets and auks to operational OWFs, which becomes apparent only if there are no disturbance from construction activities in the wider area.

2.3.1.10 For auks and gannets, both studies (**REP1-069** and **REP2-045**) identified population simulation modeling to predict population level consequence of displaced seabirds. The results of the simulation concluded that when considering the potential displacement impacts from Hornsea Four a mortality rate of up to 1% can be considered suitably precautionary, given the projects location in relation to nearest colony, proposed WTG design and array area design of the project and species behaviour. The studies also reviewed empirical evidence of consequent displacement mortality by anaslysing Heligoland seabird colony monitoring data, to understand if any population effects were detectable for either auks or gannet, as a consequence of the presence of nearby OWFs, which have been on operation since 2015. For gannet and auks, since operation the colony has showed no significant change in growth rates (both auks and gannet from the colony exhibiting continued growth). Should mortality rates at this colony be as high as 10% in relation to displacement from the nearby OWFs then this would almost certainly be detectable, but at this is not the case it provides evidence that reinforces the unsuitability of a mortality rate of up to 10%.

2.3.1.11 A summary of the Applicant's and the SNCB's advocated displacement and mortality rates for auks and gannet and the source reference for each are presented in **Table 5**. The difference in terms of impact values these rates have on the overall assessment will be presented in Part 2 of this report.

Table 5: Summary of the Applicant's and SNCB's advocated displacement and mortality rates.

Species	Displacement Rate (%)	Reference	Mortality Rate (%)	Reference
Gannet (Applicant's position)	40-60% breeding season 60-75% non-breeding season	G2.9 Gannet Displacement and Mortality Evidence Review (REP2-045)	0-1%	G2.9 Gannet Displacement and Mortality Evidence Review (REP2-045)
Gannet (SNCB's position)	60-80%	Joint SNCB (2022)	1-10%	Joint SNCB (2022), though the source would appear to be from a workshop with no evidence provided in support.
Auks* (Applicant's position)	0-50%	G1.47 Auk Displacement and Mortality Evidence Review (REP1-069)	0-1%	G1.47 Auk Displacement and Mortality Evidence Review (REP1-069)
Auks* (SNCB's position)	30-70%	Joint SNCB (2022)	1-10%	Joint SNCB (2022), though the source would appear to be from a workshop with no evidence provided in support.

Table Note: * auk refers to guillemot, razorbill and puffin.

2.4 Combined Collision Risk and Displacement

2.4.1.1 In line with current best practice for assessing the risk from OWFs to gannets the Applicant assessed for both collision risk and disturbance and displacement impacts both separately and combined. The current method of assessing the two predicted impacts combined is to simply add the two predicted impacts (or range of impacts) together. It is acknowledged by SNCBs that when simply combining the two impact values together this leads to an overinflated total predicted impact value. This overly inflated impact value is a consequence of the fact if a gannet is displaced from an OWF it is not possible for that individual to subsequently collide with a WTG. The reverse of this is that if a gannet is enters an OWF it may be at risk from collision with a WTG, but by entering the OWF would not be subject to displacement. Following the current method may lead to potential implications for consenting risk and planning with consequences for both project specific, cumulative and in-combination assessments of gannet included within past, current and future Environmental Impact Assessments (EIAs) and Habitats Regulations Assessments (HRAs), respectively.

2.4.1.2 As detailed in Section 2.2 the BTO (Cook, 2021) published a revised paper on avoidance rates for use in CRM (subsequently withdrawn due to reasons explained in Section 2.2), which provided a logical solution to this inherent issue of overinflating impacts for gannet, especially when combining collision risk with displacement consequent mortality rates. The paper proposed that by including macro avoidance within collision risk modelling for gannet the issue of double counting impacts could be resolved. In simple terms macro avoidance is a species avoidance response prior to entering an the OWF, which in this context a gannet's decision to avoid the OWF entirely, which at this level is also otherwise known as displacement. Macro avoidance in the context of displacement from an OWF can be incorporated within collision risk modelling via two mechanisms, through increasing the overall avoidance rate in the sCRM or by directly reducing the monthly flying gannet density estimates which are fed into the sCRM by the predicted levels of displacement for the species (**Table 5**). Should the current displacement range for gannets be applied to flying gannet densities ahead of input into the sCRM then those values would reduce by 60-80%, demonstrating how significant the level of over-inflation is likely to be if applied in this manner.

2.4.1.3 The Applicant is aware that Natural England are currently in the process of producing a new guidance note with a method to assess the combined impacts of both displacement and collision risk for gannet. It is understood that the aim of this guidance note is to address the risk of assessing collision impacts on birds that may have already been subject to displacement, therefore reducing any double counting or over-inflation of impacts as a consequence of combining the two. In advance of Natural England's guidance note Part 2 of this report will provide revised collision risk modelling for gannet which includes reduced monthly flying gannet density estimates to account for macro avoidance to demonstrate the differences this would make to project alone, cumulative and in-combination assessments for both collision risk alone and when combining collision risk with displacement consequent mortality rates.

2.5 Apportionment to FFC SPA

2.5.1.1 The process of apportioning predicted impacts from Hornsea Four to seabird qualifying features from the FFC SPA were consulted on through the EP process (agreement **OFF-ORN-6.1** & **6.2** – as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)) with the methods and results presented in **B2.2 Report to Inform Appropriate Assessment Part 11: Appendix H: Offshore Ornithology Flamborough and Filey Coast (FFC) Special Protection Area (SPA) Population Viability Analysis** (**APP-177**). The apportionment process the Applicant developed were applied to the named qualifying features of the FFC SPA that were screened in for assessment within the RIAA (**APP-167**)- were as follows:

- Gannet;
- Kittiwake;
- Guillemot; and
- Razorbill.

2.5.2 Breeding Season Apportionment

2.5.2.1 When apportioning potential impacts during the breeding season it was agreed with both Natural England and the RSPB (agreement **OFF-ORN-6.2** – as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)) that the best method would be to follow the SNH apportionment guidance (SNH, 2018) to apportion impact values to key receptors within mean max foraging range. Details of the SNH (2018) breeding season apportionment methodology are presented in Appendix B of **B2.2 Report to Inform Appropriate Assessment Part 11: Appendix H: Offshore Ornithology Flamborough and Filey Coast (FFC) Special Protection Area (SPA) Population Viability Analysis** (**APP-177**), including the apportionment results for all species assessed.

2.5.2.2 Although Natural England agreed with the SNH (2018) tool being used to apportion potential impact values, they requested that apportionment should be 100% of all impact values apportioned to the FFC SPA, due to likely being the only SPA within mean-max foraging distance (Woodward et al, 2019). Although this was found to be true for guillemot and razorbill, this was not the case for kittiwake whereby over 20 smaller colonies were also found to be within mean max foraging range. For gannet, Bass Rock and St Abbs Head SPA were also found to be within mean-max foraging range. However, as gannets are known to show 'space partitioning' between adjacent colonies (Wakefield et al. 2013), which results in limited overlap between foraging areas, a precautionary approach was taken and 100% of gannets were apportioned to the FFC SPA. It should be noted however that recent tracking data studies from Bass Rock show that gannets from the colony do enter the Hornsea Four array area during the breeding season, although this is calculated to be outside of their core foraging range (Lane et al. 2020).

2.5.2.3 As well as breeding SPA birds being present within the Hornsea Four array area, immature birds and breeding adults on a breeding sabbatical are likely to be present and therefore need to be accounted for when apportioning impacts.

2.5.2.4 For deriving the proportion of potential juvenile and immature birds within Hornsea Four during the breeding season, the Applicant initially reviewed the site-specific age ratios recorded within the aerial digital surveys. However, as presented in **Appendix D** of **Volume A5, Annex 5.1: Offshore and Intertidal Ornithology Baseline Characterisation Report** (**APP-074**) due to lack of age specific records, the Applicant ruled out the use of site-specific survey data to calculate age ratios on the basis of concern over reliability of these data fo that purpose.

2.5.2.5 In Natural England's Relevant Representation (**RR-029**; **RR-029-APDX:B-44**) the recommendation was made that all 'adult type' birds should be apportioned as adults. This approach suggested is highly likely to lead to inaccuracies in the apportionment process.

2.5.2.6 In relation to kittiwake only first winter juvenile birds are readily distinguishable from other age categories due to the distinct 'W pattern' across the wings and black tail-band (Svensson et al. 2009). This pattern, however, is lost by the time a kittiwake reaches its second winter moult whereby the bird is near indistinguishable from an adult bird. As presented in Coulson (2011), the modal age of kittiwakes first breeding is four years old, although the age of first breeding has been documented as late as 10 years old. This clearly shows that by treating all 'adult type' birds as breeding adults is highly likely to lead to over apportionment of impacts to breeding adult birds for kittiwakes.

2.5.2.7 In relation to auk species, the identification of first winter juvenile birds is primarily only possible in the immediate post-dispersal months whereby first winter birds are accompanied by adult males, the key indicator between first winter birds and adult males being the difference in size. Following a first summer moult differences between juvenile and adult birds are subtle and not possible to identify in surveys. The average age of first breeding in guillemots is six years old (Horswill & Robinson, 2015) and for razorbill is five years old (Horswill & Robinson, 2015). Furness (2015) also states that 80% of immature guillemots and 90% of immature razorbills from the FFC SPA remain in the North Sea and English Channel BDMPS area throughout the non-breeding bio-seasons. This clearly shows that by treating all 'adult type' birds as breeding adults is highly likely to lead to over apportionment of impacts to breeding adult birds for auk species. Conversely, relying on the site-specific data from a small number of months to represent age ratios that are only possible when juveniles are being accompanied by adult males will lead to an inaccurate 50% split between juvenile and adult birds.

2.5.2.8 For the reasons stated above, the Applicant used the data contained within Furness (2015) to calculate age ratios as used for non-breeding season apportionment, which draws upon a wide number of data sources gathered across multiple years in order to model population age structure, thus reducing the potential for any bias associated with the snapshot nature of site-based surveys.

2.5.2.9 Furthermore, not all adult birds within Hornsea Four can be classified as breeding birds. This is evidenced from adult sabbatical birds free roaming the North Sea whilst taking a break from breeding activities (Marine Scotland 2017). A sabbatical rate of 10% for gannet and kittiwake populations and 7% for auk species was recently advocated by Marine Scotland based on expert opinion for inclusion in revised Forth and Tay OWF applications (Neart na Gaoithe OWF, Seagreen Alpha and Bravo OWF, and Inch Cape OWF) in relation to the Forth Islands SPA and Firth of Forth and St. Andrews Bay Complex SPA, designated for breeding gannets, kittiwakes, guillemot, razorbill and puffin (Marine Scotland, 2017). With similarities in the seabird assemblage and distance to colonies between the OWFs within the Forth and Tay region and Hornsea Four in relation to the waters out from the FFC SPA these values were applied for use in this assessment of designated features from FFC SPA during the breeding season.

2.5.3 Non-breeding Season Apportionment

2.5.3.1 When apportioning potential impacts to the FFC SPA during the non-breeding bio-seasons it was agreed with both Natural England and the RSPB (agreement **OFF-ORN-6.1** – as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)) to use Furness (2015) to apportion impacts during the non-breeding seasons, as detailed in **B2.2 Report to Inform Appropriate Assessment Part 11: Appendix H: Offshore Ornithology Flamborough and Filey Coast (FFC) Special Protection Area (SPA) Population Viability Analysis** (**APP-177**). This is the standard approach to apportionment in the non-breeding season and has been applied by other recent OWF developments such as East Anglia One North and Norfolk Boreas (SPR, 2019; Vattenfall, 2019).

2.5.3.2 During further consultation Natural England then requested that for auks, in particular guillemot, an alternative apportionment method should be considered by the Applicant due to Natural England's concerns relating to the large number of auks passing through the array area in post-breeding dispersal months of August and September (agreement **OFF-ORN-6.12** – as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)). The Applicant, agreed to this request and came up with a weighted apportionment method for the guillemot non-breeding season as detailed in **B2.2 Report to Inform Appropriate Assessment Part 11: Appendix H: Offshore Ornithology Flamborough and Filey Coast (FFC) Special Protection Area (SPA) Population Viability Analysis** (**APP-177**).

2.5.3.3 For the post-breeding dispersal months of August and September the Applicant followed a similar apportionment process to that in the breeding season accounting for higher values of breeding birds being likely to be from the FFC SPA, but also the likely proportion of non-breeding and sabbaticals birds and also accounting for the proportion of other non FFC SPA breeding adult birds which could be present. As it is not possible to determine exactly how many guillemots within Hornsea Four are non-FFC SPA breeding adults the Applicant undertook a literature review (Camphuysen 2002; Harris et al. 2015; Dunn et al. 2020) on guillemot post-breeding dispersal to inform expert judgement of 25% being from other colonies. Since this review a further paper has been published (Buckingham et al. 2022) which provides details of auk dispersal from birds tagged primarily from Scottish colonies.

2.5.3.4 However, the number of successfully recovered tags from birds breeding at colonies immediately to the north of Hornsea Four (including the Farne Islands, Coquet Island and the Isle of May) was low overall. The limited data set provided limits any justification to use these data on a blanket scale for all individuals dispersing from the main sites that contributed to the data sets. It also lacked any tagged birds from FFC SPA, which would have been more relevant to whether birds from this site move into the Hornsea Four array area or not. Despite these limitations, the core colony distributions (50% kernel density contours) show that auk disperse significant distances in such a short space of time, particularly guillemots, whereby birds from Whinnyfold and East Caithness includes areas to the west of Hornsea Four.

2.5.3.5 This new paper therefore, aids to reinforce the Applicant's expert judgement of 25% of adult birds being non-FFC SPA birds. There is also significant evidence from other OWF baseline datasets and post-consent monitoring reports from projects across the southern North Sea that also present trends of auk peak counts in the months of August and September, demonstrating that birds from many other colonies move into this region during these post-breeding dispersal months.

2.5.3.6 In the absence of an alternative means of assessment being provided by Natural England, the Applicant maintains that the assessment method taken for guillemot non-breeding season apportionment is suitably precautionary comparatively to following the standard apportionment method as presented in Part 2 of this report.

2.5.4 FFC SPA Gannet and Kittiwake Breeding Bio-season Component Months

2.5.4.1 In relation to applicable component breeding season months the Applicant interrogated the site-specific survey data to ensure consistency between the behaviours exhibited in the survey data correlate with the correct non-breeding, migratory and breeding seasons described in Furness (2015). As presented within **Appendix C** of **Volume A5, Annex 5.1: Offshore and Intertidal Ornithology Baseline Characterisation Report** (**APP-074**) the site-specific rose diagrams suggest the most applicable breeding bio-season to be the migration-free bio-season for kittiwake and gannet, as birds are more aligned to north-south flight directions suggesting migratory movements outside of the migration free breeding bio-season. Whereas within the migration-free breeding bio-season birds were recorded flying in east-west directions suggesting foraging flights to and from the FFC SPA.

2.5.4.2 Furthermore, the Applicant also reviewed the breeding season component months of it's sister project Hornsea Three to ensure a similar pattern conclusion was reached. In the Secretary of States (SofS) HRA (BEIS, 2020) for Hornsea Three, the ExA and the SofS accepted the Applicant's use of the migration-free breeding season for gannet and kittiwake, based on their evidence, plus Langston et al. (2013) and Cleasby et al. (2018) tracking studies. SofS HRA section 5.3.1 concluded:

2.5.4.3 "Given the above, the Secretary of State agrees with the conclusions of the ExA that the use of the longer breeding season to apportion impacts to the gannet and kittiwake populations at Flamborough and Filey Coast SPA is not justified and therefore, in this case, favours the Applicant's preferred shorter breeding season."

2.5.4.4 Hornsea Four sits in a similar area of the southern North Sea that is also subject to migratory pulses of seabirds throughout the spring and autumn when birds move to and from their breeding colonies further north (both to UK and continental locations). The migratory patterns and timing of gannets, kittiwakes, guillemots and razorbills through the southern North Sea are similar when considering their routes and interaction with other projects within the Hornsea Zone, so the Applicant's consideration of migratory birds should remain an important factor in order to apportion birds appropriately from Hornsea Four and to understand the risk to FFC SPA and other colonies accordingly.

2.6 Population Viability Analysis

2.6.1.1 In order to better understand the effect the predicted impacts from Hornsea Four alone, cumulatively and in-combination with other projects might have on seabird populations, population viability analysis (PVA) was undertaken as detailed in **A5.5.4 Environmental Statement Volume A5 Annex 5.4 Offshore Ornithology Population Viability Analysis** (**APP-077**) for EIA level impacts and **B2.2 Report to Inform Appropriate Assessment Part 11: Appendix H: Offshore Ornithology Flamborough and Filey Coast (FFC) Special Protection Area (SPA) Population Viability Analysis** (**APP-177**) for HRA level impacts apportioned to the FFC SPA. PVA can be a robust method for predicting population level impacts, as long demographic and environmental parameters are accurately incorporated and the correct outputs are used to infer predicted effects. If parameters are specified incorrectly or a less appropriate output is used to infer effects then the results can lead to significant under or over estimation of potential population level effects as a consequence.

2.6.1.2 The Applicant undertook all PVAs using the Natural England Seabird PVA Tool (Mobbs et al. 2020). This was agreed between the Applicant and Natural England through the EP process through multiple consultations on the modelling approach and most appropriate demographic parameters to include within the tool, both at an EIA and HRA (FFC SPA colony specific) levels (agreement OFF-ORN-2.27-2.31, 2.42 & 2.46 – as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (B1.1.1: Evidence Plan (APP-130)). Natural England recommended that the model should be run excluding density dependence due to the concern relating to accurately incorporating density dependence within the model.

2.6.2 'Burn-In' Period

2.6.2.1 In Natural England's Relevant Representations (RR-029; RR-029-APDX:B-59) a query was raised as to why a 'burn in' period was not included within modelling. The use of 'burn-in' had not previously been raised by Natural England when consulting on running the model, as the initial guidance paper for the Natural England Seabird PVA Tool (Mobbs et al. 2020) suggested it was not ready for inclusion. However, following receiving Natural England's Relevant Representations the Applicant has subsequently further consulted with Natural England and agreed (REP2-083) to include a 'burn-in' period within any updated PVAs, which are to be presented in Part 2 of this report.

2.7 Counterfactual of Final Population Size and Population Growth Rate

2.7.1.1 Natural England's and the RSPB queried the Applicant's rationale for not presenting the Counterfactual of Final Population Size (CFPS) alongside the Counterfactual of Population Growth Rate (CPGR) within their Relevant Representations (RR-029; RR-029-APDX:B-60; RR-033-F) The Applicant provided a full verbal explanation to the Examining Authority on this topic during Issue Specific Hearing 5 on Ornithology EIA matters and Issue Specific Hearing 6 on HRA matters.

2.7.1.2 In summary, the Applicant's reasoning for not presenting the CFPS is to avoid misinterpretation of predicted population level effects caused by the low confidence in the CFPS output. This is because CFPS and CPGR are not equally appropriate for model interpretation when modelling in the absence of density dependence. A density independent population has no constraint on increased growth or any form of recovery in decline. This means that a density independent population with a positive growth rate will grow exponentially and a negative growth population with eventually decline into extinction, for which the reality of both instances occurring in a natural population are recognised as being wholly unrealistic. This is due to a natural population not being physically able to exhibit exponential growth due to constraints on natural resources such as prey availability and nesting space. Similarly, a natural population in decline will eventually stabilise and possibly recover due to reduced competition for prey and nesting space. Therefore, in a simulation which excludes these natural constraints on population growth and decline the difference between the baseline and impacted populations will diverge by an increasing amount as the simulation duration increases, meaning that the CFPS is time sensitive and becomes less accurate with increasing simulation time. Furthermore, due to the absence of density dependence, neither the baseline nor impacted population projections are likely to be credible since seabird populations are constrained by environmental and demographic variables, resulting in unrealistic population predictions for both the baseline (unimpacted) and impacted scenario modelled.

2.7.1.3 There is also significant uncertainty relating to the interpretation of the CFPS. This is because the CFPS is a highly subjective output, with no way to validate what such predicted reductions in population size (as a consequence of predicted impacts) are likely to have on a specified population. The CFPS output might appear to show a significant reduction in population size comparatively to the baseline population to a non-specialist, but this could be easily misconstrued to assume the population is therefore in population decline, which might not necessarily be the case.

2.7.1.4 In contrast, the CPGR is time and growth trend (positive or negative) insensitive and therefore, is less prone to the effects of increasing deviation between the impacted and unimpacted population in the absence of density dependence controls, making it a more reliable output in the absence of density dependence within the model. The outputs of the CFGR can also be readily cross examined against known recent and historic population growth rates of differing populations to provide an informed decision on the likely impact such an effect may have on the colony long term. An example of this is presented in Natural England's assessment of predicted impacts on the gannet population of the FFC SPA as presented in *Natural England's comments in relation to the Norfolk Boreas updated ornithological assessment, submitted at Deadline 2* (Natural England, 2020), whereby the PVA predicted CPGR were cross examined against the population growth rates of 22 differing gannet colonies across Britain, the Channel Islands and Ireland Natural England, 2020).

2.7.1.5 On this basis the Applicant continues to advocate that the CPGR should solely be relied upon when interpreting density independent PVA modelling.

2.7.2 Demographic Rates

2.7.2.1 Through the EP Process the Applicant agreed with Natural England and the RPSB (agreement **OFF-ORN-2.42** – as set out in Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (**B1.1.1: Evidence Plan** (**APP-130**)) that the most appropriate demographic rates for survival and EIA level productivity were those presented in Horswill & Robinson (2015). For FFC SPA productivity rates, the most reliable data source was agreed with Natural England and the RSPB as the site-specific colony monitoring data, albeit with differing opinion on years for inclusions for kittiwake (as captured In Natural England's Risk and Issues Log (**REP3-054**)).

2.7.2.2 Following the use of the agreed demographic rates the Applicant has since reviewed a recent paper on validating PVA models by comparing the known growth trends with that predicted for the baseline population within the model as recommended in Horswill et al. (2022). This paper highlights that population trends of the baseline simulated population within PVAs may not correlate with the known population growth trends, which could affect the accuracy of the PVA outputs as a consequence. The Applicant notes that this is particularly the case for razorbill and kittiwake, whereby for both species the PVA simulated a negative population growth, though for both species the PVA in relation to FFC SPA populations should follow a positive growth rate.

2.7.2.3 The resulting population growth trends resulting from such PVA simulations could be due to the survival rate data for both species being primarily from the Ilse of May and Skomer colonies, which might differ to the FFC SPA or the wider BDMPS populations. Furthermore, for kittiwake the calculated colony specific productivity rate might in fact not be truly representative of the colony as whole, as suggested by Coulson (2017) a minimum productivity rate of 0.8 is suggested for a colony to remain stable, whereas the calculated FFC SPA productivity rate is lower.

2.7.2.4 On this basis the Applicant proposes to undertake revised PVA modelling, which will include model validation steps to increase the accuracy of the outputs, the results of which will be presented in Part 2 of this report.

3 Part 2: Pending

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Appendix A Calculation of BDMPS breeding season population for common guillemot and Atlantic puffin

4.1.1.1 In response to Natural England's Relevant Reps detailed comment (Volume A2, Chapter 5: Offshore & Intertidal Ornithology. Point 3 Table 5.14 and 5.7.4.4 - 5.7.4.9), the Applicant has responded with a request for clarification:

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4.1.1.2 "The Applicant also acknowledges that Natural England have provided their advocated largest BDMPS values, though it is unclear how guillemot and puffin have been calculated and what sources were used to define these values, as they are not aligned with other recently consented projects values for the same species as agreed with Natural England. The Applicant is currently seeking out clarification on the methods employed and the values provided by Natural England on how they have calculated their largest BDMPS values for guillemot and puffin (Clarification will be provided in Deadline 2)."

4.1.1.3 In the case of guillemot and puffin the breeding season BDMPS populations are larger than the non-breeding season estimates presented in Furness (2015), and Natural England therefore advise that these are used in the EIA assessment. This was first raised with the Applicant during our written advice on the draft ES, associated annexes, and RIAA documents provided 21 June 2021. Natural England note that the values advised in the Relevant Reps have also previously been provided for the EA1N/EA2 (REP11-027) and Hornsea Project Two (REP6-017) projects. Natural England also note that these populations are larger than those proposed by the Applicant, resulting in a larger 1% natural mortality threshold for EIA.

Calculation of breeding season BDMPS population

4.1.1.4 Natural England can confirm that the breeding season BDMPS populations were calculated using the data in Appendix A of Furness (2015). The numbers of breeding adults and immatures from each individual SPA populations or non-SPA colony with a foraging range within the respective BDMPS region were summed to generate a total breeding population.

4.1.1.5 For guillemot the values presented in Appendix A: Table 62 were used to generate a population estimate of 2,045,078. For puffin the values from Appendix A: Table 68 were used to generate a population estimate of 868,689.